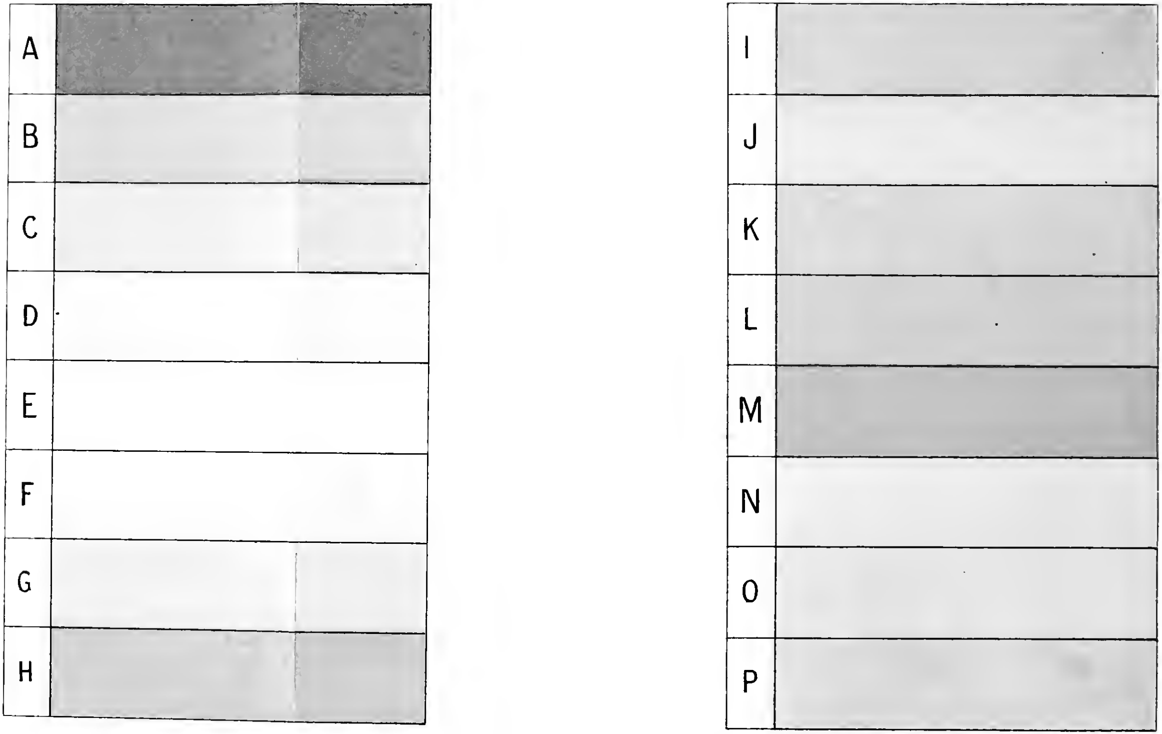
Capio Lumen

MILK, CHEESE, AND BUTTER

Frontispiece



COLOUR-PLATES TO "MILK, CHEESE, AND BUTTER."

BY JOHN OLIVER.

London:—Crosby Lockwood & Son, 7, Stationers'-Hall Court, E.C.

MILK, CHEESE, AND BUTTER

A PRACTICAL HANDBOOK

ON THEIR PROPERTIES AND THE PROCESSES

OF THEIR PRODUCTION

INCLUDING

A CHAPTER ON CREAM AND THE METHODS OF ITS SEPARATION FROM MILK

BY

JOHN OLIVER

LATE PRINCIPAL OF THE WESTERN DAIRY INSTITUTE, BERKELEY

With Two Colour-Plates, and upwards of Two Hundred Illustrations,
specially Drawn and Engraved for this Work

LONDON
CROSBY LOCKWOOD AND SON
7 STATIONERS' HALL COURT, LUDGATE HILL
1894

PREFACE.

THIS volume, the Author is happy to say, represents the accomplishment of a purpose which he has had before him for the last fifteen years. Several times has the work been commenced by him, only to be interrupted by ill-health or the pressure of duty in other directions. In the meantime, the need of such a volume has been constantly felt, both by the Author himself and other teachers, in the waste of time and toil in their class-work for want of a Text-book on Dairying, and by students desirous of mastering the subject. These delays, however, have brought with them some compensation in the opportunities given for testing previous experiences and for developing teaching methods; and the Author now offers the results of his labours in a form which he trusts will be found the most useful for the purposes of both the student and the practical worker.

The work may be described as a Handbook for the "Dairyer," a term which is used throughout the volume as distinguishing the manufacturer of dairy produce from the "Dairy-farmer" or the "Dairyman," neither of whom is necessarily a maker of cheese or butter. For this apt and comprehensive term we are indebted to Dr. F. T. Bond, of Gloucester, who has laid the community under far greater obligations by organising the first British Dairy Conference, as well as by personal research and enthusiasm in the spread of knowledge.

Now that his rivals of America and the Continent are pressing on eagerly and persistently to the attainment of the best methods, it is more than ever necessary that the British Dairyer should master his art. This cannot be done without a thorough study of milk—its composition, character, and capabilities, and the influences to which these are subject—as a preliminary to careful study and observation of the processes by which cream, butter, and cheese are obtained from the milk. And with this there must be unwearying endeavour after perfection in the actual work of the dairy. Unless the theory of his art be understood, the Dairyer will either repeat the same procedure day by day without reference to changing conditions which may upset his methods; or he will alter his methods blindly, following (it may be) mere convenience only, or taking up with practices which are inconsistent with the system or conditions under which he has to work.

To master the theory of Dairying, some acquaintance with the elementary truths of Chemistry and Physics, and the conclusions arrived at by recent observers in those departments, is required; and the Author, in his own teaching, has found that those pupils who had acquired a fair elementary knowledge of natural science have invariably learned more easily, and retained more certainly, and followed more successfully, the practical teachings of dairy work, than those who had not enjoyed the like advantage. In his first chapter, therefore, he has aimed at giving a "foundation" of natural science, so plainly expressed that any one in training for dairy work who is familiar with elementary arithmetic may be able—at all events with the help of a dictionary—to master that portion of the subject. It has been, of course, impossible to avoid the use of scientific terms, but care has been taken to make them as clear, and as easy to use and remember, as may be.

On the basis of Chapter I. is laid the work of the following six chapters, all relating to Milk and the conditions of its production and existence, matters with which every Dairyer ought to be familiar. (All the rest of the book, it may be mentioned, is written on the assumption that these earlier chapters have been carefully studied.) Chapter VIII. deals with the general principles of Cheese-making; and in Chapters IX. to XVI. the various local systems of Cheese-making are dealt with.

The two next succeeding chapters are occupied with the separation of Cream and the making of Butter; and it may here be pointed out that it will be advantageous to the Cheese-maker to read the chapters concerning

Butter-making, and to the Butter-maker to make himself acquainted with the theory of Cheese-making, if only to master the various phenomena which are common to both manufactures. In like manner, the Cheese-maker—no matter what system he may pursue—is advised to read up the accounts of the several systems here given, and then to make a special study of his own.

In the last two Chapters, the subject of Testing and Analysis of the constituents of milk and its compounds, and the question of recording the results of the Dairyer's observations and experiments, are briefly considered.

It is hardly necessary to say that the Author does not pretend to have exhausted the subject with which this volume is concerned. His aim has been to furnish a Handbook which should be of practical utility to the Dairyer in preparation for work, and for constant reference in the dairy. With this view, the illustrations throughout the volume have been specially prepared for the purpose, and where particular appliances are mentioned they have been selected as applications of the principles referred to.

KEYNSHAM, NEAR BRISTOL,
February 1894.

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CHAPTER I.

A FOUNDATION OF NATURAL SCIENCE.

Elements and Compounds.—Our study may well commence with the simplest forms of matter. It is found that all natural substances are formed out of some sixty-seven materials, just as all the words in the English language are formed out of the twenty-six letters of the alphabet. These materials cannot be divided into unlike substances, and are therefore called *elements*, to distinguish them from the many forms of matter in which two or more of them are combined, and which are known as *compounds*. The elements are sometimes found in a free state, but generally in combination with each other, and this with so many variations in kind and proportion as to give the infinite variety which we see in nature.

Elements may again be divided into *metals* and *non-metals*,—the former answering, more or less, to the general meaning of the term, the latter covering the rest.

Only eleven of these elements are believed to be necessary to animals and plants, and these, with five others concerned in dairy processes, are sufficient to the purposes of this work. In the following table the symbol of each element, by which it is described in chemical science, is given, and the weight of each as compared with the first and lightest of them all :—

Non-Metals.			Non-Metals.		
Gases.	Symbol.	Atomic Weight.	*Solids.*	Symbol.	Atomic Weight.
Hydrogen	H	1.00	Carbon	C	11.97
Oxygen	O	15.96	Sulphur	S	31.98
Nitrogen	N	14.01	Phosphorus	P	30.96
Chlorine	Cl	35.37	Boron	B	11.00
Fluorine	F	19.10	Silicon	Si	28.00

METALS.

	Symbol.	Atomic Weight.
Potassium	K*	39.04
Sodium	Na*	22.99
Calcium	Ca	39.90
Magnesium	Mg	23.94
Iron	Fe*	55.90
Aluminium	Al	27.30

The symbol is usually the initial letter of the name, with sometimes a second; but in three cases above (*) it is taken from the Latin form of the name.

The following brief notes on these elements will serve to give a general idea of their characters :—

Hydrogen forms a large proportion of the gas used for lighting. Pure H burns with a pale yellow flame, but will put out that with which it is lighted.

Oxygen is essential to all animal and vegetable life. It does not take fire, but will cause a burning substance to consume away very quickly with a bright flame.

Nitrogen will kill by suffocation animals confined in it. It will neither burn, nor suffer other things to burn in it.

These three gases are colourless, and can only be recognised by some test of their action on other substances.

Chlorine is a greenish-yellow gas, which irritates the lungs greatly if breathed into them ; while *Fluorine* is powerfully corrosive.

Carbon is best known as in coal, coke, charcoal, and soot ; but it exists in many other forms, and is found in all living bodies and their remains.

Sulphur and *Phosphorus* are most familiarly known in lucifer matches and medicinal drugs.

Boron and *Silicon* are grey substances, both found, in combination with other elements, in various forms.

Potassium, *Sodium*, and *Magnesium* are of silver-white colour, and have certain other qualities in common ; while *Calcium*, though sharing the latter with these, differs in its colour, which is slightly yellow.

Aluminium is a light and lustrous metal ; while *Iron* needs no description.

Air, when pure and dry, consists of about one-fifth (by bulk) of O and four-fifths of N simply mixed together, so that each is free to join with or act upon whatever may come within its range. The atmosphere, however, is never an absolutely pure mixture of O and N, for it contains more or less of moisture and certain gaseous compounds, which serve sundry important purposes of animal and vegetable life, as will be hereafter seen.

Water is also composed of two gases; but in this case it is H with O, and they are not merely mixed, as in the case of air, but are combined.

Statement of Composition.—The chemist is able to separate water into its elements, and finds that there is twice as much of H in it as of O (by bulk or volume). The proportions of the elements in compounds vary greatly, and he has two systems by which he is able to show those proportions in any case. One of these expresses the proportion by *percentages*, or their relations to 100 parts. The composition of water so stated will be about as in the accompanying calculation, or there are about $11\frac{1}{2}$ lbs. of H and $88\frac{1}{2}$ lbs. of O in every 100 lbs. of water.

H......	11.55
O......	88.45
	100.00

Atoms and Molecules.—The other system is based upon the *atomic* theory. The *atom* is taken to be the smallest conceivable quantity (by measure or volume) of any element. It cannot be seen or measured, but it is none the less a practical reality; just as the lines of latitude and longitude mark distances on the map of the world, and are of the utmost value to the navigator, though he cannot see them as he sails the ocean. The atom of each element is of the same size as that of any other of its class; and since there is twice as much of H in water as of O (by volume), the chemist writes the atomic statement of its composition as H_2O, which he calls the *formula* of that composition. Whenever a symbol is given without a number, it is understood to represent one atom of the element.

These two methods are used according to convenience,—the latter more especially in the statements of chemical changes.

Here, then, we have two atoms of H and one of O combined to form water; and since we cannot conceive of less than an atom of O, the quantity of water so described must needs be the smallest possible. This cannot be called an atom, because water is a compound: it is called instead a *molecule;* and in order to express molecules by number, a figure is placed before the atomic formula, as in the following, viz., $3H_2O$, which means three molecules of water.

Atomic Weight.—A comparison of the proportions of H and O in water by weight and by measure, will show that though the former gives about eight times as much of O as of H, the latter shows twice as much of H as of O. This is because the atom of O weighs nearly sixteen times as much as the atom of H; and in the third column of the table of elements the great variations in the relative weights of these can be seen, and not only compared with that of H, the standard, but also with each other. By this means the differences between statements by weight and by volume can be reconciled, and each calculated from the other.

The molecules of all compounds occupy spaces according to the number of their atoms ; and their weights, as molecules, depend on those of the various elements composing them, and their relative proportions to each other in combination. The term *molecule* is sometimes used in connection with a single element, when two or more atoms of it join each other in a free state.

Descriptive Names of Compounds.—The composition of compounds is not only described by formulæ, but also by names. When a *non-metal* combines with a *metal*, the name of the *non-metal* takes the termination "ide." Thus Fe and O combine, and the compound is called an *oxide* of iron. In the same way Cl forms *chlorides* of metals, &c. But the quantity of the non-metal may vary, and the names are made to show this, the name of the *metal* being used for the purpose. The compound which has *more* of the non-metal makes this second name (the metal) to end in "*ic*," and that which has *less* to end in "*ous*." Thus we have Fe and O combining in two proportions. In the one, Fe_2O_3, there are three atoms of O (non-metal) to two of Fe (metal); and in the other, the two elements are equal. So, as the former has more O than the latter in proportion to Fe, it is called ferr*ic* oxide ; and the latter is ferr*ous* oxide. When non-metals combine with each other, the termination "ide" is still used, but the name of the element considered to be the most important comes first.

Sometimes, however, the proportion of the O in an oxide, or of S in a sulphide, is expressed by a syllable placed before the part of the name which refers to it,—as when there is one atom of O, the compound is a *mon*-oxide (example, CaO, which is calcic mon-oxide); or as when there are two atoms of O, and it is called a di-oxide (CO_2 being named carbon di-oxide). So we have also *tri*-oxides, *tetr*oxides, and *pent*oxides, showing the presence of three, four, and five atoms of O respectively. The same "prefixes," as they are called, are placed for a like reason before other names ending in "ide," as sulphides. &c. The reader, if not already familiar with these rules, is advised to master them before proceeding further.

Acids.—Certain compounds of non-metals with O are converted by the addition of H_2O into acids. Thus C and O combine as CO_2 (carbonic di-oxide). This is sometimes, though wrongly, called carbonic acid ; its proper name is carbonic *an-hydride*,—the prefix "an" showing that it is *without* H in this case. When, however, a molecule of H_2O is added, it becomes carbonic acid, H_2CO_3.

As this is the first example of the combination of two *compounds*, the manner in which the symbols are added to each other to express the composition of the new substance is shown in the accompanying calculation.

$$\begin{array}{c} CO_2 \\ H_2\ O \\ \hline H_2CO_3 \end{array}$$

CO_2 is a colourless and heavy gas, which, like N, will extinguish a light and kill animals by suffocation when immersed in it. It is given off from the burning of oil, wood, and coal, and from decaying animal and vegetable matter, and is breathed out from the lungs of animals. It therefore mingles with the air, and there serves very important purposes in connection with plant growth.

Sulphur also unites with O as SO_3, Sulphuric anhydride, and becomes an acid with H_2O as H_2SO_4 (Sulphuric acid). This last is commonly known as oil of vitriol, a sour liquid, which either chars or corrodes objects in contact, and can dissolve many substances in nature, both organic and mineral.

Phosphorus with O, as P_2O_5, unites with 3 molecules of water ($3H_2O = H_6O_3$) to form Phosphoric acid. It will be seen in the accompanying calculation that the 3 molecules of water and 1 of the anhydride form 2 molecules of the acid; the result being capable of division by 2, and leaving whole numbers of each element. This, like sulphuric acid, is corrosive, and also of great value to vegetation.

$$\begin{array}{c} P_2O_5 \\ H_6\ O_3 \\ \hline H_6P_2O_8 \\ \hline =2H_3PO_4 \end{array}$$

Nitrogen with O, as N_2O_5 (Nitric pentoxide, or anhydride), combines with 1 molecule of water to form 2 molecules of Nitric acid, HNO_3. Thus $N_2O_5 + H_2O = H_2N_2O_6 = 2HNO_3$. It is known in commerce as Aqua-fortis.

Chlorine with H, as HCl, forms Hydrochloric acid, also known as Muriatic acid, or Spirits of salt.

Acids have, in common, a sour taste, and the power to change vegetable dyes of a blue colour to redness. The best known test for acidity is a porous blue paper coloured with a substance called *litmus*, obtained from certain lichens. This upon being put into an acid becomes more or less red, according to the acid present.

In naming acids, the relative proportion of O is recognised as before, and we have therefore Phosphor*ic* acid with a *higher*, and phosphor*ous* acid with a *lower*, proportion of O; while a still higher proportion than in the former is shown by placing the syllable *per* before it (as *per*-chloric acid, $HClO_4$); and a lower proportion than with the latter by the use of the prefix *hypo* (as *hypo*-sulphurous acid, H_2SO_2).

Bases and Salts.—*Bases* are compounds which combine with acids to produce a third class of substances called *Salts*. They are of four kinds, as described in order.

(*a*.) *Oxides of metals.*—In the accompanying calculation the base, Calcic oxide, joins with Carbonic acid, and, after the molecule of water necessary to the acid has been subtracted from the result, the salt, Calcic carbonate, or Carbonate of lime, will remain. The similar combinations of H_2CO_3 with other bases of this class are given below, the metals being given in italics.

Base......		*Ca* O
Acid......	H_2	CO_3
		H_2CaCO_4
Water....	H_2	O
Salt.......		$CaCO_3$

Na$_2$O (Di-sodic oxide) + $H_2CO_3 = H_2O +$ *Na*$_2CO_3$ (Di-sodic carbonate).
K$_2$O (Di-potassic ,,) + ,, = ,, + *K*$_2CO_3$ (Di-potassic ,,).
*Mg*O (Magnesic ,,) + ,, = ,, + *Mg*CO_3 (Magnesic ,,).

The salts are known as carbonates of soda, potash, and magnesia.

The same bases acted upon by Sulphuric acid, H_2SO_4, form *Sulphates*, as $Na_2O + H_2SO_4 = H_2O + Na_2SO_4$ (Di-sodic sulphate); while K_2O, CaO, and MgO, give K_2SO_4 (Di-potassic), $CaSO_4$ (Calcic), and $MgSO_4$ (Magnesic), respectively.

Similar results follow the action of Nitric acid, giving *Nitrates*, two molecules, $2HNO_3$ ($=H_2N_2O_6$), joining with one of the base, as in $Na_2O + H_2N_2O_6 = H_2O + Na_2N_2O_6$, or $2NaNO_3$ (Sodic nitrate).

Phosphates are formed in the same way by the acids of P, the oxide P_2O_3, making Phosphor*ous* acid, and P_2O_5, making Phosphor*ic* acid, and of the latter there are several kinds in which the proportions of H_2O vary.

$$P_2O_5 + H_2O = H_2P_2O_6 = 2HPO_3.$$
$$P_2O_5 + 2H_2O, \text{ (or } H_4O_2) = H_4P_2O_7.$$
$$P_2O_5 + 3H_2O, \text{ (or } H_6O_3) = H_6P_2O_8 = 2H_3PO_4.$$

These are also called Phosphates, with H as a base.

Now just as H is found in the examples above, so Na and Ca may be found in those now given.

Hydric phosphates.			Sodic phosphates.			Calcic phosphates.
HPO_3	...	...	*Na*PO_3	...	...	*Ca*$2PO_3$
$H_4P_2O_7$	...	...	*Na*$_4P_2O_7$	...	...	*Ca*$_2P_2O_7$
H_3PO_4	...	...	*Na*$_3PO_4$	...	...	*Ca*$_3 2PO_4$*.

Calcic phosphates are better known as phosphates of lime. There are others of iron and magnesia built up on the same principles.

We now come to the second class (*b*), in which KOH (Potassic hydrate or potash), and NaOH (Sodic hydrate or soda), are capable of being converted into salts by acids. In the following example the potash is acted upon by nitric acid.

$$\overset{\text{Base.}}{KOH} + \overset{\text{Acid.}}{HNO_3} = \overset{\text{Water.}}{H_2O} + \overset{\text{Salt.}}{KNO_3} \text{ (Potassic nitrate).}$$

Ammonia (NH_3) belongs to this class, for though differing greatly in composition from KOH and NaOH, it acts like them in all practical respects in combining with acids, and produces ammonium salts.

Those bases which can be dissolved are called *Alkalies;* they are opposite in character to acids ; and litmus paper, which has been reddened by an acid, can be restored to its blue colour by an alkali. A compound which changes the blue to red is said to have an acid *re-action*, while one which will bring it back to the blue, has an alkaline re-action. When the acid and the alkaline base balance with each other, the result is a *neutral* salt, which will not affect litmus paper either way. When an acid material has been brought to balance by an alkali, or an alkaline one by an acid, it is said to have been *neutralised.*

Finally, there are *Alkaloids*, which include quinine, strychnine, &c., formed in growing plants, with others produced in organic matter under chemical decomposition ; and sundry other substances, which will be described as they appear in the course of the main subject. The foregoing will suffice to give a general notion of the relations of acids and alkalies and their products.

Cl Compounds.—*Chlorine* combines with Na to form the familiar *common salt*, NaCl, so much used in the dairy, and which has other connections with milk besides. It is commonly obtained from mines, as rock salt ; or from springs, as brine, afterwards reduced to dryness. This substance is usually associated with impurities, such as Calcic sulphate, $CaSO_4$ (also called *gypsum*), which produces a hard cake known as "*pan-scale*," and often found as veins in the blocks of salt bought at the stores. This and Magnesic chloride, $MgCl_2$, cause bitterness ; while Calcic chloride, $CaCl_2$, produces wetness by absorbing an undesirable quantity of moisture from damp air. Therefore the less of these the better, and a good salt will not contain of them altogether more than one per cent. by weight. Another Cl compound is that with K, called Potassic chloride, KCl, the character of which may be judged by the fact that K holds the same place and power as Na in the previous case.

Silicon combines with O to form an oxide, Silica, SiO_2, common in sand and rocks, and found in the ashes of grasses and grain crops. *Aluminium* forms an oxide, Alumina, Al_2O_3, which with SiO_2 so largely makes up clay soils. Further references to these will occur.

We now turn to the consideration of certain chemical and physical laws, and the definitions concerned therein.

Suspension and Solution. These terms are often used in describing the relations of solids and liquids. A *solution* consists of a solid dissolved in a liquid, as salt dissolves in water; whereas, when the solid, though distributed in the liquid, does not dissolve, it is said to be in *suspension*. A solid which can be dissolved is said to be *soluble;* and one which will not, is described as *insoluble*. A *saturated* solution is one in which the liquid has dissolved all that it can of the solid. If salt is added to water until it will dissolve no more, the result is called a saturated brine. Many substances will dissolve much more readily in warm than in cold water. To this salt, NaCl, is an exception, dissolving equally well in either. A solution is said to be *diluted* when water, or some weaker solution, is added to it. Dilution may be made to describe the addition of water to milk, though this latter is not a simple solution.

A substance in solution will pass, with its dissolving liquid, through a *filter*,—which may be either (*a*) a porous paper, like blotting paper; (*b*) a quantity of loose particles, as sand or charcoal; or (*c*) a compressed material, as charcoal or porous porcelain, according to the purpose in view. Solid substances are held back by all filters, and dirty water is thus made clean for household use. The clear liquid which passes the filter is known as the *filtrate*, but this—with most filters—may carry through with it matter which can be separated from it by other filters of a closer character. Those forms of matter which in their natural state can only be filtered out of liquids by filters of the latter class, include *gelatinous* (jelly-like) and *gummy* substances, and are called *colloids*, to distinguish them from *crystalloids*, which are soluble, and can only be separated from their solutions by chemical action, heat, or the drying up of the water from them. Salt is left in crystalline form when the water is removed from natural brine by the two latter means. Colloids in liquids are said to be in *diffusion* or *gelatinous suspension*. These two classes of matter can be separated, when found associated in a liquid, by the use of a filter of parchment paper; and this method is called *dialysis*, and the filter a *dialyser*, names derived from a Greek root meaning to unloose.

Analysis is the discovery or separation of the different elements or compounds composing a substance.

Qualitative analysis consists merely in proving the *presence* of these by (*a*) physical separation or (*b*) the use of *tests*. These are generally more or less associated. A test may be made by some chemical action, which produces a certain result in contact with the element or compound supposed to be present; if that result is observed, the analyst concludes that it is present in some quantity. The microscope is of use in some cases, revealing what would be beyond the powers of the unaided eye.

Quantitative analysis carries the matter further, either separating the different parts of a substance and weighing them, or estimating their respective quantities by proved rules. The different elements or compounds found in any substance are called its *constituents*, because together they constitute it.

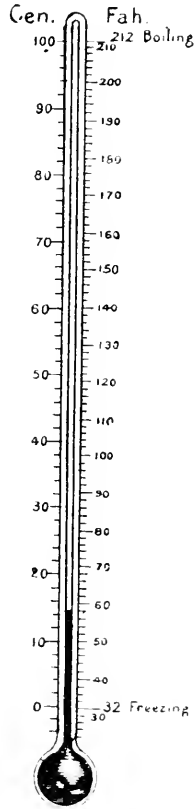


Fig. 1.
Thermometer.

Heat and Cold.—We are conscious of considerable natural variations between the greatest heat of summer and the greatest cold of winter, and the changes of temperature not only affect us but the condition of things around us. Water, for instance, *expands* with an increase of its heat, —*i.e.*, it occupies more space than it did before,— while with the increase of cold it *contracts* or takes up less space; and this heating may be carried on to a point at which the water will boil and pass away as steam, and the cooling until it becomes ice. Many things which are solid at ordinary temperatures become liquid with greater heat; liquids, likewise, become gaseous; while liquids and gases may, at lower temperatures, become solids and liquids respectively.

This law of expansion and contraction is turned to account to measure the variations in the temperature of bodies. *Mercury* readily responds to the influence of heat and cold, and is used in the construction of *thermometers*, or heat-measurers. Confined in a glass tube, with sufficient free space in which to expand upwards, it registers by its risings and fallings, as it expands or contracts, the changes in the temperature of the air and other bodies. In boiling water it rises to a point called the *boiling point* of water, and it will sink to a point at which water freezes, and which is therefore called the *freezing point*, and even higher and lower than these. Between the boiling and freezing points of water, Fahrenheit formed a scale of 180 divisions or *degrees* (Fahr., Fig. 1), making the former 212° (degrees), and the latter 32°, above his *zero* or lowest point. This scale is generally used in this country; but another is coming into use, especially among scientific men, that framed by Celsius, a Swede, and commonly called the Centigrade scale (Cen., Fig. 1), because it makes the freezing point its zero and the boiling point 100°, so dividing the scale into one hundred degrees. So as the mercury rises under heat and falls with cold, the extent of its rising or falling is known by the degrees on the scale; and we regulate our dairy processes to a great extent by its teachings. In using it, care is needed to take the readings accurately. It should be held in the liquid until the column of mercury rises no longer, and—if practicable—the figure noted there. If the scale cannot be seen without removal it should be brought to the eye as quickly as possible, otherwise the mercury will rise or sink under the influence of the air-temperature, and the user will be deceived. He should therefore be familiar with the instrument, and thus reduce his liability to error to the lowest possible point.

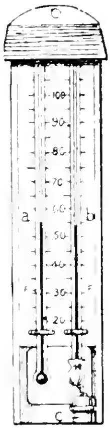


Fig. 2.
Hygrometer.

Heat is absorbed and carried by some bodies better than by others, and such are therefore called good *conductors*, as compared with bad ones, or—as they are called when this quality is very pronounced—*non-conductors*. The throwing off of heat by anything which has absorbed it, as for instance a stove, is called *radiation* (*radius*, a ray), because the heat is given out, as the sun gives out his rays. The heat of the fire is conducted by the iron of the kettle to the water inside it, and this soon becomes *vapour* and vanishes, it is therefore said to *evaporate*. There is in the soil much moisture, which similarly passes into the air, and, though unseen, loads it in proportions which vary from hour to hour with all changes of wind and weather. The dampness of the air is called its *humidity*, and this can be measured as well as its temperature. Air itself, by contact with wet surfaces, takes up moisture; and when evaporation is going on, the substance, losing its moisture, becomes colder. An instrument has been devised to show the humidity of the air. This instrument (Fig. 2) is called a *hygrometer* (*hygros*, moist). Two thermometers are fixed side by side, the one (*a*) being of the ordinary kind, the other (*b*) having its bulb wrapped around with a piece of thin cotton material, and thus kept moist by a few strands of soft cotton which suck up water from a cup (c) below. The evaporation goes on at a rate dependent on the dryness of the air; and according to the quickness with which the moisture drys off from the bulb, so is the cold and the variation of the mercury. There is therefore generally some difference between the temperatures shown by the two thermometers, and, this being observed, it can be known by reference to the table below how much moisture is in the air, the largest amount which it can carry being described as 100 degrees of humidity.

Temperature by dry bulb thermometer. Degs.	Difference between thermometers. 2°	4°	6°	8°
	Degrees of humidity.			
40	84	70	58	47
42	84	71	59	49
44	85	72	60	50
46	85	73	61	51
48	86	73	62	52
50	86	74	63	53
52	86	74	64	54
54	86	74	64	55
56	87	75	65	56
58	87	76	66	57
60	88	76	66	58
62	88	77	67	58
64	88	77	67	59
66	88	78	68	60
68	88	78	68	60
70	88	78	69	61
72	89	79	69	61
74	89	79	70	62
76	89	79	71	63
78	89	79	71	63
80	90	80	71	63

Example.—If the dry bulb shows a temperature of 62° and the wet one 58°, the difference is 4°, and by looking in the second column opposite the 62° (dry bulb) it will be seen that there are 77° of moisture present. In order to real usefulness such an instrument should be kept in a fairly sheltered spot, and out of the sun's rays.

The quantity of moisture which the air can carry depends on its temperature—the higher this is, the more it can hold. So at a high temperature the moisture may be considerable though unnoticed; but if the air gets colder, as after sunset, its ability to hold moisture decreases, and whatever it can no longer carry will be deposited as dew upon objects which have lost their heat by radiation. This process is called *condensation*, and is the opposite to evaporation.

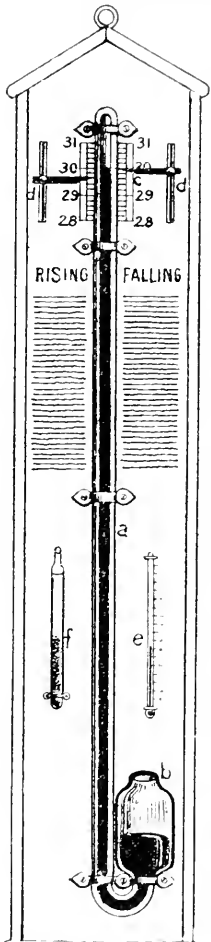


Fig. 3.
Fitzroy Barometer.

The air affected by heat becomes *rarefied*, and, like liquids and solids, becomes lighter also. Under the influence of cold it becomes heavier. As these changes occur in general harmony with certain changes in the weather, an instrument called a *barometer* (*baros*, weight) has been constructed to measure the weight of the air, by its pressure on a body of mercury rising into a glass tube, the column rising or falling according to the weight of the air. The barometer designed by the late Admiral Fitzroy, and used with his rules, is a valuable ally in dairying. This is shown in Fig. 3, with the tube (*a*) fully exposed. The bulb (*b*) allows the pressure of the air, (about 16 lbs. to the square inch at ordinary levels), to be exerted on the surface of the mercury, under average conditions balancing that in the tube, which has no pressure upon it, the space above the column being a *vacuum*, or free from air. The top of the column consequently rises or falls as the air-weight increases or decreases with weather changes. The scale (*c*) which measures these variations is three inches long, each inch being divided into fifths or tenths, and two movable pointers (*dd*) can be set alternately so as to show the extent of the variations between any three observations. The mere indications of varying weight of the atmosphere are of little service by themselves. In order to forecast weather with some degree of correctness, the rate of rising and falling, the temperature, and other considerations, should be taken into account; hence the presence of a thermometer (*e*) with every good instrument, and often a chemical storm-glass (*f*), the crystals in which rise before a fall in the weather. The rules are printed on the Fitzroy barometer, or can be bought for any others for a few pence.

Electricity is always present, more or less, in the atmosphere.

Into the nature and influence of this force it is impossible to go fully in this work. Suffice it to say that the electrical condition of the air exercises considerable influence within the realm of the dairyer, and will have further attention as occasions arise. This fluid, the performances of which are among the chief wonders of modern science, has the power—when discharged as lightning—to bring about a striking change in the O of the air, concentrating and giving to it more active chemical properties. In this form the O is known as *ozone*, and causes oxidation of such metals as silver and mercury, and such materials as indiarubber. It is usually present in the air to a small extent, but with this, as with many other things, its power is large out of all proportion to its quantity. It has the capacity for rendering litmus paper pale, and proves its presence by other tests.

In connection with thunderstorms there is a production of HNO_3, from a combination of the elements of the air with water; and this being carried down by the rain, makes the latter more valuable to crops by reason of its greater nutritive properties than that which falls at other times.

Attraction. — *Gravitation.* — The attraction of bodies towards each other, but more especially their tendency to move towards the earth's centre, and therefore towards the lowest point they can reach, is called gravitation. It is because of this that when a liquid is set free it runs down any incline to the lowest level, and this law is consequently brought into continual application in the dairy.

Cohesion.—The attraction by which bodies hold together is so called. It is much greater in some than in others; and in the same bodies at one time than at another.

Capillary attraction is the tendency of liquids to rise or sink within minute tubes. Examples will occur later.

Density, or Specific Gravity, is the weight of a substance in relation to its bulk.

We have seen that an atom of O is about sixteen times heavier than one of H, and that other elements vary to a greater or lesser extent in this respect, although their atoms are alike in size. This is also true of the substances formed out of elements. Let us test this for ourselves. Into a vessel of water we will drop a piece of cork and a stone—the former will float, the latter will sink. If we take a cubic inch of cork, of water, and of stone, and weigh them, we shall find that their behaviour is according to their weights as compared with each other. So we say that the density of the cork is least, that of the stone greatest, and that water holds a place somewhere between them. As with heat, so with density, a standard has been adopted and a system of measurement. The standard of comparison for gases is H; and for solids and liquids, *distilled* water. Why distilled? Because otherwise it would be liable to contain substances in solution which would increase its weight. Distilled water is that which has been converted into steam and condensed again. In this way it leaves behind all mineral impurities, as it leaves the "rock" of $CaCO_3$ or $CaSO_4$ on the inside of a kettle. Next there is a standard temperature. We have seen that bodies expand and contract with heat and cold; they therefore become lighter with heat and heavier with cold in proportion to their size—*i.e.*, their density decreases in the former, and increases in the latter case. Without a standard of temperature there would be confusion, and 59° Fahr. (15° Centigrade) has been fixed for liquids because of its general convenience. The old method was to weigh a given measure of the liquid to be tested, and compare its weight with that of the same measure of water, calculating its density on the difference. But a simple and more direct way is now used, an instrument called a *hydrometer* (*hydor*, water)—Fig. 4—having been invented for the purpose. This consists of a hollow body of glass or metal with a closed tube or bar rising from it, and a weight attached to it beneath. In the glass instrument this last is a bulb from the main body, containing mercury or shot. In use it floats upright, and sinks more or less according to the density of the liquid. In water, the standard instrument will sink to the unit on the scale; but if salt is added, it will rise steadily until the water is saturated, showing the power of salt in solution to increase the density. A scale is employed, on which the point reached by the instrument in distilled water at 59° F. is marked 1; and all denser or lighter liquids are estimated accordingly. While a standard instrument has a long range, there are others made with narrower limits of scale for special purposes, and described hereafter.

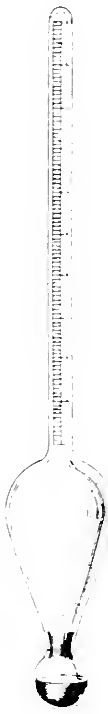


FIG. 4.
HYDROMETER.

Centrifugal Force. — When a body is made to revolve around a centre, its tendency is to fly away from it, and this it will do unless it is held to the centre by some greater force. A boy will swing a small bucket of water round his head by a cord, and without spilling; because the water, which would fly away from him but for the bucket and the cord, presses towards the bottom of the bucket. This is therefore called centrifugal force (*centri-fugal*, flying from a centre). The water, by reason of its pressing outwards, becomes denser; and its increase of density depends on its weight, its distance from the centre, and the speed at which it revolves. The boy finds it more difficult to hold the bucket when he lets the cord out to greater lengths, or swings it round him with greater speed. Proceeding on these facts, we find that there are definite relations between the force and the conditions described, and these relations are reduced to rules by which we can calculate the amount of the force, and in proportion to this the density also. This rule holds good when two substances of unequal density are together under the influence of the force. Cork has a less specific gravity than water, and if a body of that material was subjected to the same revolving motion, it would exert less centrifugal force than an equal body of water. If the boy puts a cork into his bucket of water, it will have the same tendency to fly away from him; not, however, to anything like the same extent as the water, but only in proportion to its much lower weight or gravity. Further illustration of these principles will occur in practical dairy work.

Rocks and Soils.—Soils are simply the rocks forming the earth's surface reduced to powder by natural forces, such as water, and cold and heat, which are always at work, though unnoticed, wearing down or splitting up the materials referred to. In the simplest relations there will be a gradual difference observed as the rock merges into what is called the sub-soil, and from this again into the surface soil. But there are many places where tillage has interfered with these relations; and others where soils, formed elsewhere, have been brought by air or water and laid upon or mixed with those natural to the spot. In any case, however, the rock materials form on an average 95 per cent. of the whole.

The main ingredients of soils are *clay*, *sand*, and *lime*, in varying proportions,—forming *sandy* or *clay* soils when these predominate, *sandy* or *clay loams* as they approach a balance, and *loams* in still closer proportions; and when carbonate of lime—$CaCO_3$—is found up to a fifth of their total, forming *marly* or *chalky*, or, in higher proportions, *calcareous* soils. There are present also, though in small quantities, other substances more or less helpful or hurtful to vegetation. The materials in general may be classified for our immediate purpose into *soluble* and *insoluble* substances, and since the latter form only a bed in which plants can grow, we may devote our attention to the former, upon which they feed. Among these may be found the following, viz.:—

Oxides—Na_2O, K_2O, CaO, MgO, FeO, Fe_2O_3, &c.

Alkaline hydrates—KOH, $NaOH$.

Ammonia—NH_3.

Acids—H_2CO_3, HNO_3, H_2SO_4, H_3PO_4, forming, with the alkaline bases, carbonates, nitrates, sulphates, and phosphates.

Silicates—Soluble, formed by combination of SiO_2 with alkalies.

Chlorides—$CaCl_2$, KCl, $MgCl_2$.

These are either combined with each other or uncombined, according to circumstances; and being very variable in their proportions, there are always present uncombined remainders of some of them. They are not all present at all times. Thus a limestone will contain some of them, a sandstone others, with some common to both, and even the composition of rocks of the same class will differ. The mineral constituents of soils depend, therefore, upon their original sources, and the physical and chemical changes wrought in them by the forces of nature.

Organic Substances.—These are found in soils as the products of the decay of organised animal and vegetable bodies, especially of the latter. Everybody knows how wood rots away into the mould so valued by the gardener. The same process is continually going on with the dead leaves and roots of plants, and the general product is called *humus*. This contains several acids of the *Carbon-acid* type, consisting of C, H, and O in varying proportions, and which—because of their origin—are called *organic* acids. Of these, *humic* acid, $C_{20}H_{12}O_6$, is an example. Besides the services rendered by these acids, humus takes up the valuable ammonia, NH_3, formed in or furnished to the soil, and holds it well for use by plants. Nor must we forget the soluble earthy matter brought to the soil in the farmer's manures, for these become a part of the soil for all practical purposes. Here are many forms of matter, organic and inorganic, undergoing decomposition in the chemical sense, and being thereby prepared for new uses.

Plant Life.—Now comes the seed, which finds shelter and anchorage under the surface, moisture, and the warmth absorbed from the sun's rays; and with these conditions its life-germ becomes active, throws out roots, stem, and leaves, and becomes a plant. At first, feeding upon the stores of food within itself; it is ready, when they are exhausted, to take them up from the soil. Then the stores of soluble organic and inorganic materials already described are drawn upon for whatever the plant needs. Different plants require different foods, or different proportions of the same food, in order to their best growth and increase; and they will be vigorous or weak, luxuriant or puny, according to the sufficiency or deficiency of the supply. The roots suck up, in a dissolved state, the soluble foods, and these are subjected to a marvellous system of selection and transformation done by certain parts of the plant called *formative cells.* These minute bodies consist of *proto-plasm* (meaning *first form*), a jelly-like substance ; but, though of so simple a character, they have powers which cannot fail to excite wonder and admiration. As the foods and the water which dissolves them come into contact with these cells in the movements of the sap, they are absorbed by them, and part or all are used as may be necessary. Even water is decomposed into the two gases H and O, when either or both of these are needed, for single or separate purposes, to combine with other elements in the life processes. Carbon is taken from H_2CO_3, S from H_2SO_4, and N from NH_3 or HNO_3. Now we see the value of the rotting roots and leaves, and straw of manures, and the use of applying manures which furnish other plant foods. The plant is very unlike the soil, but out of this it builds itself up, unconsciously, subject to the laws of the All-wise Creator. Almost all of the plant is constructed out of the five elements, H, O, C, N, and S, and their new combinations may be divided into two classes—(*a*) carbon and (*b*) nitrogen compounds.

Carbon Compounds.—First among these are—

Carbo-hydrates, in which C in 6 or 12 atoms is combined with H and O, these latter being always in the same proportion as in water. But it must not be supposed that the H and O are in the form of water, for they are properly combined with the C ; there are, however, cases in which extra quantities of them are present in a weaker association. They may be sub-divided as follows, viz :—

Starches, of which the typical composition is $C_6H_{10}O_5$, and of which the starch of the laundry is a familiar example, being obtained, from rice. Cereals and grasses contain starch in considerable proportions, and other plants have more or less of it. *Cellulose*, or the woody tissue of plants, and gums, has practically the same composition.

Sugars, as found in fruits, the sugar cane, and beet-root, are of the same family. Fruit sugar has a composition of $C_6H_{12}O_6$, and cane sugar of $C_{12}H_{22}O_{11}$, the difference between them being one proportion of H_2 and O more in two molecules of the former ($=C_{12}H_{24}O_{12}$). But there is another—a physical—difference, for starch is insoluble, while sugar is soluble, as every tea-drinking washer-woman knows ; for, while sugar dissolves in her tea, the starch with which she stiffens linen only becomes a jelly. Starch, however, can be converted into soluble sugar by the plant cells and certain processes referred to later.

Pectose Substances. — Akin to the starches and gums is a compound called *pectose*, which becomes jelly on boiling, *e.g.*, the jelly of fruit. Like starch, it is insoluble, and undergoes several changes, varying its proportions of H and O, which, however, are not as in water. Pectose, acted on by acids, becomes soluble *pectin* ($C_{32}H_{48}O_{32}$) ; and this in turn, and with different treatment, changes into three forms of acid, one of which separates into pectin sugar ($C_6H_{12}O_6$) and an organic acid, and so works back to the carbohydrate principle.

Fats may be divided into two kinds—the *fixed*, which are stable under ordinary conditions ; and the *volatile*, which can be decomposed by heat or dissolved out by water. Again, fixed fats can be sub-divided into those which are (*a*) *solid* and those which are (*b*) *liquid* at ordinary temperatures. The liquid fat can, of course, be solidified at low temperatures, and the solid fat can be liquified at higher temperatures. But whatever may be their physical differences, they are built up of C, H, and O, and on one plan.

The common foundation is *glycerin* ($C_3H_8O_3$), which in each case combines with a fatty acid to produce a particular fat. Glycerin, as sold by the druggist, is well known as an almost colourless viscous liquid substance of sweet taste, and useful in healing skin cracks. The fatty acids differ somewhat from our previous conceptions of an acid, because they are of an oily character and not sour ; but in composition, and in behaviour in combination, they follow the rules relating to the acid class. The way in which they combine with glycerin to form fats is illustrated below, where it is shown that three molecules of an acid unite with one of glycerin to form one molecule of fat and three molecules of water.

$$3\,(C_{16}H_{32}O_2)\ \text{Palmitic acid.}$$
$$\begin{array}{l} \qquad\qquad 3 \\ \hline C_{48}H_{96}O_6 \\ C_3H_8O_3\ \text{Glycerin} \\ \hline C_{51}H_{104}O_9 \\ \quad H_6O_3 = 3\,H_2O \\ \hline C_{51}H_{98}O_6\ \text{Palmitin.} \\ \hline \end{array}$$

Palmitin is a solid fat, which melts at 115° F. The relation which the acid bears to the glycerin in its formation makes it to be called a *tri-glyceride* of the acid, or yet again *tripalmitin*. Palm oil chiefly consists of it. It may be remarked here that fats when melted and afterwards cooled remain liquid at much lower temperatures than those at which they melt.

Stearin ($C_{57}H_{110}O_6$) is similarly a tri-glyceride of stearic acid ($C_{18}H_{36}O_2$), and is best known in the white fat of mutton. Its melting point is 157° Fahr.

Olein ($C_{57}H_{104}O_6$), from Oleic acid ($C_{18}H_{34}O_2$), is a liquid fat which, in a pure state, only becomes solid by freezing below the freezing-point of water.

These fats are found associated in plants and animals, and as olein has the power to keep the solid fats in a soft state, the melting point of the mixed fats is lower than that of either of the solid fats, and this in proportion to olein present.

The volatile fats are, like the rest, tri-glycerides of acids, but these latter make the difference in their character as compared with those called fixed fats. A few of them are found in plants, but not all; and their consideration is therefore deferred until they can be described in connection with milk.

Nitrogen Compounds or Albuminoids.—We now come to a class of bodies in which, besides C, H, and O, the elements N and S are in combination. Because of the presence and relative importance of N in them they are also called *nitrogenous* substances, and sometimes also *proteids.* The name given at the head of this section indicates that it describes a family of which *albumin* is type and chief. Though many important facts concerning them are established, their chemical composition is not in all cases fully known. The formula $C_{72}H_{112}O_{22}N_{18}S$ is typical of the group, and the range of proportions by weight is shown in the accompanying table.

C –	51.5 to 54.5
H –	6.9 to 7.5
D –	20.6 to 26.3
N –	15.5 to 18.5
S –	.4 to 1.6

Albuminoids are of a gelatinous nature and under certain conditions will *coagulate* or become semi-solid—*e.g.*, *vegetable-albumin* coagulates at 150° Fahr., and in even a more solid state is found in the husks and harder parts of trees and plants. Another kind, vegetable *casein* (ca-se-in), can be separated from an infusion of oatmeal by the use of an acid; and a third form can be obtained by simply washing out the starch from flour, the sticky residue being mostly a proteid called *gluten.* Other varieties are found, as *legumin*, in beans, peas, and vetches; *avenin*, in oats; *fibrin*, in wheat, barley, and maize.

Besides these organic substances contributing so largely to the make-up of plants, there are minerals which have been taken up from the soil. Whatever the forms in which they exist in the living plant, they are found in their ashes when burned.

Animals next claim our attention. For them has the plant lifted soil materials into a form in which they can use them; and as that work was done by the plant-cell, so now the plant materials are subjected to further changes by the action of animal cells, which raise them to the highest forms of organisation of which they are capable. Some of these cells convert the foods into blood, and others employ the blood materials for repairing waste, providing for growth, and carrying on the other functions of the body.

Foods for Animals.—The substances found in the plants must now be considered as animal foods, and classified according to their feeding qualities :—

(*a.*) *Heat-giving* or *respiratory* foods.—If plants store up force in their growth, animals expend it, and this in different ways. They must maintain a certain degree of warmth for health and vigour, and this is done in connection with the arrangements for breathing or *respiration.* It will be remembered that O assists in the burning of bodies, and this process, called *combustion*, goes on in a certain form in the animal system, which is heated by the combustion of the materials made out of the carbo-hydrates and fats of the food. Hence these are necessary to co-operate with the O breathed into the lungs in order to warmth.

(*b.*) *Flesh-forming foods.*—The albuminoids are so called, they being used for the building up of lean muscle, but, when needed, furnish also the materials for fats and other parts of the body.

(*c.*) *Mineral foods* are necessary for bones, especially lime, which these contain in large proportion.

Fermentation.—While plants and animals raise their foods to higher forms, their waste materials during life, and their whole bodies after death, become reduced to simple forms, in which they can mingle with the air and soil and serve new generations of living beings. So nature pursues one ceaseless round of building up and pulling down, and rebuilding out of the ruins of her former activities.

One of the main forces employed in the reduction of animal and vegetable matter through decay to fresh usefulness is the *ferment*, an organism belonging to the borderland between the animal and vegetable kingdoms, and so minute as only to be seen by the higher powers of the microscope. The history of the discovery of ferment and of the proofs of their capabilities and operations would be interesting, but want of space forbids their being entered into. Suffice it to say, that though a comparatively new study, many facts of inestimable value have been established, which will be helpful in practical matters.

Because of the confusion which prevails about names and systems of classification, we will adopt the term *ferment*, and its French equivalent *microbe*, as best meeting our case for the whole class of organisms in a *living* state ; and *germ*, as properly describing the seed from which the ferment springs.

Ferments are differently shaped, round and oval, rod-shaped, wavy, and spiral, &c., &c., but all of simple forms. They increase under favourable conditions at an incalculable rate, partly by each dividing into two distinct and complete forms, and partly by forming germs in a certain state and scattering these to form a new generation of living ferments. If fission, the former method, occurs once in every hour, as is the case with many kinds, this continuing for twenty-four hours will give a progeny of $16\frac{3}{4}$ millions for the single original ferment!

The conditions which are essential to the germination of the germ, and the increase and action of the ferment, must now be stated. These are—

(*a.*) Moisture in some degree.

(*b.*) The food of the ferment in an available form. The albuminoids are especially important, with O and C, alkaline phosphates, and ammoniacal salts. Some kinds need free O throughout their life work, others require it only to begin with, and can afterwards obtain it by the decomposition of the substance attacked.

(*c.*) A suitable temperature. Each ferment has its own best temperature, with a range above and below, within which it can thrive, and beyond which it grows feeble and inactive with greater distance from the most favourable point. Heat from 140° Fahr. and upwards, according to their kind and state, will kill them; but the germs resist very much higher temperatures, and some only become incapable at 240° Fahr. and upwards. Cold within any range possible to the present does not kill them.

The electrical condition of the air, or of the substance attacked, affects their activity; the prevalence of *negative* electricity, as in "muggy" weather and thunderstorms, being very helpful to some kinds at least; while in a clear state of the atmosphere, when its electrical condition is *positive*, they are feebler.

Although O is necessary to them, it is also a destructive agent when in excess of their needs, and especially in Ozone (O_3); and as this influence is more considerable in the open country than in places thickly populated, fermentation is more liable to the latter, and in its most rapid development.

Ferments are not only found in substances actually fermenting, but also in the air, water, and soil; carried by the first, especially in the germ state, and in every current; and finding in the others their food materials and necessary conditions. Their distribution is very uncertain under these circumstances, not being alike at the two ends of an hour in any place. This explains many irregularities which perplex observers, who find substances which keep well at one time and place, quickly spoiled at another time without any apparent difference in conditions. They are usually most numerous on low grounds, damp spots, and in warm seasons.

The decomposition of albuminoids, fats, and carbo-hydrates sets their elements free to form new and simpler combinations—H and O forming water, C and O forming CO_2, while N is found with H and O as HNO_3 and HNO_2 (nitrous acid), and NH_3; and P and S give rise to H_2SO_4, H_3PO_4, and other kindred compounds. The ash constituents of the decaying bodies follow suit in the general breaking up.

The direct products of fermentation are also important, the *Ptomaines* (*to-ma-ēens*, from *ptoma*, a dead body) being always unwholesome, and in some cases poisonous. They are akin to the Alkaloids, which are of two types,—the one having no O and being fluid and volatile, as pyridine C_5H_5N; and the other having O, and represented by creatin $C_4H_9N_3O$, and allied compounds, and by poisons of the narcotic and strychnine classes, which are crystallisable and non-volatile. These act as bases with acids as NH_3 does. The alkaloids of fermentation are akin to one or other of these. Besides there are other highly poisonous compounds, colloid, related to the Globulins, and commonly grouped under the head of "fermentative extractives."

The work does not generally, if ever, proceed under the same ferment from beginning to end. There are several successive main fermentations, in each of which the products form a limit to its progress in its own direction; when that limit has been reached, other ferments take up the work and carry it on to their limit, and so on; even the ptomaines joining, in some cases, with the larger products to bar their way.

The leading forms of fermentation are briefly as follows, viz. :—

(*a.*) *Alcoholic fermentation.*—Solutions of sugar are attacked by a ferment, *yeast*, which separates the sugar into alcohol and carbon-dioxide, as in the following formula, — $C_6H_{12}O_6$ (sugar) $= 2C_2H_6O$ (alcohol) $+ 2CO_2$, with a certain proportion converted into other substances by the feeding of the ferment.

(*b.*) *Ammoniacal fermentation.*—The decomposition of urea in the urine of animals is effected by another microbe with the production of ammonium carbonate, as CH_4N_2O (urea) $+ 2H_2O = (2NH_4)CO_3$ (ammonium carbonate), which again decomposes into $2NH_3$ (ammonia) $+ H_2O + CO_2$.

(*c.*) *Lactic acid fermentation.*—This form, so called because of its best known connection with milk, may also take place in any sugar solution under the necessary conditions. The simplest conception of the work is shown in the formula $C_6H_{12}O_6 = 2C_3H_6O_3$ (lactic acid).

(*d.*) *Acetous fermentation.*—This follows the alcohol formation of *a* by taking up two atoms of O for every molecule of alcohol, as $C_2H_6O + O_2 = H_2O + C_2H_4O_2$ (acetic acid). It is by this process that vinegar is made.

(*e.*) *Butyric acid fermentation.*—This form may follow lactic acid formation, as $2C_3H_6O_3 = C_4H_8O_2$ (butyric acid) $+ 2CO_2 + H_4$ (free); but it can also be produced in starches, albuminoids, and organic acids, the processes involving further combinations, into which it is unnecessary to enter.

(*f.*) *Mannitic, viscous, or gummy fermentation.*—This is a more complicated process than the foregoing, and probably consists of two actions making progress at the same time. In one case mannite—$C_6H_{14}O_6$ with some CO_2—is produced; in the other, gum—$C_6H_{10}O_5$ with H_2O. The former result is akin to the mannite of manna juice, and the latter to the vegetable gums. This fermentation causes a peculiar slimy "ropiness" in wines, milk, and other liquids.

There are besides the foregoing, microbes producing coloration, as that which forms litmus in an infusion of the lichen, *Rocella tinctoria*, and others; and even more important to us, the many and very-little-known ferments which cause taints in perishable liquid foods, of which more by and by. Of the latter, however, it may be said that they are all helped by filth and carelessness in management, and no small part of the mysteries of the pantry, the cellar, and the dairy arise from the encouragement afforded to the mischievous ferments by the presence of the decaying materials on which they depend.

In the light of the facts so far given, we may proceed to the study of our special subject with the advantage of a general conception of the principles which will be specially applied in connection with it.

CHAPTER II.

ORIGIN AND PRODUCTION OF MILK.

The Cow and her Milk.—The original purpose of the milk of the cow is the sustenance of her offspring; and the other uses to which it may be put, though doubtless in view of the Divine wisdom in creation, must all be regarded as secondary. When therefore the dairyer employs it in the manufacture of foods, he must be guided in his processes by the natural laws which govern its composition and behaviour.

The cow makes her milk out of her blood, which she has made in the first place out of her food, and it is therefore proper to consider the processes of transformation in order to understand the bearing of the cow's personal functions, health, feeding, and other conditions, upon the milk and the foods prepared from it.

Foods, how Converted into Milk.—Given, then, suitable foods, grasses, or other plants, hay, roots, meals, or what not, with their varying proportions of starches, sugars, fats, albuminoids, and soluble minerals, the cow converts these into blood by the processes of digestion, absorption, and transformation. Digestion consists in the change of the insoluble parts of the foods into the soluble forms necessary to their conversion into blood. The starches are so changed into sugar by the action of *saliva*, an alkaline liquid which is secreted by glands in the region of the mouth, and mixed with the foods during eating and the chewing of the cud. The active agent in this case is *ptyalin* (tí-a-lin), one of a class of substances called *enzymes*, which are secreted from the blood and specially concerned in such changes, acting with water in producing them. In this they resemble the life-cells of animals and plants, though they differ in other respects. The formula $C_6H_{10}O_5$ (starch) $+ H_2O = C_6H_{12}O_6$ (sugar) shows the chemical change, but the physical differences between the starch and sugar are much greater and make all the difference between uselessness and usefulness.

The colloid albuminoids are changed from the *proteid* or insoluble into the *peptone* or soluble form by the *gastric juice*, which is secreted by glands in the inner lining of the fourth stomach, and mixed with the finely chewed foods by contractions of that organ. The enzyme in this instance is *pepsin*, the action of which is aided and modified by HCl and certain mineral salts, which vary with the feeding and consequent composition of the blood. Vegetable casein is coagulated by the juice, and the other nutrients of the same class are entangled with it, the whole being speedily reduced to solubility. It now enters the small intestine, in which it is at once mixed with *bile*, a bitter alkaline fluid of yellow colour, formed in the liver. This acts upon the fats, producing with them an *emulsion*, in which they are finely divided and separated. The *pancreatic juice*, coming from the *pancreas* or *sweet-bread*, goes on to digest the remaining undigested starches, emulsifies fats, dissolves gelatinous foods, and even, it is said, albuminoids on occasion, besides decomposing some part of the fats into glycerin and acids. The foregoing are the main agents in bringing the foods into the *chyme* (kime) state, in which they are found in the following forms, viz. :—

1. Fats, in emulsion,
2. Carbo-hydrates, sugars,
3. Peptones, albuminoids,
4. Minerals, salts,

} in solution.

5. Water and digestive juices.
6. Digestible food still undigested.
7. Indigestible fibrous materials.

The main parts of the first five items above are now absorbed into the blood, and changed into it also, by two stages,—the first being wrought by cells covering the tiny organs of absorption which line this intestine, and the second by those of the *spleen*. When the entire transformation is effected, the blood made differs strikingly from the chyme. It consists of a nearly colourless fluid called the *plasma*, in which float many yellowish-red disc-shaped bodies called *corpuscles* (cor-pus-kels), with others which are colourless and are called *leucocytes*. The red corpuscles are mostly albuminoid ; a colourless proteid called *para-globulin*, having another—*hæmo-globin*—distributed among it, and this latter containing *hæmatin*, which has 9 per cent. of Fe, and gives the red colour. They are about one-third solid, and contain nearly one per cent. of inorganic substances coming originally from the soil. The leucocytes are usually nearly globular, but alter their forms much and undergo considerable physical changes, breaking up finally and leaving their denser internal part as red corpuscles. These latter are in much greater numbers than the colourless sort. The plasma has about 10 per cent. of solids, of which

7.88 per cent. are proteids, .17 fat, and .39 extractives, while minerals are present in trifling quantities.

Blood coagulates when removed from the living body, when a new substance, *fibrin* (Fig. 5), appears in the shape of fine threads, which entangle the corpuscles and with them form the "clot." Fibrin, as such, is not found in blood, but is believed to arise from the operation of an enzyme upon a proteid called *fibrinogen*. The liquid remaining is called the serum, and differs from the plasma in not having the proteid which has undergone coagulation.

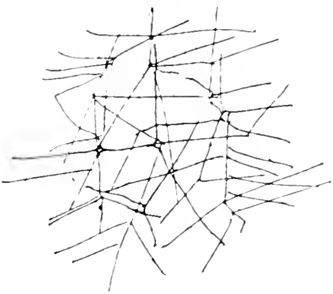


FIG. 5.—FIBRIN IN BLOOD.

The blood, having been changed in the liver, goes to the right side of the heart, and is from thence sent into the lungs, where it comes into contact with the air breathed into these; being distributed for the purpose through many tiny blood-vessels called *capillaries*, taking in the free O of the air, and giving off CO_2, vapour of water, and various impurities, changing from its previous dark colour to a bright red, and increasing its vitality and fitness for the offices of nutrition. The red corpuscles take up the O in association with their hæmo-globin.

Fresh Air and its Relation to Temperature.—The exchange of gases in the lungs points to the necessity to the health of the cow, of an abundant supply of pure and fresh air. Pure air breathed in, contains in 10,000 parts about 2,100 parts of O and only 3 of CO_2; whereas that breathed out, contains only 1,600 parts of O and 470 of CO_2. At this rate, it would not take long to convert a considerable body of confined air into a gaseous combination dangerous to life, for the suffocating effects of CO_2 will be remembered. The N of the air has a similar tendency. The injury to the health and vitality of animals lacking proper air must therefore be great.

Here we may conveniently consider the office of O in the blood, as it is obtained by respiration. The nutrients of the blood are carried to all parts where cells are building up fresh growth, or repairing the waste caused by the various forms of activity; and there, with the production of force, and the formation of new substances, (whether incorporated with the solid parts of the body or circulating with the blood), they are used up. Decomposition takes place because of the agency of O in the kind of burning called *oxidation*. Now, just as the burning of wood or coal furnishes heat and force to water, which in the form of steam will drive engines, so the using up of blood materials provides force for the requirements of the animal; and just as the combustion of wood or coal is helped by O, and gives off CO_2 and H_2O as gas and vapour, so these are given off whenever the oxidation or combustion of the carbo-hydrates and proteids of the blood takes place. With albuminoids there is some N to be disposed of, and one product of combustion is *urea*, CH_4N_2O, which is cast out of the system, not from the lungs but by a different route.

The temperature of the body is maintained within a few degrees above or below its average—with the cow 100° Fahr. to 102°—by the circulation of the blood, absorbing heat, and carrying it to all parts where the temperature would naturally be lower. Within reasonable limits, the flow of blood can be easily regulated; for if the air becomes warmer, the capillaries, expanding with the expansion of the blood, give off more moisture than usual, and this evaporating as sweat helps to reduce the temperature. On the other hand, cold affects the nerves, which partly control the capillaries; and causing them to bring about contraction of those blood-vessels, helps to preserve the heat which would otherwise be lost. When, however, the cold is too great, these nerves become unable to act, being, so to speak, paralysed; and their control being suspended, too much blood is passed into the capillaries, and inflammation follows. This is aggravated by dampness in the air; for the bracing influence of a dry cold is lost in such case, to a great extent, because of the reduced evaporation. The effects may be local at first, but the whole system must be damaged by them, poverty of blood naturally arising out of the diseased condition, and waste of materials. So, also, too great heat may, by way of relaxed nerves, produce a similarly mischievous effect. Hence the necessity that the air temperature should rise or fall but little above or below that point which is best for the health and comfort of the animal body.

For combustion, fuel is necessary, no less in the animal than in the fire-grate. This means that the food must contain sufficient fats and carbo-hydrates to meet the demands of the system for heating as well as for building. But heating by foods is a wasteful policy when the surrounding temperature is made a matter of no concern. Plainly, the greater the cold the heavier must be the demands made upon the foods for warmth; therefore, arguing the other way, the warmer the air, within reason, the less the food required to serve that demand,—so that shelter and comfort save food, and, costing less, are more economical.

Milk in Process of Secretion.—Returning to the blood circulation, we find that which has passed through the lungs returning to the left side of the heart, and being sent out through the arteries to all parts of the system. Certain branch arteries supply the *udder* or *mammary gland* with the blood for milk secretion. The udder is a body of tissue of spongy character, divided lengthwise into two main parts, called *lobes*, by a wall of *ligament* or fibrous tissue which supports the organ. From this wall fibres run through the structure and join the outside coat beneath the skin, so binding the whole well together, and yet, by their elasticity, giving scope for motion and expansion. The cavities which give it a spongy appearance belong to four systems, and connect with tubes which join each other, and enlarge (just as streams join to form rivers), finally opening into the four large *milk cisterns* situated above the four active teats of the organ. Two of these systems lie on either side of the ligament, and a cow is therefore said to have four *quarters*. There are sometimes two other teats, not fully developed, and having no milk-forming organs. Each system is distinct from its fellow, and it is possible for either to fail while the rest yield milk.

The tissue is of a grey colour, flushed with the red of the blood. In the cavities referred to above the milk is secreted. They are of globular or pear shape, and extremely small. Each is an independent organ of itself (Fig. 6), and described as an *alveolus* (meaning a little cavity, plural *alveoli*). It is lined with epithelium cells *a*, surrounding and close to which are the blood capillaries *b*, fed by an artery *c*, and emptying into a vein *d*. The cells receive the blood which escapes from the capillaries, and convert certain parts of this into certain parts of milk, while the remainders pass into the interiors of the alveoli without practical change. It appears to be reasonably certain that both kinds of blood-corpuscles, as well as the plasma, furnish the cells with milk-making materials. The red corpuscles alone contain Fe,

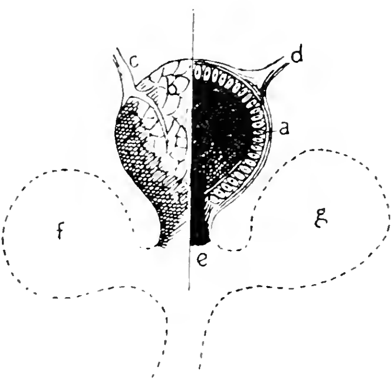


FIG. 6.—ALVEOLUS.

and this (in Fe_2O_3) is present in the ash of milk. A complete decomposition of the constituents of blood, and their reconstitution in new forms, is quite within the range of cell possibilities. There are albuminoids in all parts of the blood, fats mainly in the corpuscles, sugar among the extractives, and inorganic substances. It is not, however, suggested that all these furnish directly, and only, the milk constituents of their own types; for some parts of milk are of wider origin, and are the products of the cells' operations upon unlike substances. But neither is it admitted that, as some claim, some of them have no share in the constitution of those parts of milk to which they are most nearly akin. The blood supplied to the udder does not contain enough fat to account for the usual proportion in milk, and in sugar the deficiency is striking; so that at least there must be a production of these in part from other blood materials. But the fat and sugar of the blood are certainly not all used up in maintaining force and heat, as is proved by the influence of fatty foods which, within limits, increase the fat in milk, and, what is more important, stamp their character on that product.

On the other hand, it is found that specially fatty foods, used in large proportion to the whole feeding, do not increase fat in milk, and even cause it to fall off somewhat; while albuminoids, with but little fat to accompany them, cause an increase of milk-fat beyond the proportion of fat in the food, or the amount available after warmth and force have been provided for. It has therefore been hastily assumed by some people, that all the fat of milk must be made from the albuminoids of the blood, a conclusion which is opposed to practical observation. The apparent contradiction and confusion are due to the ignoring of certain elementary facts which explain the matter clearly.

The cells are proteid, and must be fed with foods of that nature. A purely fatty food would therefore starve them; and any food deficient in proteids would weaken them, and reduce their activity to an extent proportionate to the deficiency. But cells well fed with proteids can also deal with fatty foods to a certain extent, and the milk will increase in fats proportionately. Meanwhile, in the deficiency of fats and carbo-hydrates, the cells can make fats out of the C, H, and O of the proteids. But the powers of the cells to deal with any kind of blood materials is necessarily limited as to quantity. The limits may not be alike in every case, but they are there, and they are narrow; and what cannot be used in milk-making will go to the building cells, and be used to pile flesh and fat on the animal frame. The limit will be discussed further under breeding and feeding.

The tendency of high feeding is to improve milk in all its constituents, but especially to increase its fat; and attempts to greatly augment the albuminoids by feeding foods of that character are disappointing in their results, the improvements being distributed all round, with a special increase of the fats. But this might be expected, because the excess of albuminoids necessarily means a decrease in proportion of carbon foods, and the blood would use up the smaller quantity of the latter to a greater proportionate extent in making heat and force, leaving the milk-cells to make up the deficiency by converting the proteid elements necessary into fat. Evidently the Creator's wisdom has conferred on these minute bodies a selective instinct, if it may be so called, requisite to maintain a general distribution of any enrichment, arising out of special feeding, in due proportion among the constituents, and to throw any excess of blood proteids used into the form of fat. Here the original purpose of milk puts a limit on any alteration of its composition upwards. The nutrients in the milk are kept within a range suitable to the needs of the calf, for which if one constituent is increased the rest should follow suit; and if any one in particular must be in final excess, it should be that which will most tend to early maturity. This very provision has been made, for fat has that tendency, because it sets the proteids free for muscle building, itself furnishing heat and storing up its balance as the fat of the calf's body; while the growth is not only rapid, but procured with the least expenditure of cell force, because the conversion is into like substances.

The same rule holds good on the other side. Poor feeding tends to impoverish milk all round, but especially to reduce the fat. Here the proteids form the final refuge; for the calf can live with but little fat, but not without flesh-formers, which never fall so low in milk as fat will do. Given the proteids, even in their lowest proportion in milk, with just enough fat and sugar to maintain warmth, and the calf will live, though its growth will be slow and early maturity impossible. So it is evident that the proportions of the constituents are ruled by the secreting cells for the advantage of the calf; and we are taught that the cow is not a mere milk-making machine, to take in, and grind up, and turn out, just whatever it may suit our convenience to desire.

The Sources of Milk Constituents.—In view of these considerations, it may be argued with good reason that the cells convert the albuminoids of the blood into similar substances, and, if necessary, into fats and sugar also; making up the lack of the two last, and bringing the proportions of all three to a proper basis of relation. In all probability the fats are secreted first from the blood-fats, then from the proteids; the sugar first from the sugar of blood, afterwards from the proteids.

There are, however, two main albuminoids in milk,—the one albumin, nearly like the kindred substance in the plasma; the other casein, differing radically in certain important points of behaviour, and from seven to nine times more in quantity. To these may be added *nuclein*, which is commonly included with the casein, though a distinct compound.

The ash materials of the blood used are probably all conveyed into the milk without change; this is certainly true of the water, which is continually oozing through from the capillaries, removing the changed or newly-made milk constituents, and retaining them, either in suspension, as the fats; in diffusion, as the casein; or in solution, as the sugar.

The fats are cast out in globules, in a semi-liquid state, and join together in many cases, and in varying numbers, to form larger globules. This is evident from their great variations in size, the largest being eighteen times greater in diameter than the smallest; and the fact that many of them, as found in milk, are larger than the secreting cells. As seen under the microscope, milk presents the appearance shown in Fig. 7, where these variations in size are manifest. This gathering is arrested by the formation of an envelope of casein, which becomes attached to the surface of each globule by cohesion. This statement is made with the knowledge that it is directly at issue with recent theories. But all evidence at present to hand on this subject has been carefully considered, and it is found that most of it confirms the envelope theory, and that the rest has no practical bearing on the matter.

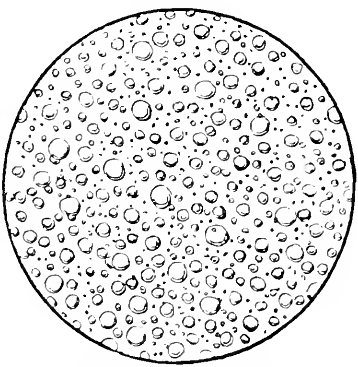


FIG. 7.—MILK UNDER THE MICROSCOPE.

Such facts as are necessary for immediate purposes will now be presented, and the remainder will follow as they arise in other connections. First, however, it is not claimed that the covering is of such a character as to justify the use of the terms "membrane" and "cuticle" to describe it; these, when employed, have possibly expressed more than was intended by the writers. Nor is any appearance of rings in the globules, as seen under the microscope, to be advanced as proof; neither their presence nor their absence can count in the case at all, for they arise from refraction.

A leading argument, which can be dealt with here, is raised against the envelope theory out of the fact that soaps, syrups, or sugars, in water, when shaken up with fats, separate the latter in a fine state of division, and make what may be called artificial emulsions, in which the fats behave like the globules in milk. Whether all such liquids are precisely like casein in water in their relations with fats is of no consequence to the present question ; for in milk we have to do, not with soap or sugar, but with casein. A nearer and more natural parallel is found in alkali-albuminate (albumin diffused in water, with an alkali added), which will be recognised as akin to casein. Milk, in a dialyser, will leave its casein behind ; alkali-albuminate, when tested in the same way, passes through. But if fat be shaken up well with the latter, it acts like casein, and leaves part of its albumin within the dialyser. Does not this show that the albuminate enters into the relations with the divided fat, which we claim to exist between the globules and casein in milk ? This argument, therefore, illustrates the very theory it was intended to destroy. In view of the foregoing and forthcoming facts, the presence of envelopes on the fat globules of milk will be assumed, and consistently maintained. The practical value of this belief is considerable ; it is admitted by opponents to be "a good working theory," but if it be unsound let it perish.

The milk secreted in the alveolus passes through its mouth to join that from neighbouring alveoli in a common tube, and with other supplies on the way to the milk cistern, and occupy these or, when they are full, the tubes, until removed. The teat is simply a spongy tube, more or less distinct in different cases, but closed at each end by a ring-shaped muscle, which is relaxed at will, and in response to the sucking of the calf or the hand of the milker.

CHAPTER III.

PHYSICAL PROPERTIES OF MILK.

FIRST for consideration among the physical properties of milk is its density. The standard for liquids being 1 (or, as sometimes given, 1000), the average density of whole milk is 1.031 (or 1031); which means that a measure of such milk equal to 1000 ozs. of water would weigh 1031 ozs., or 31 ozs. more than the water. Pure milks, however, may range between 1.028 and 1.034, according to the proportions of solids (Fig. 8). The density of milk is for this reason, and in some measure, useful as an indication of its quality. As with other bodies, this property is affected by changes of temperature, and it is found that a milk of 1.031 at 59 F. (15° C.), when heated to 67° F. is lighter by one degree of density, or when cooled to 50° F. becomes heavier by one degree, the difference on either side being caused by a variation of about nine degrees of temperature.

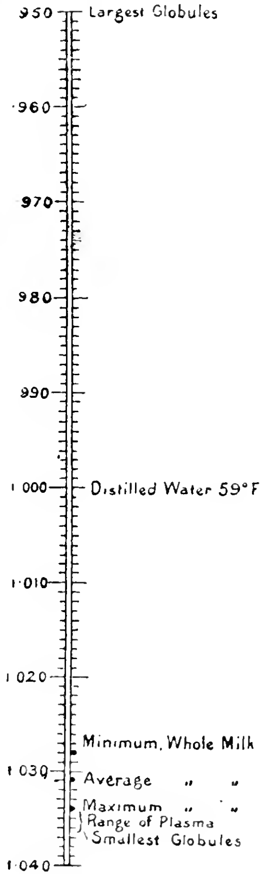


FIG. 8.—SCALE OF DENSITIES.

The constituents of milk vary in their specific gravities when separated. The casein is about one-third heavier than the standard water, and when coagulated it sinks with a rapidity proportionate to its solidity. The sugar is one-half heavier than the standard, and the ash materials are also on the same side. The fats average .930, or .070 below the standard; and albumin rises on coagulation, showing that it is lighter than the remaining part of the *serum*. This latter term is now used for the first time in this work in connection with milk; and it may be explained that, as in the coagulation of blood the clot separates the corpuscles from the main body of the plasma, so in milk the coagulation of the casein separates that constituent and the fat globules enclosed in its coagulum from the watery remainder, which may therefore be properly described as the *serum* of *milk*, though commonly called *whey*. This contains the albumin, which is not coagulated with the casein, but can be separated afterwards by heat, when it will rise and form a flaky layer on the surface.

The fat globules rise to the surface of milk at rest, leaving behind what is often, though improperly, called the serum. Following the distinctions already observed with blood, it may be more correctly called the *plasma* of milk, and this term will be used. The globules do not gather so closely as they appear to do, but float in the upper part of the plasma, and the globules and plasma so associated form cream. The collection of the globules in milk is hastened by certain methods, and the removal of the cream is carried out in several ways; but the whole process of collection and removal is properly described as *creaming*, whatever means may have been used to bring it about.

Under ordinary conditions, creaming takes a considerable time, and is never entirely completed. The reasons are not far to seek. The globules, which range from the $\frac{1}{1500}$ to the $\frac{1}{25000}$ of an inch in diameter, have to carry up burdens of casein in their envelopes: their rising is also resisted by the plasma; and, finally, the distances between their starting-points and the highest which they can reach vary according to the depth of milk.

A comparison of the globules of milk is given in Fig. 9, where they

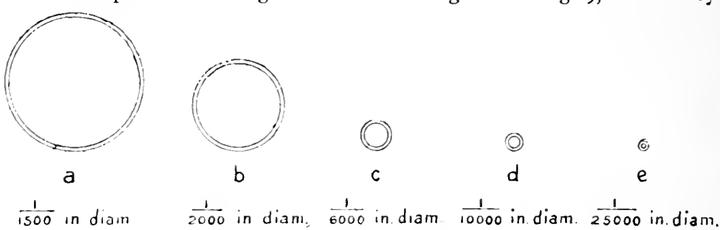


FIG. 9.—FAT GLOBULES.

are shown as magnified 1000 times. The largest (*a*) and the smallest (*e*) are the extremes in size at present known, while (*c*) and (*d*) represent the more common range, and *c* is the average globule. The thickness of casein in the envelopes is equal though covering globules of varying size, for their origin is simply cohesion. It will now be easy to understand how the globule *a* can reach the surface in much less time than the globule *e*, because the proportion by bulk of the lighter fat to the heavier casein is so much greater in the former than in the latter, and the speed of their rising will therefore correspond with their size. This natural law may be applied to all globules in their varying sizes. The largest globules probably have a density of .950 (.020 heavier than the free fats), and the smaller ones an increased density in proportion to their size. In the smallest globule the proportion of the envelope by weight to the contained fat is such as to balance it. Their specific gravity is therefore about the same as that of the plasma, and they do not rise unless indeed, as is believed, they are in some cases carried up by some of the larger ones. These non-rising globules in milk which has been well creamed form about 10 per cent. of the original whole, by number, but their extremely small size makes the loss in butter very trifling.

The resistance of the plasma is an item of considerable importance Water itself would to some extent oppose their progress, though it would also help it when once they had begun to rise. Just as the water in front of a ship resists her onward movement until it is parted by her prow, and then closing in behind her actually urges her forward, so it is plain that the globules must be both hindered and helped by the same force. Every globule in rising must displace its own bulk of the plasma, which must needs descend as the globules ascend. Therefore as much of the plasma as the bulk of the whole body of the globules must descend as they rise, and both hindrance and help will be caused in proportion to this displacement. In milk, however, we have to do with special conditions, which require some study and skill to reduce their opposition to the lowest point possible. The sugar and salts in solution increase the resistance of the plasma, but they also increase its relative density, and thus help the creaming. But the main hindrance is in the presence and condition of the albumin and casein, which are in a state of gelatinous diffusion, and therefore, by reason of their character, capable of making milk viscous or sticky. The larger the proportion of these in milk the more difficult is its creaming. Experiments have been made to determine the resistance offered by the albuminoids, and it is computed to be $5\frac{1}{2}$ times greater than that of sugar, and this may be safely accepted.

But this is not all. The fine threads of fibrin have been discovered in milk by Prof. Babcock, of the Wisconsin Agricultural Experiment Station, U.S.A., and though in very small quantity, yet so distributed in its cobweb fashion as to increase the difficulty of creaming. Its proportion in milk is about $\frac{1}{5000}$ of 1 per cent., while in separated blood it is about $\frac{3}{10}$ of 1 per cent., or 1,500 times more in blood than in milk. This fact shows that in the process of milk secretion, either the albuminoid of the blood, which is specially concerned in the formation of fibrin, is so changed as to be almost incapable of producing it, or that for some reason the enzyme is less in presence or power. In either case, the possibility of fibrin formation in milk may be regarded as due to an incomplete action of the secreting cells, or to some cause behind them, such as unnatural conditions of the health, vigour, or feeding, of the cow, with consequent conditions in the blood beyond the power of the cells of the udder to remedy; and it is morally certain that any unusual quantity of fibrin must be due to such disturbances of the regular processes, and their effects in the animal economy. Milk occasionally coagulates spontaneously, —*i.e.*, without evidence of the causes which generally produce coagulation,—and this is believed to be due to an excess of fibrin. If this theory is correct, the coagulation is like that produced in blood, the fibrin being in great excess, and using up a proportionate quantity of the albuminoids of the milk in its production. In such cases it is evident that the cells have not wrought the usual change in the albuminoids of the blood, by which the fibrin formation in milk has been reduced to $\frac{1}{1500}$th part of that natural to blood, as noticed above. The failure of the cells may easily be accounted for by something unnatural in the health or feeding of some cow, or perchance of a whole herd. This theory is the only satisfactory one known to us, and agrees with the observations which have been made on such occasions, and which have pointed to the causes named. Such experiences are happily uncommon, but the presence and influence of fibrin in ordinary milk remain, and add to the difficulties besetting the globule in its ascent. The formation of fibrin is hindered by cold, and even prevented by freezing; but on the restoration of warmth it takes place, showing that cold does not destroy, and only temporarily impairs, the tendency to produce it.

Distance is a factor in the undertaking; for it is evident that if two globules of the same size, the one an inch from the surface, and the other four inches from it, start at the same time, the latter will take more than three times as long as the former to reach the end of the journey, after allowing for all variations in help and hindrance. Therefore some of the smaller globules near to the surface reach it as quickly as many larger ones which start from lower points, and the earliest cream does not consist only of the largest globules, though these are most numerous in it, and the average size is high.

The combined results of these conditions is that the globules require from half-an-hour to forty-eight hours to rise as completely as they can in an ordinary vessel at air temperature. Some milks with large globules begin to show cream within the time first named, and in six hours have cast up two-thirds of their whole fats; while others, under similar management, have yielded less than half that proportion

The speed of creaming can be observed by the use of glass cream-tubes (Fig. 10), which are graduated to show the percentage of cream which has risen at any time. With these, too, simple experiments can be made, testing and illustrating the principles here laid down. The globules can be caused to rise through water from milk introduced below, and the cream which collects is like that ordinarily found on milk, which would not be the case if the fats were free.

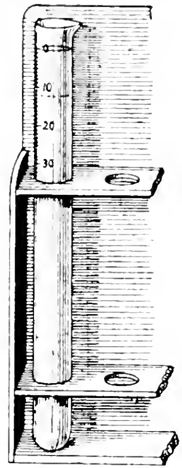


FIG. 10.—CREAMOMETER.

Variations of temperature not only affect milk as a whole, but even more strikingly its two divisions of globules and plasma. Water is a good conductor of heat, and the plasma responds to its action by expanding, or contracts under the action of cold, with all readiness. Not so the globules. Whatever may be the character of fats as conductors of heat, the main reason for the slow response of the globules to its influence and that of cold, lies in the restriction of the envelopes, which hinder those influences from reaching the fats, and these, therefore, from expanding or contracting as much as they naturally would in a free state; so the density of the plasma may be increased or decreased out of proportion to that of the globules, and the difference originally existing between them be widened or narrowed thereby, with a more rapid or a slower rising of the globules in consequence. To put the matter in another form: the globules, by reason of their materials and construction, need a longer exposure to the influence of heat or cold to bring about an expansion or contraction equal in proportion to that of the plasma.

Let this principle be considered as applied under various conditions. Heat causes both globules and plasma to grow lighter, but the plasma is so much earlier affected that it approaches nearer to the globules in density; and as long as the temperature then reached is simply maintained, the density of the plasma becomes fixed (apart from the influence of evaporation, which need not be considered in this immediate connection, and which is very little at any time). The globules, as they were last to respond to the heat, now continue to expand under its influence as maintained; and, becoming lighter in proportion to the plasma, quicken their pace until all possible advantage has been gained, and they have resumed the relations with the plasma which existed before heat was applied. Cold has a precisely opposite effect. With a falling temperature the respective densities of the globules and plasma both increase; but that of the latter so much more rapidly than that of the former, that the difference between them is increased, and a quicker rising of the globules takes place. But when the temperature is fixed at some low point and steadily kept there, the plasma ceases to contract, and has a constant density according to the temperature; while the globules continue to contract, and, coming nearer in density to the plasma, ascend more slowly.

This view of the case is, however, imperfect, because it does not take in all conditions. When heat is conveyed from some source which does not admit of its being equally shared by all parts of the milk at one time, currents are set up, which greatly interfere with the regularity of the rule of "slow rising with a rising temperature." If the source of heat, for instance, is below the vessel containing the milk, the lower parts of the milk are first warmed and begin to rise, the colder upper parts descending. The globules are probably carried downwards by the falling currents to some extent, especially the smaller ones, but not to anything like the same extent as they are carried upwards by the ascending currents; for their own tendency is to rise, and the falling currents have to overcome this, while it is in entire accord with the tendency of the ascending currents. It therefore follows that, with a rising temperature brought about by heat from beneath, all the loss of speed caused by the nearer approach of the densities, may be counterbalanced by the influence of the helpful rising currents, and possibly even better results may be obtained than with a fixed air temperature. If however the vessel be surrounded by hot water, so that the heat reaches the upper parts of the milk nearly as quickly as the lower parts, it is plain that very little if any help would be given to the creaming.

The reversal of the process, by cooling the milk from above, will give similar results, if the cold is as directly applied, and of equal intensity to the heat in the other case. Downward currents create the necessity for corresponding upward ones; and these, of course, are as helpful as those caused by heat. These currents, if not of the gentlest, would doubtless do more harm than good, and creaming would be imperfect, because of their disturbance of the globules which had risen, and their tendency to drag down the smaller ones; but if slow, they would leave the deepening layer of cream in its place, besides adding to it.

Heat and cold also affect the condition of the albuminoids; the viscosity caused by which is slightly and proportionately reduced by the former, and increased by the latter. But whatever advantage is gained in this way by the use of heat, the disadvantage of fibrin formation must be put against it; while cold, by hindering it, gives the falling temperature help as a set-off to the increased natural viscosity.

The quantity of cream, by measure, is dependent on (*a*) the size of the globules, (*b*) the temperature under which creaming is carried on, (*c*) the depth of the milk, and (*d*) the surface exposed to the air. (*a.*) The larger the globules, the higher they rise, and the nearer they crowd together; so making a thicker cream. (*b.*) The higher the temperature the narrower is the cream layer, the lighter density of the plasma offering less resistance to the approach of the globules towards each other; on the other hand, the lower the temperature the deeper the cream, because of the resistance which the greater density gives to the gathering of the fats. (*c.*) A deep body of milk gives a thinner, and therefore a deeper, layer of cream in proportion to itself, than a similar quantity in a shallow vessel. And (*d*) evaporation, which is according to the surface of milk exposed, causes a greater loss of water from between the topmost globules on a shallow body with a large surface, than from a similar quantity set deep with a smaller surface.

Milk is, of course, subject to the laws of density before it leaves the cow, and we accordingly find that the "fore milk" (first drawn) and the "strippings" (last drawn) differ greatly in their proportions of fat; the latter having most, because the globules have remained nearest to the surface of the stored milk. The globules of the fore milk are mainly small ones, the largest being found in increasing numbers as the removal approaches completion. The stripping has five or six times more fat in it than the first pint of fore milk. The sugar is equally distributed throughout, but the albuminoids are in slightly larger proportions in the first than in the last milk.

The *boiling-point* of milk is practically the same as that of water, and its freezing-point is 30° F. The *colour* of milk is due in part to its fats, and in part to its casein, the whiteness belonging to the casein, which is more or less tinged with yellow by the fat in the globules. If the cream is removed, the plasma is found to have less colour, while the cream itself will appear slightly more yellow; but if the fat alone is taken, the remainder has a sharper whiteness than whole milk. The *opacity*, or non-transparency, of milk (which is only partial, for objects can be seen through narrow layers of it) also arises from the presence of the same constituents, and depends for its degree on their proportions.

CHAPTER IV.

CHEMISTRY OF MILK.

Constituents of Milk.—These are found to show differences of proportion in different examples, due to the influence of the breed and individuality of the cow, and her health, feeding, and management.

There is no small difficulty in fixing upon a general average, but the composition given in the middle column below, which has been prepared from many sources, is very near to the desired accuracy. The highest and lowest proportions of the constituents, as found in very exceptional cases, are given in the other columns.

	Maximum.	Average.	Minimum.
Water - -	90.00	87.60	79.00
Fat - - -	12.00	3.25	1.80
Albumin - -	.70	.45	.30
Casein - -	5.00	3.40	3.00
Sugar - - -	5.50	4.55	3.30
Ash - - -	.85	.75	.70
		100.00	

The average above shows more water, and less solid matter, than is usually given by writers on dairying, but there is good reason to believe that the quality of milk is commonly overstated.

Milk submitted to analysis may be divided into three classes—(*a*) milks which are exceptionally poor, and which come into the hands of the public analyst under suspicion of having been robbed of fat or adulterated with water; (*b*) milks which are remarkably rich, analysed for special private or trade purposes; and (*c*) milks which are received by the leading milk-dealing firms in cities, and examined by their chemists for their own protection.

Neither of these can give a general average, they having reference to exceptional experiences; for even in the last case, stringent contracts, and the constant testing of milk received, ensure a higher average than is common to the country at large. The same objection may be taken to the milking trials of the British Dairy Farmers' Association, in which only cows specially selected for the quality as well as the quantity of their milks are entered, and in which special breeds are out of all proportion to the common classes of milking cattle. Important confirmation of our average is found in the yields of butter and cheese common in our dairy districts, which show a milk quality lower than we have given, requiring the better records to be set against them in order to our result.

The relative proportions of the various constituents are not subject to any absolute rule; and the statement that all the "solids not fat" are constant in their relations, is very misleading. The fat varies much more than the other solids; but these vary also, and enough to make serious differences in the processes of manufacture and their products. It will be observed that the downward limit, in each case, is nearer to the average than is the upward limit; *i.e.*, the range of improvement is wider than that of impoverishment. This for the advantage of the calf. The constituents may now be considered separately.

Fat.—The butter of milk consists of nine fats, which may be classed as follows, viz.:—

Fixed	*Solid*— Palmitin. Stearin. Myristin. *Liquid*— Olein.	Volatile	Butyrin. Caproin. Caprylin. Caprin. Myricin.

Palmitin, stearin, and olein have been already described. Myristin, $C_3H_53C_{14}H_{27}O_2$, of which traces are found, is also known in nutmeg butter. It is built up on similar lines to the others of its class.

The volatile fats, with one exception, are constituted like the fixed fats, but differ from these physically in a striking degree. They are so called because they can be dissipated by heat. They are also more easily decomposed than the fixed fats, and some of them are soluble in water. If a volatile fat is dropped on paper and heated it will disappear, while a fixed fat will remain even when the paper is charred. This class includes the "essential oils" of plants, from which, as found in new milk, they are derived, at least in part, though it is believed that they are also produced by the cells from other blood constituents. Their proportions in milk are by no means certain, and probably vary much; but they are much more influential than the fixed fats in affecting the flavours of dairy produce.

The chief fat of this class is butyrin. Its acid has two forms in nature—the normal, C_3H_7COOH, and the iso-butyric, $C(CH_3)_2HCOOH$. These, though containing like numbers of their several elements, have them grouped in different physical relations, and the former is much more pungent than the latter, which is probably the form found in plants, as in the parsnip, and the locust bean now so much used in mixed cattle foods. The proportion of butyrin has been estimated at from $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent. of the total fats, but there is no constant rule.

Caproin, capryllin, and caprin are akin to butyrin, but not so soluble in water. Human sweat contains normal caproic acid, which is there a waste product of the system. Myricin is found in beeswax, being that part of it which boiling alcohol will not dissolve. It is differently constituted from the rest.

These fats, all of them sometimes, and most of them always, present in milk, are so blended as not to be distinguished ; but if butter in a linen bag of close texture, be put under heavy pressure, the olein and volatile fats will separate as a fine yellow oil and leave behind the solid white fats. The relative proportions of these three kinds vary according to the feeding of the cows ; the liquid increasing with succulent foods, such as grasses, forage crops, and silage ; and the solid with drier foods, hay, cakes, &c. It has been a custom to state these variations as arising out of the *seasons*, but in this age of winter silage feeding, it no longer follows that the solid fats will be high at that time of the year. Estimating the volatile fats at 5 per cent., the general proportions of the whole, as in pure, dry, unsalted butter, may be stated as below, that being the average of the best available analyses :—

Solid fat - - - - -	60 per cent.
Liquid - - - - -	35 ,,
Volatile - - - - -	5 ,,
	100 ,,

The average melting-point of butter is 97° F., varying above and below this point according to the proportions of the different fats. Such, however, is the influence of olein, in proportion to its amount, that it keeps the solid fats in a semi-liquid state in the globules of milk ; and these, sheltered by their envelopes from the immediate consequences of changes of temperature, retain that condition under ordinary circumstances until released.

Albumin.—This constituent is the albumin of blood plasma, somewhat changed in physical character. If found in larger proportion than .50 of 1 per cent., the excess is probably due to unnatural cell action. Its composition is as follows, viz. :—

C	53.5
H	7.0
O	22.4
N	15.5
S	1.6
	100.0

It is colloid, and may be obtained by dialysis, and by ordinary analytical methods. By the former, a transparent substance of yellow colour is found ; by the latter, a solid in flakes, brittle, odourless, and tasteless. In its ordinary milk form it coagulates at 163° F., forming a scum on the surface in which some of the fat globules are entangled. From the serum of casein coagulation it rises in flakes at the same temperature.

Casein, when separated, is yellow and transparent, and readily absorbs moisture, which causes it to swell. Its composition is as follows, viz. :—

C	53.57
H	7.14
O	22.03
N	15.41
S	1.11
P	.74
	100.00

After separation it is easily rediffused (some say dissolved) in an alkaline solution. Although it is so much like albumin, it differs from it radically in behaviour, for while heat coagulates the latter, casein does not respond to heat. On the other hand, casein is coagulated by acids, and animal and vegetable juices of several kinds, to which in its turn albumin does not respond. Further, the physical forms of this substance vary according to the cause of coagulation. The coagulants include the gastric juice of digestion, which produces a coagulum or "curd" different in certain important respects from those produced by the others. The coagulum of an acid has less cohesion, and of a different kind, to say nothing of the after-variations in result. Some plants, as the common nettle, give out juices which coagulate casein. It was formerly believed, and is still asserted by some writers, that the casein is held in solution by free Na_2O which might be neutralised by an acid, so making coagulation possible, but the late Dr Voelcker reported the coagulation of alkaline milk with a whey having a like reaction. Sundry experiences of later date confirm his position. Certain ash constituents are now known to affect the character of coagulation, but the "free soda" theory cannot be maintained. Nuclein, $C_{22}H_{49}O_{22}N_9P_5$, can be separated and coagulated, when it forms an opaque jelly-like body, diffusible to some extent in water, and readily in an alkaline solution. It coagulates in company with casein, and is, for that reason, generally included with it in statements of milk composition, in which it forms about a twelfth part of the casein stated.

A peptone called *Albuminose* is found in milk in uncertain proportions, and probably a remainder of peptone unchanged by the cells of the intestine and udder. As separated it differs only from the other albuminoids of milk by being white. It is associated with a colouring substance called *Lacto-chrome*. This is probably derived from the hæmatin of the blood, is of resinous character, of a bright orange colour, and soluble in water. This causes the colour of butter and of whey. It is in very small proportion, and varies much in that respect according to the action of the alveolus cells.

Milk Sugar—*lactin or lactose*, $C_{12}H_{22}O_{11}H_2O$—differs from cane sugar only by the extra molecule of H_2O, as here stated, but has striking physical differences. It can be obtained from whey in colourless crystals, which are hard, do not readily absorb moisture, and are of low sweetening power.

Ash.—The constituents collectively so termed came originally from the soil. They include the metals K, Na, Ca, Mg, and Fe, with the non-metal P, which are separated by the analyst, and estimated in combination with O as oxides ; and Cl, which is combined with Na and K as NaCl (common salt) and KCl (chlorides). Their proportions in these forms are as follows, viz. :—

	In proportion to Ash.	In proportion to Milk.
Cl ...	16.34	.122
P_2O_5 ...	28.31	.212
CaO ...	27.00	.200
K_2O ...	17.34	.129
Na_2O ...	10.00	.076
MgO ...	4.07	.030
Fe_2O_3 ...	.62	.004
	103.68	.773
O of oxides	3.68	.023
	100.00	.750

In milk, however, these are mainly in other combinations with each other, and with organic constituents. In the conversion of blood materials into those of milk, certain remainders are left—*e.g.*, the N and S of albuminoids converted into fats. The N in this case combines with remainders of C, H, and O to form *Urea*, CH_4N_2O ; *Creatin*, $C_4H_9N_3O$; and *Creatinin*, $C_4H_7N_3O$—all products of the natural operations referred to. These having no means of removal in the udder are found in milk, though, unless in cases of disease, in very minute quantities. The S joins with O to form SO_3, and this again with K_2O to produce K_2SO_4, while remainders of C and O form CO_2, and, with H, citric acid—$C_6H_8O_7$—a soluble acid, known in the lemon, and which is supposed to exist in milk, with K, as a neutral salt. The P_2O_5 of the table forms phosphates with the calcic, magnesic, and ferric oxides, the first-named giving the important result $3CaO + P_2O_5 = Ca_3 2PO_4$, or tribasic calcic phosphate, which, by reason of its larger proportion of the metallic base, exercises a great influence on the conditions and character of casein coagulation. Gastric juice cannot coagulate casein in the absence of calcic salts ; a deficiency gives defective results, as also does an excess, which brings the casein nearer to the soluble state. The influence of the other phosphates is not fully known as yet. In addition to these, traces of F are found, which is a constituent of the teeth of animals and is therefore con-

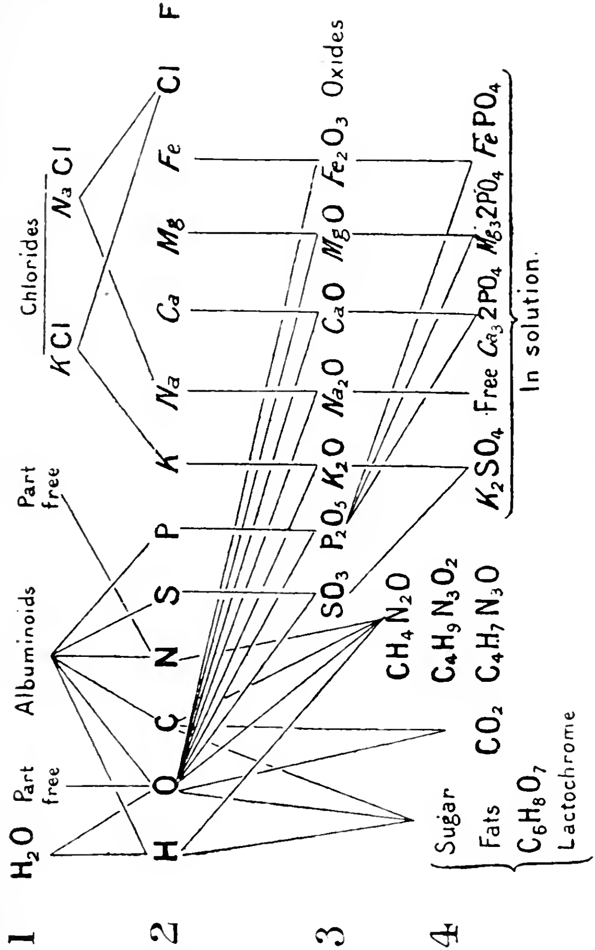


FIG. 11.—DIAGRAM OF MILK COMPOSITION.

sidered to be necessary to a perfect milk, but its relations with other elements is not certainly known.

Gases.—As a consequence of the decomposition of blood materials and only the partial recombination of their elements, there remain three gases in a free state—viz., N, O, and CO_2—estimated at from .1 to .3 per cent. of newly-drawn milk. The N is in by far the largest quantity, about $\frac{3}{4}$ths of the whole, as shown by analysis, the O about $\frac{1}{6}$th, and the CO_2 covering the balance. It is useless to attempt any definite figures, because the causes of their presence are continually varying; and as they are soon lost to the milk, they are not of great consequence.

The presence of alkaline substances gives to new milk a reaction of the same kind, while the CO_2 originally in it, with some probably absorbed by it during milking, and acid phosphates—if such are present,—give it an acid reaction. This makes the milk both alkaline and acid at the same time, and this double character is called the *amphoteric* reaction. This tends to mislead the dairyer when testing such milk for condition. The alkalinity of new milk is increased by heating, because the CO_2 is driven off.

Finally, there is the *oil of milk*, a volatile essence, which can be dissolved out with ether, and is believed to be the cause of the natural odour of new milk.

Such, then, is milk as given by the cow. In the accompanying diagram the original elements are displayed in line 2, and from these a series of lines lead to the secondary combinations in line 3, and the final ones in lines 1 and 4.

CHAPTER V.

INFLUENCE ON MILK OF THE BREED AND INDIVIDUALITY OF THE COW.

Terms Defined.—"Breed" and "individuality" must first be defined. The former includes whatever is common to the breed as a whole, the latter those characteristics in the cow or her milk in which she varies from the breed standard. The one tends to a common level, the other to variation; the one is inherited from past generations, the other is the result of special influences fixing the tendency and character of the one animal. These two influences reach and affect milk by the following channels, viz.:—

(*a.*) By the digestion and blood formation, which are ruled by the vigour and health of the cow, these in turn being inherited and influenced by personal conditions.

(*b.*) By the relative provision and tendency on the one hand to build up the body, and on the other to secrete milk. These are ruled by the breeding, and the greatest milkers are the products of breeding for milk. Either of these capabilities can be cultivated in the one case to beef-making, in the other to milk-making. In the latter case, the tendency is to width and depth of the hind part of the animal, to size of udder, and a relative number of alveoli and milk-forming cells; and where the individual constitution is equal to the task the provision is complete.

(*c.*) The milk-secreting cells also touch milk in certain special respects, regulating the colour, and, in some degree, the proportions of the constituents.

Breeds Compared.—In the light of the foregoing facts, the various breeds may now be considered and compared. They may be conveniently divided into two classes:—

I. Breeds which give large yields of average milk, and are therefore suitable for the cheese dairy.

The Shorthorn, when bred for milk, holds a high place in this class. The average yield is about 400 gallons, but the range reaches 1000 gallons and upwards with special individuals. The quality is usually good, the globules comparatively small, and the average colour of the fat medium.

The Ayrshires, in comparison with Shorthorns as a whole, are better cattle for our special purpose. The general quality of the milk is not higher, but the casein is in higher proportion, and the globules are consequently smaller and easier kept from rising. The milk is therefore well fitted for cheese-making, and correspondingly unsuited to the butter dairy.

In this class must also be reckoned the great body of cattle of mixed blood, found all through our cheese-making districts. Their yields, and the quality of their milks, make them in many cases profitable, but in far more they are altogether unprofitable.

II. Breeds which give milks richer in fat than those of Class I., and are therefore fit for the butter dairy.

The Channel Islands cattle, bred first in the islands of Jersey, Guernsey, and Alderney, and called by these names for distinction. Though differing in build and colour somewhat, they have all a common type, and give milk of the highest quality, the fat being in large globules, its colour high, owing to the special secretion of lactochrome by the cells, and the texture and body of the butter being better than that of other breeds under equal management. The creaming and making of the butter is brought about in a time proportionate to the size of the globules.

The Devons are associated with the production of the famous "Clotted Cream," for which a milk of extra quality is required; and though the fat proportion is much lower than that of the Channel Islanders, it is higher than those of Class I., and the globules are somewhat larger. The fat is of medium colour.

The Kerry and Dexter-Kerry breeds are very small, but give a good supply of milk, equal to that of the Devons in quality and speed of creaming, but yielding a pale butter.

The Welsh cattle of the southern type are also small, but closely follow the Kerries when bred for the purpose.

The other breeds are mainly bred for beef, and dairying is a secondary consideration; although, as the milk must be dealt with, its quality in such cases generally makes it more fit for butter than for cheese. Where the making of either product is the chief business of the stock-owner, it is most profitable to choose the breed which gives the largest returns, and is in other respects suitable to the occasion.

CHAPTER VI.

INFLUENCE ON MILK OF SEASON AND OF THE FEEDING AND MANAGEMENT OF THE COW.

Personal Conditions.—The share of the cow's personality in determining her yield of milk and its character, only is superior to that of her food and conditions of health, age, and season. Among these influences, those which are most intimately connected with the animal herself shall have first attention.

The milk given by the cow for a few days after the birth of a calf differs greatly from her ordinary secretion. The old cells of the alveoli are cast out of their positions to make room for new cells, and occupy the interiors of the cavities until calving takes place. Then they are carried down with the milk secreted, and appear in it as clots; noticeable at first, and imparting a thickness and yellow colour, but growing daily less, until they disappear altogether, and the milk reaches its normal condition.

During that period it is called *colostrum*, or *beastings*, and in Fig. 12 its appearance under the microscope is shown. The clots are of just the character which would suggest the conclusion that they are the displaced alveolus cells. They contain albuminoids in a granular condition — the nuclei being still seen in most of them, and fat enclosed in some as if they had ceased to be active while actually engaged in transforming the fats or proteids of the blood into the fats of milk. It is not quite possible to conceive fully of the conditions under which these cells exist after their displacement, but it is highly probable that a breaking down of their structure takes

FIG. 12.
COLOSTRUM UNDER THE MICROSCOPE.

place to some extent, and that some of the new fat globules adhere to the viscous albuminoid clots even before leaving the udder.

The proportions of the various solids, as shown in the first flow, and their averages for the whole colostral period, are as follows:—

	First Flow.	Average.
Fat	8.5	4.0
Albumin	15.5	7.5
Casein	11.2	7.3
Sugar	0.0	3.0
Ash	3.3	1.0
	38.5	22.8

The extraordinary maximum quantity of albumin (34 times the average) is the most striking item in the first column, and the casein ($3\frac{1}{4}$ times the average), the fat ($12\frac{1}{2}$ times the average), and the ash (nearly $4\frac{1}{2}$ times the average) are also in considerable excess.

These figures probably represent the highest upward limits, and the constituents rapidly decrease until they reach the natural level. The sugar is nearly, or quite, absent at first, but very soon rises to its usual proportion. The albuminoids are accounted for by the needs of the calf,—an exceptionally nutritious milk being required for its earliest days of independent existence,—and these are, in all probability, physically different in some degree from the corresponding constituents in ordinary milk, and more easily digested. The gastric juice of the calf is also at its greatest digestive power at that time, so that the whole benefit derivable from its food may be secured. The loss of the sugar cannot be so easily explained, but the excess of fat more than compensates for it, and fully meets the requirements of the young animal for respiratory foods. Colostral milk also exercises a purgative action in the intestines of the calf, and clears them of their contents accumulated before birth—a matter of necessity for life and health. The milk reaches its ordinary composition in from four to fourteen days, the time depending on the constitutional tendencies of the cow and her state of health. During that time it is entirely unfit for use in cheese-making. Rennet will not produce a natural coagulum with it, and any product possible would be liable to early putrefactive decomposition. It is therefore necessary that the cheese-maker should avoid the use of any milk which is not quite free from this character. In the butter-dairy it is less troublesome, but more than usual difficulty will arise in securing a good product. It is therefore best to feed it to the calf, thus fulfilling its original purpose, until all danger for dairy purposes is past. This may be ascertained by heating a small quantity to 163° F., or higher, when the unusual proportion of albumin manifests itself by coagulating, and enclosing within its curd some casein and globules, just as the casein will do under the action of rennet and acids; though, of course, the result will differ from the ordinary casein coagulum. With the reduction of albumin, the coagulum caused by heating changes until the milk assumes its ordinary character; when it yields but the usual thin scum, it may be safely used in the dairy.

At the beginning of the milking period the milk will be at its greatest flow, though usually of its poorest quality. Later, the quantity will fall off, and continue to do so, though generally with some periods of slight increase or steady yield, until milking ceases. Just before this point is reached changes take place in the alveolus cells, which sometimes render the last milk of the season scarcely less dangerous in the dairy than average after-birth colostrum. The quality of milk should improve as the season advances, but this will be to a large extent dependent on the conditions yet to be described as affecting the health and milk secretion of the cow. In no two seasons will the milk quality run on parallel lines, but the natural tendency is to increase with the lapse of time. In the earlier part of the milking period the fat globules are at their largest for each animal. As the season progresses the casein increases its proportion at a greater rate than the fats, and the globules become smaller, the covering by the envelopes putting a stop to the gathering process at an earlier stage. Creaming by setting systems, therefore, takes longer, but this is an advantage to the cheese-maker, because less fat is lost in his work in proportion to the amount present in the milk.

The age of the cow will also affect the quantity and quality of milk. In the first milking seasons she is usually at her best in quality, but with the passage of time this falls somewhat, while the quantity increases. This rule is, however, subject to exceptions arising out of variations in management. The general tendency is determined by the vitality, which is usually greatest in young animals, but which varies so much with feeding and other conditions as to give a much wider range in experience than is suspected by most stock-owners.

Daily Variations.—The milk drawn in the morning differs from that of the evening in yield and quality, but here, even more than in the case of age, no dependable rule can be made. The variations among cows of the same breed, occupying the same field or cow-house, and fed alike, would scarcely be credited by any who had not fully tested them. In a large number of cases observed, the morning milk was in the largest quantity; but there were a few exceptions, due probably to local or temporary causes. The solids were highest in about two-thirds of the cases in the evening's milk, and in the remaining one-third were in greatest proportion in the morning's milk. The variations ranged from .02 to 3.5 per cent., both in total solids and fat ; and though a considerable part of the increase or decrease was in the fat, its variations by no means corresponded with those of the solids as a whole. The fat was in greatest quantity in the evening's milk in about three-fourths of the instances referred to.

These figures serve to show the uncertainty of the relative quantity and quality of the milk which a cow will give under constantly changing conditions. When, however, the variations are reduced to an average for a herd, the daily result is much more uniform than the foregoing facts would suggest. As an example, eighteen Shorthorns, in comfortable quarters, and subjected as nearly as might be to the same conditions in other respects, furnished in one day a range between $\frac{1}{4}$ lb. and $12\frac{1}{2}$ lbs. in variations of quantity, and from 0.2 to 2.60 per cent. in solids ; but the average was only 5.4 lbs. in the former, and .66 per cent. in the latter case.

The milks of different days from the same cow vary also in both ways, though probably with a less range and average than may be noted in comparing the morning and evening milkings. Here, again, the range and average of a herd is below those of some individuals. The analyses of large buyers do not bring the variations to light, they are lost in the averages of mixed milks. Still less are they noticed in the farm dairy, where the falling off in milk quantity, or cheese or butter yield, only point to them as a whole. Only by recording the doings of each cow separately can they be correctly estimated.

These variations are not merely, and wholly, inevitable occurrences, which must be borne because they cannot be hindered. They are due to definite causes operating with more or less of effect in all cases, and when it is known that of two cows under similar management one makes variations from two to ten times greater than the other, it is necessary to inquire into the reason. The facts drive us to one conclusion, viz., that while common conditions changing from day to day, or from morning to evening, naturally produce common variations in the quantity and quality of the collected milk of a herd ; the greater variations which occur in the milk of individual cows can only be explained by differences between the animals themselves, one cow being better able than another to resist the effects of such changes. In so far as breed touches the constitutional vigour of a cow, so far also does it affect the present question. That a delicate creature like the average Jersey should be more generally affected by changes than the hardy average Kerry cannot be disputed ; and if only wide ranges of variation occurred with the former, and only narrow ones were found with the latter, it would be easy to point to breed-constitution as the great cause, and to give a proper credit to the hardiest breeds for greater uniformity of milk yield and quality. But when such disproportion is found in the variations of every breed, we are compelled to admit that the personal influence lies at the very foundation of the matter, and to attribute to individual capacity, vitality, and health the power to determine how much and how good milk the cow shall give within her breed possibilities.

The share of breed in fixing these characteristics has already been discussed ; it now remains to consider that of feeding and management, these including all the points which are more or less within the control of the stock-owner. These exercise a powerful influence on the directly controlling forces named, and therefore through them on the milk, and they must be studied carefully with a view to reducing the losses caused by changes to the lowest practicable point.

By a treatment which will secure this with the animals most easily affected, those possessing the greater constitutional resistance to change will be included, with the advantages of greater quantity, quality, and soundness in the material upon which the dairyer operates. Each distinct condition, with its appropriate effects on the cow and her milk, will be dealt with as it arises in the development of facts, to anticipate which would be inconvenient.

The length of the milking season is also subject to considerable variation. One cow milks well up to her calving, another ceases to milk several months before that event. These are extremes, of course, the common experience being from six to eight weeks' loss of milking. Here the same conditions rule as in the previous cases, for an animal which is able to continue her milk-giving while feeding her fœtus must needs have good milking powers and a strong constitution. Such a cow must be more than usually well cared for during the time when others would be dry, but she will pay for it.

The tendency to dry off early usually goes with that of laying on flesh, and the better milkers are less troubled with it. Years of the best breeding, feeding, and cultivation, will greatly reduce the dry periods in any good milking herd, and it is decidedly a point to aim at, but no great improvement is immediately possible.

Feeding.—A cow may inherit the best of constitutions and milking capabilities, but the value of these will depend on the conditions under which she exists. Not only is it impossible for her to make something out of nothing, but her profit at the pail will be in proportion to the judgment exercised by her owner in those matters which directly affect her yield of the day or the season. Knowledge and care in feeding must accompany skill in breeding, or the latter will be of little service. A very large proportion of the food of the cow is grown on the farm, and of this again no small share is consumed in the growing state, or as green fodder, hay, or silage. Other foods, whether home-grown or imported on to the farm, properly take a second place in the inquiry.

The pastures must first be considered. The conditions affecting these having been already described, we may inquire briefly in what ways they can in turn affect milk. The "land" and the "herbage" are commonly blamed for most failures in dairy work, the true causes of which are either unknown or inconvenient to confess, and it is certain that their influence has been greatly exaggerated.

The soil itself—*i.e.*, the product of the rock—can only reach the milk by the soluble minerals which pass into it by way of the food and blood. We have already seen that the calcic phosphates are capable of influencing the coagulation of the casein helpfully or injuriously according to the proportion present. How that can interfere with the success of practical cheese-making will later appear. In the meantime, we may understand that the proportions of phosphate-forming materials (P_2O_5 and CaO) vary greatly in different plants, and somewhat even in the same plants on different soils, according as these soils furnish them abundantly or in lesser quantities. There may be, therefore, an unsuspected excess or deficiency of Ca salts in the milk brought from any pasture or from the hay made therefrom, and other foods—having all come from some soil—may exert a similar influence in their various degrees. Milks so affected will behave differently in manufacture, and the subtle quality which rules its behaviour may be properly called "character." This, then, will vary with the soil; and it may be readily admitted, that wherever the variations are not recognised, and an unchanging line of practice is blindly followed in the dairy, inferior and irregular results will follow. When, however, our eyes are once opened to the facts, and we are able to trace the influence of the soil on milk character, it is but a step to the possession of the knowledge which shall enable us to conquer the difficulty, as we shall by-and-by see in regard to the case before us. What the influence of the other alkaline salts may be is not yet fully known; but so far as can be judged it is at most small in comparison with that of the calcic phosphate, and covered in the dairy by simple changes in details of management.

When we turn to the herbage, we find other sources of difficulty awaiting us. The plants which may be considered good for feeding cows will give us no trouble; but these are commonly associated with others which are mischievous. The true grasses and leguminous plants may cause changes in milk quality by their many mixtures, proportions, and growth, but they will not interfere with the dairy processes, or give to the products ill qualities. The miscellaneous plants, which may all be considered weeds, include some which are dangerous to the health of the cow; others, more numerous, which flavour milk undesirably; and a few which colour milk, or produce irregularities. To these causes of mischief must be added those arising from plant-diseases of a fungoid nature.

Do cows eat any appreciable proportion of such plants? The occasions known may be few in which the mischief is recognised and traced to some particular plant; but such do occur often enough to make the matter one of great importance; and we believe that a very considerable amount of harm is done daily by such weeds as are incapable of giving a distinctly bad flavour to milk, but in their many kinds combine to give one generally inferior.

What is the cure? Clean pastures. If a weed is a pest in a cornfield, it is a much greater one in the case before us, where it not only takes the place of a better plant, and hinders the superior growths around it, but actually does direct damage to the dairyer's goods. Weeds are the natural and almost inevitable consequences of neglect. There are few pastures which can keep sweet and free from such trouble by the mere force of natural conditions. Draining and manuring can do much in reducing the miscellaneous plants to small numbers and the more innocent kinds, and a constant war against them should be maintained.

Hay includes, in a comparatively dry state, whatever grew in the field. If well made it will differ mainly in the lower proportion of moisture and digestibility. Some of the essential oils will have been lost, but the making process will have given the food a higher flavour and odour than the growing grasses had. It must be noted that weeds are as harmful in hay as anywhere, and that good hay can only be made from good pasturage. There are also difficulties special to the case. When heated in the rick, hay suffers the loss of fats, carbohydrates, and proteids, from the materials of which acetic acid, $C_2H_4O_2$ (practically vinegar); acetic aldehyde, C_2H_4O; ammonia and other such substances are formed in sufficient quantities to give characteristic odours and flavours to milk

Silage is a comparatively new form of cattle food in this country. On account of its value, and more especially because of its peculiarities of character and influence, it must be briefly described. It consists of green plants placed in a *silo* or pit, or in a stack, and subjected to pressure. Fermentation, which raises the temperature, determines the kind of silage which will be made; above 120° F. the result is *sweet*, and below that point, *sour* silage, with more pronounced character as the temperature rises above, or falls below, that level. The greater digestibility secured is heavily discounted by the tendency to injure milk, which has led some large firms of milk-buyers, particularly in the condensed-milk trade, to refuse all supplies from silage-fed cattle. It tends to increase milk, but unless well made from the best materials it will reduce the quality, and if badly made, should not be used for milking stock at all.

Cereals, whether fed green, in the ear, or fully ripened, as threshed grain or straw, are valuable in their various ways, and under proper conditions only affect milk by their variations in feeding value.

Certain succulent foods, as cabbage, rape, turnips, swedes, mangolds, carrots, and parsnips, are much employed, and in reasonable proportions are useful as foods, but, with the exception of the two last, affect the flavour of milk and its products in some degree, and injuriously. The same is true of brewers' grains and distillers' refuse.

Meals and cakes of various kinds are much used, generally with more bulky foods, and with good effect on the quality of milk. The meals of peas and beans are in great favour with some feeders, their proteids being in high proportion (upwards of 20 per cent. digestible); while maize meal is used for its fat (ranging from 4.5 to 5 per cent.). Either will increase the quality of milk. Linseed meal, within narrow limits, has the same tendency; while cotton seed and palm nut meals are both coming in, being credited with an increase of butter production and an improvement of its flavour, and the former is said to give a larger proportion of solid fat. Gluten meal, on the other hand, is reported to increase liquid fat.

By-products of the mills, such as bran of wheat, &c., and the cakes made when pressing oil frcm linseed and other seeds, are in some cases good for milking stock, as also the mixed foods specially sold for them; but these should be watched for their influence on the flavours of the final products in all cases where this is not known, for some of them are distinctly mischievous. Condiments of various kinds are used to excite the appetite, and have some food value of their own. If they do not give unnatural tastes to the milk they are permissible. But they are being recommended to make inferior foods more appetising; and when these latter are of themselves injurious, the disguising of their character is foolish. Bad hay and silage cannot by such means be made fit for feeding; and the supposed economy of spicing them is really a means of increasing the original loss. The supply of salt in blocks which the cows can lick when they will is helpful to health and vigorous digestion, and increases the quality of milk, thereby.

An occasional but troublesome experience in the dairy is in some cases caused by changes in feeding. It is known as *sleepy milk*, the creaming being very slow and imperfect. This must not be confounded with sleepy cream, which will not churn into butter, for though they occasionally proceed from the same causes, they do not always, and must therefore be separately considered. This is doubtless due to the formation of fibrin to an unnatural extent, and follows changes from dry to succulent foods, as in turning out to pasture in spring. The effects are not necessarily, nor often, common to a whole herd, one cow passing through the change without her milk being noticeably affected in this respect, while another gives evidence of it in the way described. Special plants may sometimes be concerned in it, but there is every reason to believe that the constitutional or temporary inability of the cow's digestive powers to accommodate themselves readily and completely to the new form of diet, interferes with the physical condition of the albuminoids in the blood, and furnishes those concerned in the formation of fibrin and in the physical form favourable to it. This suggests the propriety of a gradual change from one style of feeding to another, when the differences intended are radical.

Water of good quality and in plentiful supply is more necessary to milking cows than to any other stock. Beyond what is required for the use of the system, the cow must have enough to maintain the natural proportions in her milk. Under proper conditions she will not use more than is good for her.

The quality of the water is of the utmost importance. On this point certain errors are prevalent. One is that cows prefer filthy water to clean, but this is a mistake both as to the preference and its results in the dairy. That cows have been known to turn from spring water to some dirty pond in the farmyard may be true, but the purpose has been misunderstood. They prefer soft to hard water, and that which has "the chill off" to a colder supply, but if soft water, not lower than 50° F. be provided, and foul sources cut off, the stock will be contented. The hardness of water will also affect the proportions of Ca salts, and through these the character, of milk.

Management.—In what may be collectively termed "management," are included a number of points which have to do directly with the health and comfort of the cow, and indirectly with the value of her milk, and leading up to the time at which it is received by the dairyer for manufacture.

The earlier teaching as to the effects of cold and heat must be applied by the provision of proper shelter and the use of it whenever the atmospheric conditions warrant, with good and dry bedding when the cows are housed by night. The quarters should be clean, and the animals also, for with them as with human beings, cleanliness is conducive to health.

The cows should be brought in and milked with gentleness and quiet, for excitement is not only injurious to them, and liable to reduce their yield, but is also mischievous to the keeping quality of milk. The milking should be done by clean-handed milkers, the udders of the cows having been also cleansed, and the vessels should be beyond suspicion. Wet-handed milking, with its common accompaniment of filth, is bad even with clean hands and udders, because the sweats of both skins, with organic acids and other products of decomposition, are carried into the milk to its certain damage. If the dairyer helps in this work, he should wear a special dress and boots, changing these before returning to the dairy ; and this last should be provided with such means of delivery as will obviate the necessity of the milkers ever coming within its doors, thus avoiding one cause of taints. The milk of each cow should be separately weighed and recorded, and all other methods conducive to the increase of profit and prevention of waste adopted, for while the commercial success of the dairy may be to a great extent dependent on the manufacture, it is certainly also much affected by the management up to this point.

CHAPTER VII.

INFLUENCE ON MILK OF FERMENTATION, ANIMAL DISEASE, AND NON-PUTREFACTIVE TAINTS.

Liability of Milk to Fermentation. — Milk, in a remarkable degree, supplies the conditions essential to ferments — namely, ample moisture ; the sugar and albuminoids upon which they feed, and which, in turn, they decompose ; and the inorganic compounds which influence their operations in various ways ; everything is ready to their use, and a suitable temperature alone is needed to fill up the demand. As drawn from the cow it is usually free from ferments, and has even been preserved indefinitely, simply by being milked into clean bottles and hermetically sealed. Experiments of this kind have succeeded so often as to justify the belief that germs in the air or on the milker's hands, or the teats of the cows, or in the receiving vessel, must account for the failures ; and although the risks in these cases are too great for trade purposes, they certainly point to the advantages of even such partial security as can be afforded by care in milking and immediate protection from the general risks run by milk on the farm.

Moreover it is at this time slightly alkaline, a condition helpful to many ferments even of the worst kinds ; and the temperature is also specially favourable to most of them, ranging from the animal's blood heat when flowing from the teat, to 85° F. or lower, before it can be discharged at the dairy on a cold day. The fine streams reach the pail through air which is liable to contain a high proportion of germs of different kinds, and doubtless carry some of these with them into the body of milk, from which they cannot be separated.

Our raw material, under the best conditions, thus meets with the active causes of fermentation on the very threshold of its separate existence, and in general circumstances will soon give proof of their presence in it. When to the ordinary, and well-nigh unavoidable, conditions described, there are added a filthy condition of the cow-house, the cow, the milker, neglected pails, and wet-handed milking, it must be plain that the mischievous conditions are increased in proportion to the neglect, both by the introduction of the more abundant germs, and even of active ferments, and of the dirt which —once diffused though the milk—will meet the needs of bad ferments even more perfectly than the natural milk constituents can do. This is no fancy statement, drawn from imagination, for the almost excusable purpose of frightening careless people into carefulness. Every item is supported by observation, both by scientific experimenters and practical handlers of milk. The honest truth is, that very little is received in the average dairy from which it is possible to make the finest of cheese or butter. There are risks at the best, but they are trifling as compared with those commonly encountered. More of this when the patent effects have to be discussed.

In the dairy, too, ferments are found, and the milk receives them from the passing air currents, or by their settling in it when the atmosphere is still. But, from whatever source derived, they may be divided into two classes,—(*a*) the *friendly*, which are either essential or helpful to the processes of cheese and butter making; and (*b*) the *unfriendly*, which introduce objectionable conditions or qualities into the milk and its products. These shall be taken in connection with the special objects of their attention.

Sugar has qualities which definitely assist certain ferments and hinder others. To such as produce lactic acid, it offers facilities in its physical make-up, and speedily becomes changed into that substance under their influence. The $C_{12}H_{22}O_{11}$ H_2O becomes $4C_3H_6O_3$, the water of crystallisation sharing in the conversion, and combining fully with the H and O of the changed sugar.

This would not appear to be a step towards ultimate putrefaction, but such it is. The physical conditions and relations of the sugar elements are changed, and the way is prepared for still further changes. The ferments which produce these results are several in number. That shown in Fig. 13—*Bacillus acidi lactici*—is best known to the bacteriologist, and is probably far more numerous in the dairy than any other, though such may have a minor share in the work at any time. This is of rounded form, 1 to 1.7 μ. long, is found in pairs or chains, and multiplies by fissions and germ formation at a great rate in favourable temperatures. It does little below 50° F.; but with higher temperatures steadily increases in vitality and activity, until at 95° F. it is at its greatest

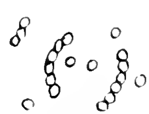


FIG. 13.
LACTIC ACID FERMENT.

power. At 115° F. it is feeble, if not totally inactive; and at 140° F. is killed. Its germs, however, are only killed at 240° F.; and as this is beyond any experience in the dairy, it may be seen that though by much lower temperatures it is easy to destroy the living microbes, their germs remain, ready to come to life when a suitable temperature is reached.

Another ferment, separated and cultivated by Dr Storch of Copenhagen, and designated No. 18, is shown in Fig. 14. This has been used in experiments with milk and cream, with satisfactory results. No others have as yet been isolated. Further references will be made by the initials L.A.F., for brevity's sake.

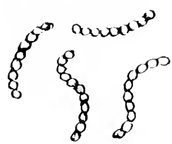


FIG. 14.
LACTIC ACID FERMENT (No. 18).

These ferments probably use up some of the sugar as the alcohol yeast does, producing a small quantity of CO_2.

When the maximum quantity of .7 to .8 of 1 per cent. of acid has been formed they cease to operate, and as in dairying no attempt is made to neutralise the acid in order to set the ferments again in action, we must consider their limit as reached. Long before this, smell and taste will have proved the presence of fermentation, and the milk will have passed beyond the useful stage. The sugar ferments, therefore, are only friendly up to a certain point, which will be better indicated in connection with their necessity in the dairy.

Of unfriendly ferments, the *alcohol* ferment (A.F.) produces small quantities of C_2H_6O and CO_2; but the sugar but slowly responds to its action, differing noticeably in this respect from fruit sugar. The *butyric acid* ferment (B.A.F.) probably carries the work much further, the milk becoming noxious under its influence. After a certain stage has been reached, a general attack is made on the whole series of organic compounds by whatever ferments of general putrefaction are at hand, and in this the sugar elements reach their lowest forms of combination.

One constituent of milk—*Casein*—is attacked by so many unknown microbes that it is difficult to describe its position in the general course of decomposition. It has been said that the whole movement commences with the action of a casein ferment, in the absence of which L.A.F. is idle, and this theory is supported by certain practical considerations. But it is by no means certain, being mainly based on the fact that fermentation is slow in a sugar solution, which may merely mean that the L.A.F. is to some extent dependent on proteid food. On the other hand, the existence in milk of any other friendly kind of fermentation than that producing lactic acid, is either ignored or denied by not a few writers and teachers, probably because it is the only one which can be readily proved by a chemical reaction.

There are, however, strong grounds for believing that while the sugar is being changed, the casein is also being attacked, and that in a way and to a degree which cannot be accounted for by any supposed action of the L.A.F., for this does not appear to affect the casein when sterilised milk is inoculated with it.

It is not claimed that there is absolutely no influence exerted by the L.A.F. on the casein under those conditions, but simply that, as none is observable, it cannot be sufficient to explain the behavionr of casein in ordinary experience. Nor can it be set down to the B.A.F., for that does not appear to come into operation early enough for our purpose. At or about the limit of L.A. formation the casein coagulates, and has for some time before this betrayed increased viscosity, with other varying tendencies, most likely dependent on the ferments present. Unless we imagine the B.A.F. to be capable of attacking it, before it can do anything of consequence with the sugar, we shall have to dismiss it as an unlikely agent. Moreover, the B.A.F. has been used with sterilised milk, the casein coagulating in a firm mass in a week, and being dissolved in two or three weeks, with the appearance of NH_3, leucine, tyrosine, and other fermentative products. Here, in the tendency to give a firm coagulum, it resembles the L.A.F., though it appears to digest it afterwards, which there is every reason to believe the L.A.F. never does. This digestion is, however, altogether too slow to explain our case, nor is it likely to be proportionately more rapid in the presence of lactic acid, as present in dairy processes, but rather the reverse.

Now there can scarcely be a doubt of the presence of a ferment (possibly more than one), the action of which tends to an opposite effect to that of the L.A.F., rather a softening and disintegration of the casein—both the denser form of the original in the envelopes of the fat globules, and the coagulum when formed. Such effects we have realised under conditions which could hardly deceive, when the usual tendency of the casein was plainly checked by another agent, locally and temporarily in excess of power, but not so easily recognised in its normal proportion of influence at other times. After estimating all known conditions, the results could only be accounted for by a ferment which could produce a much more rapid softening effect than the B.A.F. could be expected to do, and of a somewhat different character. Happily we have not to calculate only on the existence of such a ferment, for one at least is known to us, and it is not unlikely that more will be shortly discovered.

The *Tyrothrix bacillus* (of Duclaux), Fig. 15, appears to meet the case fully. This microbe is very like the B.A.F. in form, and might easily be mistaken for it under the microscope; but its action, in all moral certainty, is altogether in the direction of softening, and not of hardening, even for a time, the coagulum of natural fermentation. We may therefore—awaiting the coming to light of a more powerful agent of this tendency—dub it casein ferment No. 1 (or C.F.1). Further, since there are weaker alcohol, lactic acid, and other ferments of definite character, there is a probability of others bearing a similar relation to the C.F.1, and assisting in its work.

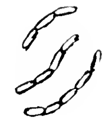


FIG. 15.
CASEIN FERMENT (No. 1).

Some ferments coagulate milk without the formation of acid, and such a coagulum will be much more easily broken up by the later fermentations than one caused by L.A.F., or probably B.A.F. either. In this respect it will approach in character the coagulum of rennet in a neutral milk.

In view of the foregoing, the necessity for a kind of fermentation balancing with the influence of the acid forms, and explaining certain constant experiences and occasional difficulties in the dairy, is met by C.F.1 and its fellows, known and unknown. Such as properly fulfil this requirement may be reckoned among the friendly ferments.

The decomposition of casein by all forces involves the separation, and in some cases recombination, of its elements very much as in other dead matter, and with the same variety and uncertainty of form. The taking up of O and H_2O, and the setting free of N, CO_2, and sundry other gases, occur as usual. Sulphogenic ferments assist in the task, setting free the S to form sulphuric acid (H_2SO_4). This does not generally come within the experience of the dairyer, and it would be fortunate for him if it never did; but under some fermentations such evidences of special or advanced character are met with while the ordinary processes are going on, and some of them are recognised by the sense of taste and smell.

Albumin, though it does not coagulate under ordinary fermentation, is undoubtedly the subject of attack at some stage of the general decomposition. In the serum, where any changes in its condition can be easily noted, the only unfriendly fermentation which we have seen has been the viscous or "ropy" form, and this but twice. Then the albumin appeared to be involved, although the change is in such case wrought in the sugar. The same remarks apply also to the *albuminose*.

The protection of the *fats* of milk by their envelopes has in all probability much to do with the real or apparent non-fermentation of these substances *in* milk. There can be no doubt of their fermentability, and that, in the presence of sufficient casein and water, the action is rapid, accompanied by an odour, pungent and well-nigh unmistakable. Evidences of B.A. fermentation, however, do not appear until an advanced stage of the general course of change has been reached, and even then is probably first due to the lactic acid being attacked. Later, when the C.F. and others have carried their work far enough to allow of the fat ferments reaching the contents of the globules, there is every probability of their being reduced to new forms, and especially to butyric acid and the other products necessary to account for the original proportions of the fat elements. The B.A.F. is pretty certain to take a leading part in this, though it is not likely to act alone.

It has been asserted that the presence of volatile fats in milk is due entirely to fermentation, but this is unreasonable. We have already met with examples of the same substances being produced in living plants and animals, and in fermenting bodies; and there is no more reason for saying that volatile fats are ferment products only, than for asserting that mannite is entirely a product of fermentation. Abundant evidence is at hand to establish the closest kinship between some of the results of the activities of the living animal and vegetable cells and those of ferments, and that volatile fats are among the former has already been shown. It is now readily admitted that they are among the latter also; and while it may not be proved that caproin and its fellows are so produced, it seems likely, though they may need special microbes to produce them. It is but a step between the point here reached and the common putrefaction of all organic bodies, the nature of which has been already pointed out.

Two kinds of ferments have been mentioned as necessary or helpful in dairy processes, viz., those which produce lactic acid and those which soften and digest the casein without producing any objectionable effects from the dairyer's point of view. All the rest may be properly regarded as his enemies.

Taints.—Unfriendly microbes may, in some cases, be altogether idle until the conditions necessary to them have been brought about by others, or by human or accidental means; while others, though usually kept in check by the more numerous lactic acid and casein ferments, may be able, when in larger numbers, to take the lead and work much harm; while others again are always busy, and do as much mischief as their numbers will admit of. It is possible that some of them may bring about changes in milk constituents which will more or less interfere with dairy processes without giving any noticeable taste or smell; but most of them produce taints of one kind or another, often so mixed as to make it difficult for even an expert to determine their direct causes.

By taints we mean odours or flavours, or combinations of these, which are not natural to milk during that period of its separate existence in which it is used for manufacturing cheese and butter, and which are not caused by the friendly ferments during that period, if at all. These are not all necessarily caused by ferments, and we may therefore divide them into putrefactive and non-putrefactive taints. With the former we have now to do. They are of many kinds; indeed, it is doubtful if most existing ferments have not the power to work havoc in milk under favourable conditions. That these last never come to their aid in ordinary cases, and that the actual kinds which can get a start and an advantage in relative power against the friendly ferments are comparatively few, may be true; but, after making all reasonable allowances, there is little room for comfort in these reservations. There are enough left to baffle the best manufacturing skill, and the exceptional conditions occur often enough to make taints the terror of every dairyer who values his reputation. At present only a few have been identified and described, and these have mostly been mentioned already.

Ropiness is caused by the V.F. or some of its kin, and is exceedingly troublesome to get rid of, besides making the milk useless for manufacture. Bitterness, and peculiar tastes not easily described, can be recognised by the watchful, and these are generally caused by ferments. An exhaustive series of experiments will be necessary to secure the facts concerning them.

Pasteur, the eminent French bacteriologist, has aptly called such affections of wine and beer "diseases" of those liquors, and the term is applicable to the same in milk. Diseases they are,—some of them fatal to the usefulness of our fluid, others cured with difficulty—and leaving behind changed conditions comparable to those which, after sickness, render human beings weakly and ready for other troubles; and those due to fermentation are capable of transmission to other milk by the mixing of the diseased milk with it or by germs. To prevent—or, when our best efforts fail, to cure, as far as is possible—must be our aim.

Ferments of the Soil.—In the pastures there are ferments of the soil and manure, and these doubtless of the worst kinds where town sewage is applied. Milk from lands treated with this latter has been known to become putrid in thirty-six hours. Silage, bad hay, grains, distillery refuse, decayed roots, cooked foods which have been allowed to ferment, and foul air and water, are a'l liable to produce mischief. The germs from all such sources are liable to be taken into the cow's system in eating and breathing, and to interfere with her health; though only in disease are microbes believed to find their way into milk by way of the blood. There is, however, nothing to hinder the products of fermentation so reaching the milk, and creating conditions unfavourable to the dairyer's aims. There is no more reason to doubt of the passage of such, than of the flavours of turnip or wild-garlic. Milk from cows fed on brewers' grains has been found to contain free acid, and could not be digested by children. The fermentative products of decayed roots eaten by cows have been known to produce diarrhœa in their calves. Such milk, if brought into the dairy, could not fail to produce inferior goods. A more direct infection of milk may be by the germs being taken up in the field or byre, and carried by the cow's body, or by the air, into the pail, and here again experience confirms reason. Fermented foods and foul bedding, especially of bad hay,—"only fit to put under the cows," as the thoughtless would say,—can do more harm than the cleverest dairyer can cure. In the light of these facts, the gravity of the objections to the use of such, and to dirty udders and wet-handed milking, is increased tenfold.

One great source of contamination is the land pond,—in dry weather a mere puddle of foul water and mud, into which the cows go to cool themselves, splashing their bodies with the festering filth. We have directly traced some of the worst cases of bad milk we ever encountered to this cause. Even the cleansing of the cow's udder, if not done with clean water and cloths, may fail to prevent the harm possible from such a source. Even teat plugs and milking tubes may contaminate our raw material if not cleansed and sterilised after using.

The dairy may become infected, and we have known cases of complete failure; the dairyers, unconscious of the true cause, changing methods and making wild attempts to cure matters; the cheese meanwhile continuing to rot and stink. The only cure in such cases is to cleanse the dairy and all its contents, while cutting off permanently the chance of recurrence by whitewashing the walls and ceiling with materials to which a disinfectant, as nearly inodorous as possible, has been added.

Coloration.—Microbes producing coloration may now be mentioned. Several of these have been identified and tested by experiment. The *Micrococcus prodigiosus* produces redness with acid, and casein coagulation. The *Bacillus pyocaneus* causes a greenish yellow; *Bacillus xanthogenus*, an orange; and *Vibrio* *cyanogenus*, a blue colour. Their products are liable to change with varying chemical reactions.

Infected Milk.—Contagious or infectious animal diseases can be communicated by milk. In certain cases this is established, and in others suspected on reasonable grounds. These sometimes infect the milk by way of the blood, but are always liable to do so by free germs. Human diseases of this type may be carried by milkers. Sometimes the products of disease are infectious, and these can always reach the milk within the animal. Since there are no conditions in any of the processes of the dairy destructive to germs which would not also prevent success in manufacture, it may be said, once for all, that no milk which has been exposed to real danger of infection should be taken into the dairy, much less made into human foods. It should be received in a vessel kept for the purpose, disinfected thoroughly, and discharged where it can do no harm.

Tests for Fermentation.—We now turn to the means which may be used for ascertaining the presence, kind, and degree of fermentation in milk, dealing first with the tests for the friendly forms. The need of such has been felt by dairyers for many years, and various attempts have been made to provide them, but only with partial success. The Highland and Agricultural Society of Scotland recently offered a prize of £100 for one which would properly meet the case; but the prize was not awarded, the jurors deciding that the entries did not fulfil the conditions. Such tests should be reliable, simple, very quickly applied, and reasonably cheap. Some fail on one point, some on another, and there is not at present any absolutely certain test of the kind.

Litmus paper is the simplest, readiest, and cheapest, now obtainable, though it is often objected to as failing in common practice. The charge of general unreliability we deny: for experience of years has proved that it is safe in 95 per cent. of tests made, and the failures cannot only be accounted for, but turned to account in practice. The truth of the matter is, that few people have ever used it long enough to prove it, and still fewer have attempted to reduce its use to any system. For want of a means of determining the extent of acid formation, the user has had to work long before he could become so accustomed to its indications as to depend upon them with safety; but having such means in our possession, we now offer them to the reader.

Litmus paper when plunged into milk which is acid in any appreciable degree, becomes reddened by absorbing the liquid with its lactic acid distributed in it, this depending naturally on the stage of fermentation. As time passes, therefore, each test shows greater redness, and various useful stages of this are shown in the coloured plate opposite the title-page. The last example is reached a little before fermentative coagulation occurs ; but as this shows a stage within or below which every experience in this kind of fermentation comes which has need to be estimated in our work, the test fully covers the case in that respect.

The real value of the test lies in the fact that the L.A.F. and C.F. generally bring about a well-balanced pair of results which combine to determine when the milk shall coagulate by fermentation, for otherwise the mere observation of the acidity alone would not suffice where it is only one of two powerful, and not always equal, influences. The acidity is alone revealed directly by this and sundry other tests, so that we have to take it for granted, in the absence of indications to the contrary, that the desirable balance of power is in operation. When it fails, registering a degree of acidity which does not agree with the time required for coagulation, or with the behaviour in other respects of the material tested, abundant evidences prove the presence of unfriendly forms of fermentation. In such cases the smell generally shows this ; but failing the appearance of a distinct odour, other tests can be applied to confirm the suspicion which the error in litmus indication awakens.

Further, it is true that persons whose colour-vision is defective cannot perceive the distinctions necessary to its use, but this is true of all colour tests, and can only be regretted. To the multitude of dairyers it will be serviceable, and the colour-plate will make its application an easy matter.

The paper is sold in tiny books of twenty-five slips (equal to fifty tests), and by all respectable chemists. It is liable to gradual spoiling by exposure to air or damp, and should therefore be bought fresh, or well kept, and should be carried in a little tin box. The fingers should be dry and free from acid when handling it. It should not be glazed, the greasy and viscous character of the dairyer's materials hindering such a surface from properly absorbing the acid. Before using, the paper should be of the colour of A in the plate.

Other tests might be mentioned, but they fail more frequently than litmus, and fiom the same cause, and the difficulty or cost of their employment would make it unnecessary for the advantage of confirmation.

Rennet, which shows the nearness of milk to fermentative coagulation without estimating the acidity as such, is a valuable testing agent. This, as usually prepared, is an infusion of the stomach of the calf, the gastric juice of which gives it the power to coagulate a neutral, or even an alkaline, milk. Therefore, in order to its use, its strength must be known, and the relation of that strength to a common standard of action, so that it may be said that so much of the work was done by the rennet, and the rest by the ferment. If three equal quantities of milk be tested by equal measures of the same rennet, and one milk coagulates in a fifth more time, and a second in a fifth less time than the third, it must be judged that fermentation tending to coagulation had reached a point in the first case one-fifth in advance, and in the second one-fifth below, that of the third case. This test is of great value in cheese-making when taken in comparison with the litmus test, in which case the rennet being that employed in the manufacture, the indications are immediately applicable.

As a means of more certainly discovering the causes of taints, a kind of "ferment forcing" may be resorted to. In Fig. 16 an apparatus is shown which fulfils the necessary conditions. It consists of a metal case *a*, the upper part of which contains water heated by a lamp *b*, which should be regulated to maintain the water temperature at 100° F. Into the upper part, or tank, fits the tube frame *c*, to hold glass tubes *d*, of one-quarter pint each, with an inch and half of space to spare. The frame *c* is divided into cells by divisions, and has a bottom of wire framework which support the tubes two inches above the bottom of the tank. The cells allow of any tube being removed without interference with the treatment of the rest. Each tube is closed by a rubber stopper having a bent tube *f* passing through it to allow of all gases escaping, and these are conducted into two water troughs *g g*, so that no external air can affect the results. A thermometer occupying a central tube shows the temperature of the contents of the testing tubes, and pipes *j k* provide for the admission or overflow of water as may arise.

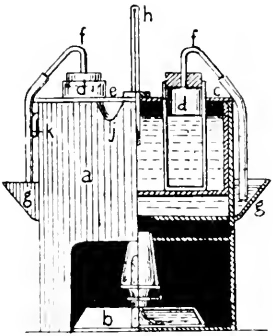


FIG. 16.
TEST APPARATUS FOR TAINTS.

The whole apparatus may be enclosed in a ventilated chest or cabinet if desired, and locked up while in use, so preventing any interference. With the water maintained at the temperature named, the ferments in each of the tubes are enabled to develop and multiply rapidly, out of reach of all others. By observing the time required to produce fermentative coagulation in comparison with sound milks, and the odours and other evidences of special forms of fermentation, it is easy to trace troublesome milks, which may not be discovered by the litmus test, only developing their character when dairy processes are somewhat advanced.

Protection and Preservation of Milk.—Milk, as it comes from the cow, is within the range of temperature favourable to fermentation. By cooling it to a point at which this will proceed more slowly, the milk may be sent in a closed can some distance to a factory, or kept more safely in the dairy than when left to the air influence. By exposing it to the latter in a thin body and in contact with a metal surface cooled by water within, not only is the temperature reduced, but the gases of milk are scattered, and the "cowy" odour also, the latter by oxidation of the materials causing it.

The best known apparatus for the purpose is the capillary cooler, Fig. 17, which consists of a series of tubes so arranged as to present continuous outer surfaces, over which the milk can flow from the distributing trough, until it reaches the collecting trough, and is discharged from its spout. Cold water enters by the lower pipe, rising until it reaches the top, where it flows out by the upper pipe, having cooled the milk on the way, and itself become warmer. The warm milk is therefore first influenced by the warmest water, and at last by the coldest.

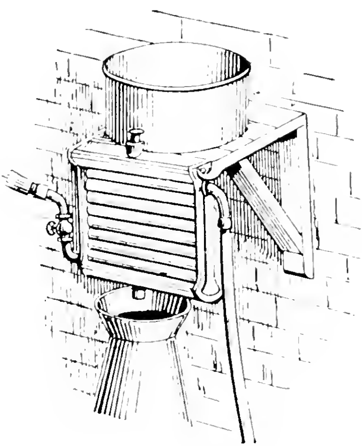


Fig. 17.—Capillary Milk Cooler.

If the cooling reduces it to 60° F. or less, and the air and other conditions are not in opposition, the keeping quality of the milk will be well-nigh doubled. The effectiveness of such cooling depends on (*a*) the temperatures of the milk and the water, (*b*) the rate of milk flow, and (*c*) the water supply and its rate of passage.

(*a.*) The higher the temperature of the milk, the more work has the water to do ; and the warmer the water is, the less chance has it of doing its work well. (*b.*) The more rapid the flow of milk, the less heat can the water extract from a given quantity ; while with a slower supply, the extraction is more perfect up to the point where the temperatures of water and milk at corresponding points of the apparatus nearly agree. (*c.*) The more rapidly the water passes, the more cooling can it do ; if more slowly, then so much the less ; and the supply regulates the quantity, the passage of which can be distributed over the time required for the milk to pass. The regulation, therefore, may secure efficient or deficient cooling, as the case may be, and the thermometer will show which is being obtained. Only pure air should come into contact with the milk while being cooled, so that the work should be placed beyond the ferments and smells of the farm steading. With this precaution air will be beneficial.

Heat may be used for the purpose. At 145° F. the living ferments will be killed; and if the milk is cooled rapidly to 60 F. or less, it can be kept under protection for a still longer time than by cooling only.

Antiseptics, or chemical preservatives, may also be employed, if they be wholesome, and not liable to interfere with later dairy processes. Those which we regard as safe in these respects have for a common foundation the element Boron, the most familiar being Borax $Na_2B_4O_7$, found in nature, and from which is obtained Boracic acid H_3BO_3, a still more effectual agent. But neither is so good as certain patent preparations of similar origin, one of which we have used for years with scarcely a failure; and another of which we have employed as a disinfectant, because of its safety and freedom from odour with vessels which have become tainted, and without any contamination of milk afterwards put in them.

But there are other substances sold which are either worthless or mischievous, and the reader is advised to experiment with them before buying in quantity. A special advantage arising from the use of good antiseptics, is that they serve when water fails, which happens commonly at a time when it is most needed.

Non-infectious Animal Diseases.—Such of these as reduce milk quantity and quality—as pneumonia, and other effects of over-exertion and undue exposure—give also products of disease, and injure its keeping condition. Mammitis, or garget (of the udder), produces local inflammation, and in bad cases the milk coagulates. Sometimes blood appears, as also with the cow's eating of certain acrid plants.

Non-Putrefactive Taints.—These may be absorbed from the cow's feeding (as to which, see Chapter VI.), or by the milk itself when it is drawn. Its powers in this direction are remarkable, and it seldom parts with its ill-gotten gains entirely, though much may be done by airing and oxidation. If suspected milks are tested as previously advised in the present chapter, it will be easy to detect these, and distinguish them from putrefactive taints, by the behaviour of the milk.

CHAPTER VIII.

GENERAL PRINCIPLES OF CHEESE-MAKING.

Cheese and its Varieties.—Cheese consists of the casein of milk reduced by coagulation and after-treatment to a more or less solid state—commonly having the fat distributed within it, together with other constituents always present but in varying proportions, according to the manufacturing processes pursued and the attendant conditions.

Upwards of ninety varieties are made in different parts of the world, their characteristics depending in the main on the principles and practices of the special methods of production, and not on the locality or the soil and herbage concerned in the matter, as is commonly believed. The overwhelming influence of the *manner* of making will presently appear; in the meantime, we may remark that the belief that certain famous cheeses can only be produced in certain districts has done much mischief, by misleading the consumers, and encouraging the local makers to lean on a supposed "natural monopoly," instead of on sound principles and skilful practice.

The only influence which the soil, as such, exerts on the character of cheese, is by way of the ash constituents already described; and of the herbage, beyond this, by flavouring plants, for which the farmer is responsible. There is nothing to hinder the dairyer from making any variety of cheese, if he will provide a suitable dairy and sound milk, and follow the producing methods with proper care. Given half-a-dozen milks of equal quality, in as many different parts of the country and on as many different soils, and let these be made into cheese by one method, with no more variation in practice than is needful to balance conditions: the resulting cheeses shall be so much alike as to make it impossible to say from which district each comes.

On the other hand, let a given quantity of milk be distributed into half-a-dozen vessels in the same dairy, and equal in every respect, and let these be made into cheese by as many different methods: the results shall be as if they had actually been made in the districts in which those methods are usually pursued.

A system consists of a number of practices based upon certain principles, and so related to each other and applied as to give certain definite results, which may be repeated from day to day simply by repeating the system and its conditions. Such a system may be named after the district where it first came into use, or after its originator; but when once the name has become associated with the cheese made under it, all goods so made in any part of the earth should bear its name. In this way only can we avoid endless confusion.

Characteristics of Good Cheese.—The best system is that which gives the most good qualities, and the fewest defects in its product, considered as a food. The qualities desirable in cheese are—

(*a.*) *Quality*, or *richness*, arising from such a proportion of fat as will properly balance the casein, and a mellow, plastic condition of the latter, caused partly by moisture and partly by fermentation. The larger the proportion of fat in the milk used, within certain limits, and the more skilful its management with a view to avoid waste of it, the better will be the quality of the product. The conditions already described as influencing the composition of milk, and the fact that, of all its constituents, fat is the most quickly and largely increased or decreased, will be remembered here, and their importance realised. Sometimes fat is intentionally removed from milk before cheese is made, and this, of course, reduces the value of the latter; but by a suitable treatment foods of considerable value can be made from such milk. A fragment of cheese crushed between the thumb and finger, and rubbed abroad, will reveal its quality—the softness and unctuousness of the rich being easily distinguished from the dryness and resistance of the poorer, with many gradations between, only to be recognised by experience.

(*b.*) *Digestibility.*—The value of any food cannot be determined by its nutrients in the gross, but only by the proportions of these nutrients which can be secured for the building up of the system and for its other needs. Here the digestion steps in, and determines whether cheese is or is not suitable for any person, according as he may or may not be able to digest its casein, and by so doing also set free all its fat for use. This is not by any means decided only by the digestive powers of the consumer. The cheeses of different systems differ in relative digestibility, and even the goods of the same maker; and while some are half-digested in the making, and are therefore easily dealt with by the ordinary human stomach, others resist the gastric juice so successfully as to be of low food value. It is of the utmost importance that cheese should be digestible for this economic reason, and no less, because if it fails in this respect, it interferes with the health, producing constipation, nausea, and other harmful effects, disturbing the comfort of the consumer, and discouraging his use of cheese altogether.

(*c.*) *Freedom from objectionable substances.*—This includes the ptomaines of the unfriendly ferments, waste animal or disease products, the vegetable oils or juices producing non-putrefactive taints, and anything added to the milk not entirely natural to it or necessary to the production of the cheese. The whole matter is concerned with the soundness and integrity of the raw material, which should neither be tampered with by doubtful chemicals, nor enriched with animal fats, nor allowed to damage the consumer by carrying into his system anything liable to cause even temporary disturbance. We have known of dairyers who actually employed copper dissolved in sulphuric acid to correct the tendency of cheese to go out of shape under bad forms of fermentation. The poisonous nature of the curative agency was worse than the disease it was intended to cure. When once the addition of animal fats to creamed milk is taken up, it is impossible to say where it will stop in the direction of danger to the consumer. It is plain enough that animal diseases and disease products may be directly introduced, to say nothing of the questionable trade practices encouraged. The only wise policy, in spite of the opinions of certain authorities to the contrary, is to let it severely alone.

(*d.*) *Flavour and odour.*—These are of great importance in the eyes of the cheese consumer, with whom what is pleasant and natural is almost everything. He will pay a good price for a fine flavoured article, and use it constantly; and, in the absence of this quality, no faith in the nutritive value of the food will persuade him to countenance it. Therefore the money value of the product is reduced by taints of any kind. The management has also a powerful influence in the case. Some kinds of cheese are made with a view to mildness, others for high flavour, and attract different customers accordingly.

(*e.*) *Keeping quality.*—This is dependent upon the soundness of the milk, the tendency of the system, and the conditions under which the product is kept. The first-named point should be secured in any case, and the last should be favourable to long preservation as far as may be consistent with other aims, but the management will be ruled by the purpose of the maker. Different systems give different degrees of this quality—in one it is aimed at; in another the cheese is intended for early consumption, and the system is constructed to give that result, which is altogether inconsistent with long keeping. The advantage is great in one case, in the other it is of little consequence. Most of the kinds which are liable to early spoiling fetch higher prices, and therefore cover the evident risks attending on accumulation of stocks and uncertain demand; while the others, though of lower market value, are safer, because they improve by keeping, within proper limits. These opposite aims and their consequences will be illustrated as occasions arise.

(*f.*) *Firmness and texture.*—These are almost entirely controlled by management, though the character and condition of the milk have some bearing on them. A firm and close cutting cheese is safer in handling, and more economical in use, than one of loose texture. Dryness and hardness, however, are very undesirable; also crumbliness and "chippiness" (the breaking of an apparently solid cheese into chips or angular fragments); while "toughness" and "soapiness," which are well described by their terms, are at the opposite extremes, and should be avoided.

(*g.*) *Size and shape.*—These are of more consequence than would at first appear. Cheeses of a soft character can only be made in small sizes, while the harder kinds are better in larger forms. They must in any case be portable without undue risk of breakage, and with as little loss by drying as is consistent with other purposes.

Local and trade customs have combined to attach an unnecessary importance to size and shape as they relate to the naming of cheese varieties. It is supposed that one variety must be cylindrical, and another flat, in order to bear certain names; but this is an error. A cheese may be made in any conceivable form or size, and yet be properly named after its producing system.

The qualities, *a*, *b*, *d*, *e*, and *f*, are largely dependent on the same principles of the manufacturing system, and bound up together. There is an old maxim that "a good cheese is never of an ill shape," the term "shape" here referring to the bulging and ungainliness seen in many inferior examples. This would point to a bad texture and insufficient firmness, and almost invariably be accompanied by low keeping quality, objectionable flavour, and general lack of value; points which would place it beyond the pale of even comparative "goodness" and worth.

A cheese combining the afore-named good qualities in the highest degree is not to be excelled in food value by any solid food obtainable. We do not mean by this that there are not more highly concentrated foods, for such there are, but they are not used in the same manner as cheese. Extract of beef, for example, is not eaten at the rate of a few ounces to a meal. Nor do we mean that cheese may be used by itself. It needs a balancing of carbonaceous food, such as bread and fruits. A comparison of cheese with other foods, such as butcher's meat, shows that pound for pound it is much more nutritious; but figures are eschewed, because, apart from an exhaustive statement of conditions, and descriptions of all the articles concerned, they would only mislead.

Separation of Milk Solids.—In separating the constituents of cheese from milk, the dairyer has to choose between albumin and casein; for these cannot both be secured at once, coagulation taking place in their respective cases only under different agencies. So, as the casein is both in the largest quantity, and of the more manageable character, it is chosen, and the albumin is allowed to pass off in the serum.

In a general way the dairyer secures about half of the milk solids, the remainder passing off in the whey. Taking an average milk, its constituents are distributed about as follows by English systems, viz. :—

	Curd.	Whey.
Water	5.50	82.10
Fat	3.00	.25
Albumin	Trace	.45
Casein and Nuclein	3.10	.10
Albuminose and Lactochrome	Traces	.20
Sugar	.20	4.35
Ash	.20	.55
	12.00	88.00

These figures are not intended to represent the average composition of curd and whey, but only the proportion of each constituent as shared between the two physical divisions into which cheese-making separates milk.

In some systems the solids lost in the whey would be less, in others more, and in each system they would vary with the skill and care of the maker, and with the kind of implements used.

Stages of Cheese-making.—These may in general be stated as seven in number. They do not follow each other in the same order in every system, but may be taken as given here for comparison, and for establishment of the relations between the several stages, and of their individual and combined relations to the result.

(1.) *Ripeness and ripening.*—These terms convey a correct idea of the principles involved in this section of the work. A familiar parallel occurs with fruit. An apple or pear is at its best for eating when it has reached a stage known by the term "ripeness." Up to that point it is improving, beyond it the progress is towards decay. The natural changes are proceeding, and we simply wait for them in order to derive the largest degree of benefit and pleasure from eating the fruit. We may, however, cook it at an earlier time, and bring about such an immediate alteration in its condition as will fit it for eating.

Now, just in the same practical sense, there is a certain condition of milk in which it may most successfully be made into cheese; and to do so before or after it has reached that point, is to invite more or less of failure, as the actual condition is more or less remote from the proper one. But we can either wait for that condition, or hasten it, as may seem best in view of our several aims. Ripeness in milk is really a stage of fermentation, and arises out of the action of the friendly L.A. and C. ferments. The activities of other ferments are liable to disturb those of the friendly ones, and the indications in testing by which their progress is ascertained.

In the slightly alkaline condition of the milk it is unfit for our purpose. After it has passed out of that and the neutral state, it is steadily improving up to the point desired. That stage of ripeness is not the same in every system, and the highest is but on the threshold of fermentative possibilities. In some systems it will appear to be almost disregarded; but it is not so, for though the process of manufacture is started without allowing the milk to show any evidences of acidity, in such cases the fermentation is provided for later in the work, and this very early stage is properly called ripeness for that system. In other systems the progress of the fermentation must be well marked and ascertained before any attempt is made to enter on the next part of the process. It is by these variations that those in the products are partly obtained and regulated.

The general tendency of the friendly forms of fermentation is to firmness in the coagulum, and hardness in the cheese ; for though the C.F. distinctly checks the special inclination of the L.A.F. to that result, there is reason to believe that it helps to provide the conditions necessary to the life and activity of its powerful neighbour. Therefore coagulation by fermentation alone would not give a satisfactory food product, and the C.F. would have a heavy task before it to reduce the curd even to a comparatively digestible state, before the other ferments could carry their work far enough to make it unfit for use by reason of general decay. This is not the case in cheese-making, however, for another agent, rennet, is brought into the reckoning, but it is a distinct advantage to know what the ferments could do alone, in order to estimate their power in combination with other forces.

The alkalinity of the milk has to be neutralised in any case, and in proportion of this will be the amount of work to be done, and the time to be allowed, or help provided for doing it, before ripeness can be reached. Here comes in the influence of the soil and its Ca salts ; when these are in excess, more fermentation must needs be allowed for to secure the right condition, and this is found in practice to do so. Here also we believe the influence of fermented foods is felt, reducing that of the alkaline salts, and possibly in some cases neutralising them fully. While it may seldom, if ever, be detected in the milk by an acid smell or taste, it certainly narrows the time necessary for ordinary fermentation to produce coagulation. Hence the feeding of silage, grains, &c., must be kept in memory when estimating probabilities.

The state of the milk after it comes from the cow is rendered so variable by the many influences described in the last two chapters, that it cannot be depended on, and must, from the outset, be the subject of careful tests and calculations. In cases where the evening's milk must rest until next day before it is made up, the necessity for these commences as soon as it comes into the dairy. It cannot properly be left to take care of itself; its condition at the time that the manufacturing process commences will be according to its management in the interval, and we can understand how a few degrees of temperature may make a great difference between the experiences of two days in this respect. Therefore the dairyer should watch the barometer, the thermometer, and all other indications of the probable state of the air during the night; and while allowing for possible sudden unfavourable changes, and making himself safe against an excess of fermentation, he should provide for as much progress towards the needful ripeness as may be made within that safe point.

If to the night's milk the morning's is to be added, then more progress may be allowed in order to bring the mixed milks speedily to the ripe stage. But it will be readily agreed that as a deficiency may be made good, while an excess cannot be got rid of by means suitable to the case, the wise dairyer will choose to come out every time somewhat below his standard rather than the least beyond it.

In this event he will have to encourage fermentation in the morning, and three methods are open to him.

(*a.*) The milk may be kept at the temperature suitable to the opening processes until it is ripe. This is the best method, when the result may be obtained in a quarter of an hour; but from that time onwards it is an undesirable waste of time, which is no mere matter of the dairyer's convenience, but one of consequence to the later part of the day's work. While time must not rule the process, but be servant to it, it is yet unwise to lose any, as will be realised when the methods are described as in practice. Here he will have to test the milk frequently until he finds the evidence of ripeness.

(*b.*) The milk may be heated to a temperature at which fermentation will be more rapid, and from which he can safely return to the process-temperature within the time necessary to the ripening. This involves some very careful calculation, for it is easy to go so far as to reach ripeness before it is possible to return to the right temperature for other purposes, when the choice is offered of either starting at a too high temperature, or allowing the milk to become over-ripe, in order to have the right temperature. Again, it is equally easy to fall short of ripeness when the process-temperature is reached, and to be compelled to waste time waiting on it, and while this would be better than the previous case, neither is satisfactory. Experience only can give a safe judgment. Here, too, a test is needed at the start as a basis for calculation, and throughout, to determine the progressive condition. The highest temperature which can be of real use is 97° F., at which the friendly fermentations proceed most rapidly, and beyond which no gain can be made, except as the return through the most favourable ranges of temperatures would be longer maintained. But it is rarely if ever that this is necessary.

(*c.*) A fermented material, such as milk, partly or fully creamed, or whey, may be employed to introduce its many active ferments into that which requires to be ripened, and so to hasten the result. The advantages and dangers of this course will occur to us at once. Time is saved, a definite effect can be relied upon with proper management, and no small amount of watching and waiting is disposed of. On the other hand, the practice is admittedly liable to abuse, and in careless hands may do far more harm than good. Not only may the effect exceed or fall short of the ripeness, if the calculations are wrong; but mischievous ferments may be conveyed into fresh milks from day to day with disastrous effects. At a first glance it would seem as if the risks are greater than the benefits. But is there any necessity for such risks? We believe there is not. In our own experience they have rarely arisen, and these might have been avoided with proper watchfulness of the persons responsible. If suitable precautions are taken, the results are under control of the dairyer, as will be seen.

The ripening material should be kept in a stoneware or glass vessel,—not in a wooden or metal one, because of the influence of the acid on either, soaking into the one and acting chemically on the other, also entering into the pores of tinned plates when the surface metal is worn off. The vessel must be kept scrupulously clean, scalded with boiling water, and afterwards aired and cooled, before receiving a fresh supply. It is not wise to take the ripening material from a large body of whey which has been kept for skimming; in such quantities, the liability to excessive fermentation, and dangerous forms of it, is greater than with small quantities. The material must also be kept in a pure air, where no smells or putrefactive germs from the farm-yards or other sources can reach it.

When using, it is necessary first to learn the stage which fermentation has reached in (*a*) the milk and (*b*) the material, and to estimate how much of the latter is required to produce the proper condition in the former. This must be done in view of distinct and understandable conditions, taking into account everything which can affect the results. It does not serve to put such ripener into the milk to-day at half-an-hour before the coagulating process commences, and to-morrow at only two minutes before that time, and yet to calculate the quantity to be added on the same basis in each case.

It is quite admissible for the addition to take place at any safe time, if only proper allowance be made for the variations involved; but if these be neglected, disappointment must follow. It is best to adopt a regular practice and adhere to it, rather than to run the risks of error by daily changes in the calculations arising out of those made in the details of management.

Moreover, the state of the material is as important as that of the milk. Suppose, for instance, that between the ripening materials used in two days' experience the litmus test showed the difference represented by the colour indications of O and P in the colour-plate, it would be plainly unreasonable to use equal quantities of these to bring about equal effects. The conditions which help or hinder fermentation in the milk will similarly influence the material used for ripening, and in heavy weather the latter will make much more advance than in bright or cold weather.

Unwearying watchfulness must be maintained over the forms of fermentation possible to the ripening material. If it be found in possession of any taint-producing ferment, it should not be used under any circumstances. In general the sense of smell will give warning, but must not be depended upon in any case of doubt. Other tests confirming suspicion, the dairyer should fall back on the heating process. With such care, there need be no mishaps, and security is the reward of the painstaking.

Comparing this method with the preceding one, it may be said that this is more easily reduced to rules, and therefore, literally, less of a tax on the judgment than the heating process. Two other special benefits must be noticed.

Though the L.A. and C. ferments are usually so numerous as to be able to maintain their proper leading, with its corresponding check upon other ferments, yet they are not always so numerous or so able. In such case the heating helps their mischievous rivals to overcome them; while the use of a ripener, in which the friendly ferments are in power, brings these to the help of their kindred, and gives them a great advantage.

The second touches the alkalinity of milk. The ripener contains acid already formed, which partly or wholly corrects the opposite condition at once, and thus reduces the task of the ferments and places them under more favourable circumstances for doing it. Heating would more slowly effect the same result, but would not give the chemical conditions at the outset; these the ferments must create for themselves, while unfriendly ferments may gain ground in the meantime. This last point we take by inference from facts observed in the dairy.*

The ripening materials may now be compared. Milk has been mentioned. This may be set aside as whole milk; but by the next day, when it is wanted, much cream will have risen, and this should be removed, as nothing is to be gained by putting it into the new milk beyond the slight gain in fat, which, on any quantity required for our present purpose, will be trifling. Milk mechanically creamed or separated will serve even better, because the process of its creaming rids it also of any foul solid matter it may have contained, and by so much brings it nearer to absolute purity and freedom from risks of bad fermentation. But neither form of milk is at all commonly used, probably because neither is convenient. Whey is ready to the dairyer's hand, and whatever of the supply set aside is left after the demands of the day's cheese-making have been met, goes without loss to the general destination of all, the pigstyes. It might seem that either milk, being most nearly like that requiring help, would be more likely than whey to contain the ferments in correct relative proportions of number and power. The almost entire removal of the casein in the cheese would suggest a deficiency of the C.F., and a necessarily undue prominence of the L.A.F. in the whey. But it must be remembered, that while the latter has its advantage in much more sugar than it can deal with, the C.F. germs are present in full force, and have only need of the favourable temperature, and the presence of casein in the milk under treatment, to start into full life and activity.

It is also questionable whether the C.F. cannot live on albuminose, or even albumin, in such cases; but whether or not, there is no evidence in practice that the effect of whey is to increase acidity out of proportion to the casein fermentation,—*i.e.*, no irregularity in action, such as an ill balance of the two ferment influences could cause, appears to arise out of the use of it. So far as theory goes, there is nothing to discount the employment of whey. What does experience teach?

Many, probably nearly all, of the best cheese-makers in this country and America have used—or, if among the living, still use—whey, with entire satisfaction. But many others have made bad work with it, and this has led certain prominent teachers on both sides of the Atlantic to discontinue it altogether. The abuses which they discovered seemed only to be curable by such a course. We have witnessed these also; the keeping of whey in any filthy vessel of wood or tin, and that cleaned once a week only, or even more seldom, and never scalded; or the supply taken from a huge wooden tank in which the whey was kept for creaming, and the cream on which was often so highly fermented as to be frothy; the measuring it into the milk by "bucketfuls" and "bowlfuls" (!), in great excess, and with only the roughest calculation of the needs of the case,—all these we have seen, and admit that they argue a state of affairs which justified a radical remedy. One dairyer of the gentle sex has been known to pour the whole of the whey retained for ripening into the milk, and upon being told that it was far too much, asked what was the good of keeping it if it was not used! Nor were these rare examples, but only types of common experience. We have but few home-taught dairyers who make a proper and intelligent use of whey, and those few are among the famous.

In trying to kill so serious and widespread an evil, it appeared to be necessary to instruct the people in some process of ferment-encouragement entirely new to them. When, however, those who attempted this fell to denouncing whey as unnatural, and as unfit as vinegar, they overshot their mark and weakened their cause. Acetous fermentation is very different from the L.A. fermentation, which is equally natural to, and found alike in, milk and whey; nor would there be in vinegar the C.F. so necessary to the cheese-maker. Their eloquence, however, availed with those who were not aware of its errors to put down the use of whey in some districts, though by no means generally in either country.

Since fermentation has been better understood, the question has been reconsidered; and the chief teachers are recommending the use of a "starter," which is neither more nor less than such fermented material as our forefathers have employed time out of mind. Nor must the "starter," either as taught or commonly understood, be confounded with the "pure cultivations" of the bacteriologist, which are proposed, and by-and-by will be called for, as an aid to our purpose. It means simply milk or whey, cream, creamed milk, or buttermilk, as the dairyer may reign over a cheese or butter dairy.

In view of the greater knowledge of the matter, and the improvement daily wrought in the cleanliness and other conditions of the dairy, the cure of the old-time whey abuses may be confidently reckoned on. At any rate, it may be finally said that those who are not desirous or capable of improvement in the use of whey, will prove equally untoward with the other methods.

The frontispiece, with its gradations of colour, exhibiting the characteristic reactions of litmus paper, gives the foundations to the safe management of milk fermentation by any process, provided the friendly ferments alone rule; and this proviso may be ascertained by the rennet and heating tests, and by the smell and behaviour of the milk. The applications of these will be referred to in connection with the systems in practice.

(2.) *Coagulation of the casein.*—This is the next in order, and is brought about by a special agent acting with a suitable heat, and the ripeness just described. The coagulating agent is *rennet*, produced from the *abomasum* or fourth stomach of the calf. The dairyer imitates nature by exposing the milk to the digestive action of the gastric juice; just as it is done in the living animal, but with a much lower proportion of the juice to the milk treated. This is reasonable, for the calf must immediately reduce its milk-meal to a form in which it can be made into blood, while the dairyer wants to hold his product at convenience. The calf secretes enough gastric juice in a day to coagulate ten gallons of milk in one minute; but the action is instantaneous, and is intended to carry on the reduction of coagulum to peptone form within an hour or two at the outside. The only other differences between the case of the calf and that of the cheese-maker lie in the accompanying conditions. The milk food is not ripened; the tendency of the L.A.F. would be mischievous, as checking the action of the juice, hardening the coagulum, and thus hindering the digestive process. Nor, on the other hand, has the juice any help from the C.F. or kindred microbes. Even if present, their action must be so slow in comparison with the juice, as to practically put them out of the reckoning.

Apart from these distinctions, the cheese-maker's imitation of natural conditions is remarkably close. The gastric juice meets the need of milk digestion, as it only can when that food is the sole source of nutriment. As soon as the food is changed to cereal products and grasses, even though milk may be retained in some degree, the composition of the juice changes to meet the new requirements, and is no longer so powerful for dealing with milk as it was. This explains the fact that the strongest stomachs, or *vells* as they are called in the trade, are those which are taken from calves solely milk-fed, and the relative values of others depends on the extent to which milk has continued to be a part of the diet. It is usually taken for granted that the Irish vells are obtained from milk-fed calves only, and they have therefore a high reputation among those who make their own rennet.

The calf is fasted for some hours beyond the ordinary intervals of feeding, in order to the largest quantity of the juice; but this extra secretion does not long continue, falling off with the loss of vigour which necessarily accompanies even the beginning of hunger. If the fasting is carried beyond that point, the stomach becomes inflamed, and carries its evidence of this in an unnatural redness which will mark it out in contrast to good vells as diseased and to be thrown aside. At the same time the digestive value of the secretion is damaged. The use of such vells is more wasteful than their rejection. There are two forms in which vells are cured and sold, viz., in wet salt, and stretched on sticks and salted dry. The former is followed by the Irish, the latter by the Continental curers.

The home-making of rennet has been long practised in ways more or less satisfactory. The old-time practice of soaking a piece of a vell in water shortly before use, and of making a steep in whey, are both bad; the former wasteful and uncertain, the latter liable to give mischievous forms of fermentation. The best method is to boil and filter rain-water, in which mineral impurities are in the least possible proportion, and to add to this as much salt as it will dissolve, adding the vells when it has cooled to the air temperature, and at the rate of four to every gallon. They should be kept in steep for a month, turned inside out, and at frequent intervals wrung and rubbed. The best vessel for the purpose is a stoneware jar (Fig. 18, *a*), provided with a cover *b* (shown reversed), the strips on which give ventilation. A piece of muslin of open texture tied over the whole, as in *a*, will keep out dust. Ten fluid ounces (half pint) of a rennet so made with best Irish vells will coagulate 100 gallons of milk ripened to E standard (colour plate), and form a good curd in an hour, as required for most English systems. Otherwise stated, this rennet coagulates, under such conditions, 1,600 times its own measure of milk; and this may be taken as a standard, and the strength of any other rennet stated in comparison, as when one coagulates 4,000 its own measure of milk, its strength may be described as 2.5 times that of the standard.

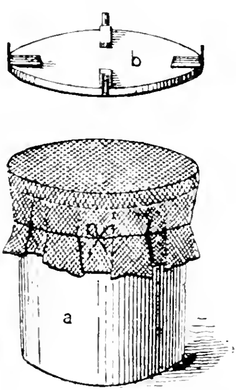


FIG. 18.—RENNET JAR.

There is one difficulty with brine steeps, for this material, though a good preservative, does not extract the vell strength satisfactorily, and eight vells once so used will make a second gallon of steep. So it was proposed some years ago to steep in boiled and filtered rain-water, or distilled water, for several days, to procure more complete extraction, and then to saturate the steep with salt. This, though ingenious, has given such unfortunate results as to put it out of the pale of sound practice. Though unperceived, a bad fermentation frequently sets in, and the after-salting does not put out or render harmless the foul products of such fermentation. Moreover, the coagulating strength is reduced at the same time. The cells of animal digestive secretions though acting so much like ferments, are nevertheless themselves capable of destruction and putrefaction, as it is morally certain that ferments also are, both being related to the proteids in their main composition.

Excellent rennet may be made with good preservatives, and some of these extract the vell strength more quickly and perfectly than brine. The trade rennets are numerous, but by no means all of satisfactory character. Like the preservatives they have need of being tested before use, and it is therefore not desirable to mention one or another, because they have proved to be good in our practice. We have found some of the best known to us to vary in strength at times, and others to a more serious extent, to say nothing of flavours and odours imparted to the cheese by the more worthless. There are good reasons for believing that some makers are careless in the selection and treatment of their vells; there are such men in every trade, and safety lies only in personal test. Far better than any but the best trade rennets is such an one as may be made at home under known conditions, where any vell which is not entirely fit may be resolutely thrown aside, and nothing put into the steep which ought not to be there. We have not yet met with a single article among liquid extracts which will make better cheese than the home-made steep already described. Its equals are sometimes seen, but not once its superiors. Of late years dry preparations have been offered by the trade, and one of these is in the form of tablets, which are estimated to coagulate regular quantities of milk under proper conditions. These, so far as we have proved them, are decidedly better than the liquid extracts, and the home-made steeps also in the one respect of innocence of flavour or odour, and are equal to them in uniformity and other essential points.

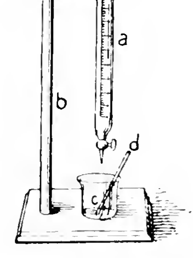


FIG. 19.—APPARATUS FOR TESTING RENNET.

Every cheese-maker should test his rennet before general use. The method is simple, the apparatus costs but a few shillings. A burette *a*, Fig. 19, divided by scale into cubic millimetres, a stand *b*, two glass or ware cups *c* of a pint capacity, and a glass stirring rod *d*, only are necessary. The rennet already in use, and the effective proportions of which are known in relation to the standards of ripeness and temperature suited to the cheese-making system pursued, forms a sound basis for calculation. The proportion of this necessary to coagulate say ten gallons is put into the burette, and the number of cubic millimetres which it measures noted. Now it is not necessary to wait on the time for coagulation proper to any cheese system; one-fourth of that time will suffice, and therefore four times as much rennet must be used in proportion to the milk as usual. The measure in the burette must be reckoned, not as for ten gallons, but for two-and-a-half gallons, or forty half-pints. Therefore one-fortieth of that measure of rennet ought to coagulate one half-pint of milk in one-fourth of the ordinary time. That proportion of the rennet of known strength may then be run into one of the cups, the burette emptied, rinsed with water, and dried, and a similar measure of the rennet to be tested measured from it into the other cup. A pint of milk ripened and heated according to the system pursued may then be divided into two exact half-pints, the one poured into the one vessel, vigorously stirred for a minute, and then watched until coagulation takes place, the time occupied being noted even to seconds. The other may afterwards be treated in the same way. It is best to test them separately, because the attention is fully taken up in noting time and coagulation in one case, and to attempt two is to court confusion and inaccuracy. Any difference between the times required by the two rennets to produce the desired results marks the difference in their strength; if the new one takes five minutes to do that which the other does in four minutes, then one-fourth more by measure of the former is needed in daily use. From the same figures the relative strength of the new rennet, to the standard, may be ascertained and marked upon it, and a quantity table constructed for ready reference. So, from make to make we may proceed with our changes without any fear of failure.

An example will assist in understanding the method of calculation. Given a rennet of which ten fluid ounces form a proper curd from 200 gallons of milk under proper conditions in an hour, this would constitute it of "2" or "double standard" strength. We will suppose that the time to coagulation should be twenty minutes, one-fourth of which will be five minutes. In this case, half an ounce would cause coagulation in ten gallons in twenty minutes, or two-and-a-half gallons in five minutes. There may be, however, a slight variation from this, and we cannot afford to take it on trust. So we test it with the same milk in the same condition that we use with the other. Working on the lines laid down, we find that it actually takes the five minutes as expected, and the new rennet to be two-fifths weaker than the one in use; so that, instead of ten fluid ounces being sufficient for 200 gallons, it will only serve for 120 gallons; or the 200 gallons will need 16.6 ounces to deal with it, and other quantities in proportion. The strength of this make will be 1.2 in comparison with the standard 1. The cost may be calculated in the following manner: at 8s. per gallon (supposed nett price) the cost of coagulating 100 gallons by the rennet in use will be 3d. At the same price per gallon the new rennet will be 3d. for coagulating 120 gallons of milk, or 5d. for 200 gallons, while to be as cheap as the old it should be sold at 4s. 9½d. per gallon.

The trouble taken in learning the strength and commercial value of a rennet is trifling compared with the economical advantage in purchasing or making. Guess-work here is no more excusable than in the dairy processes, but we feel sure that only a very small proportion of British cheese-makers know the relative cost of the preparations they use. We have had offered two rennets the strength of one being "2," and of the other, "3," with only 2s. 3d. per gallon difference in price. The more costly, of "3" strength, at 9s. per gallon was the cheaper by 9d. per gallon in proportion, and equal in all other respects as proved by experience.

In the absence of some general system of estimating coagulating strength, the quotations used by writers and speakers are practically worthless. We often see that Professor A. or Cheese-maker B. have recommended the use of so many ounces of rennet to a thousand pounds of milk. What possible good can such advice do if the strength of the agent is not stated?

Returning to the subject of rennet action, we proceed to notice that as in the calf, so in the cheese, its action is digestive, and although, under cheese-making conditions, a slow process, yet a sure one. The complete chemistry of the case is hardly known as yet, but it seems to be certain that in the act of coagulation the Ca salts are taken into a kind of partnership with the more active agencies, the action and effects of these being modified by them as already shown. At all events the proportion of ash constituents in cheese is larger than in the whey, which would not be the case if they remained simply in solution in the water of the whey. There is no reasonable doubt that in coagulation the changes in the physical and chemical relations of the elements of the casein allow of such new combinations as attach to the cheese division of the milk a quantity of those ash constituents which are found in solution in the water of uncoagulated milk. Apart from such addition, the final result in the casein seems to be entirely a physical change, the diffused gelatinous material being set free from its diffusion, and its molecules gathering by a mutual attraction into a closer relation. This does not happen, of course, without a rearrangement of chemical relations also; but the effect is mainly physical. When a large relative proportion of rennet is added to milk, as in the case of the living calf's stomach, coagulation is almost instantaneous; but when only a small proportion is used, some time elapses before any evidence of change is seen. Yet even during this time the rennet cells are certainly not idle. Acting much as ferments do, they attack the casein, and having wrought in it the changes described, they proceed to reduce the coagulum to the peptone form at a rate dependent on the proportion and strength of the rennet used, and the modifying influences of fermentation and temperature. The whole after-tendency of the coagulum is to contract; and although its greater solidity would suggest a greater resistance to any attack, the very solidifying is but a step towards the soluble state to which rennet will, in course of time, bring it. However contradictory this may seem, it is proved not only by consistency of theory, but also by practical results, as will by and by be seen.

That this contraction is the joint work of the rennet and ferments, is shown by the fact that it varies in rapidity according to temperature; for at 97° F. it is most rapid, while at higher and lower temperatures it is slower, until at certain limits—much the same as those governing the most common forms of fermentation—it ceases, the agencies both being inoperative.

Here the natural law which makes substances to expand with heat and contract with cold is reversed, and this simply because the attendant conditions are not alike in the two cases. Here it is not a case of a substance merely occupying less space under cold than under heat, but of one spread abroad, and held in its diffused state by the absorption of water, the molecules of the former being separated by those of the latter; and the coagulation consists in the setting free of the casein molecules from the influence of the separating force, to run together in a nearer relation.

The same thing takes place in creaming, the fat globules coming much nearer together in cream than they originally are in milk; but there they are ready to collect as soon as the purely physical conditions described in Chapter III. will allow, whereas here there is need of a chemical and physical force, not belonging to the milk, to act upon the casein molecules before such a gathering of them is possible.

Started and maintained, the end would naturally be the complete expulsion of the serum, and the production of a hard and dry coagulum, but for the fact that the rennet cells reduce the casein to a peptone, and the ferments join to reduce both that and the contained fats to new and lower forms of decomposition. The peptone is therefore distinctly a stage on the down grade, hence the power given to the blood-forming cells to bring the digested peptones in the intestine back to the proteid form in the blood, and the maintenance of that form in the casein of milk. Even the albuminose, in its association with lacto-chrome, is probably subject to the same law of diffusion awaiting the ferment action to set it free.

Rennet is, to all appearances, as dependent as fermentation on favourable temperature for its action and rate of progress. This is true of cells in the living animal, their vitality and vigour being ruled in no small degree by this influence. They are so constituted as to operate best at the heat of the animal body, as we might naturally expect, and these facts have an important bearing on the cheesemaker's art. He does not use that temperature throughout his process in any system, and in some never rises so high, because he does not want to bring about speedy digestion of the casein ; but he knows that the rate of that change depends partly upon the temperatures used by him, and the variations in their maintenance, as well as in the quantity and strength of the rennet.

It is well that the temperatures proper to the friendly fermentations are also helpful to rennet, for the dairyer has no conflicting interests to reconcile, and he is able to regulate the action of each according to his need. Heat, however, influences the curd directly in the way of a hardness which is not in proportion to the contraction caused by rennet and fermentation, as is observed when an excess of heat is used to make up for their deficiency, and which suggests a separate physical action of its own, such as it has on many non-fermenting organic bodies.

Let us now see what would happen in a coagulum produced by the friendly ferments only. The action of the C.F. and its kin we have reason to regard as in some sense digestive, though not precisely like that of rennet. But this is only in low proportion, and has to contend with the opposite influence of the L.A.F., the tendency of which to check both the C.F. and rennet, and to harden the coagulum in a manner different from the contraction, and therefore to render it more indigestible, is known to practical observers. The two ferments, when properly balanced in power, will give a coagulum which, under any circumstances, will be much longer in reaching the digestible state than that made with rennet.

It will be seen, then, that in procuring coagulation we have to deal with three forces—(*a*) fermentation, (*b*) rennet, and (*c*) temperature. Now when once the dairyer has determined what kind of cheese in all respects, but especially in its richness, digestibility, flavour, and keeping quality, he will make, he has next to estimate the individual and relative amount of influence which each of the three forces ought to have in his process and product. The rennet, which peptonises the casein, and renders it more fit for a human food than it naturally is; the L.A. and C. fermentations, which respectively modify or aid the rennet action; and the heat, which has its own hardening influence,—all are in the reckoning. Therefore, upon his familiarity with their tendencies, and his judgment in allotting to each its proportion of power, will be his success in making that good start which is proverbially "half the battle." Having laid well the foundations of his work, he must build consistently upon them, keeping in view at the same time the final result, and the services which these separately and jointly may render him in attaining to it; so will he be able to control them at every stage, and compel their help where otherwise they might work confusion and disaster. It is true that within the proper range he may raise his milk temperature to help an insufficient quantity of rennet, or lower it when an excess of that agent has been used, but no such attempts at compensation are entirely successful, although they are supposed to be so, and are continually being made by half-informed and careless people. It is a great advantage to know how to make the best of a bad case, but it is far better to begin aright, both for the dairyer who has less tax on memory and judgment, and for the cheese, which in turn affects his profit and credit. Let us then, in his interest and that of the consumers of Britain, insist on an intelligent and careful estimate and allotment of these initiatory forces.

It is not quite possible at this stage of the subject to make any standard, but a comparison of imaginary, but easily realised, relations and results may be made. These shall be given in the form of two propositions:—

(*a*.) Required a cheese to be fit for consumption at an early age. Here it will be proper to use more rennet than in the case of a cheese allowed longer time to get ready for market. A higher temperature may accompany this, if a greater degree of fermentation is not objectionable; but it is by no means necessary that any increase of one force should be accompanied by proportionate increase in the others, as so many makers seem to believe. When it is simply desired to give the rennet greater power, it is unwise to set against it the modifying or even opposing influence of the L.A., which will assuredly increase with higher temperatures within the range proper to cheese-making. In this case the production of early flavour in the usual proportion to digestibility is purposely left out of the account; that belongs to a later stage of our study.

(*b.*) Required a cheese to keep for a long time before use. Here, so far as we are at present concerned, the lower proportion of rennet is necessary in comparison with the preceding case. The fermentation in such case will help the rennet in part; but the hindering influence of the L.A.F. will be in higher relation to the rennet action than before, and we may be sure of slower digestion.

All the combinations and variations of relative influence proper to the many graduations in result of the many systems will be described as they arise, but it is easy to see how powerful they may be in fixing the character of their products. It is inevitable that the flavour and keeping quality of the cheese *a* will be different from those of *b*, as the rennet and fermentation vary in proportion of power. Therefore, if in these items of management two systems differ, though agreeing in all other respects, there must be permanent differences in the character of their goods.

The temperature suitable to any system or time is not decided only by its relation to the work of rennet and ferments, but also by the practice, and the varying temperatures of the air. In some systems, the first temperature is the last; in others, a second heating takes place; and as, in the former case, the starting temperature has to fit in with all possibilities to the end of the process, while in the latter it has only to carry forward for two or three hours, a higher temperature is necessary in the former if the results are to be of nearly equal firmness and general character. But since such equality is not always sought for, the variations have their share in producing cheese variety. In any case, however, changes of air temperature must be met by corresponding ones in practice. A difference of two or three degrees for every five degrees lost or gained by the air is generally necessary.

The thermometer may here be noticed. Its value depends on its accuracy, and the dairyer is warned that cheap instruments are generally dear. Out of a dozen, scarcely three are alike, and these probably incorrect. There should be in every dairy one reliable instrument, by which all others should be compared before purchase. If, for the sake of cheapness, one will take the trouble to remember that this scale is 2° too high, and that one 3° too low, he may do so, but it is best to avoid confusion and risk of error. Few instruments costing less than 2s. 6d. are worth their price, and even with those costing more, it is well to take the standard one to compare when buying. The best make we have ever used is set in a strong copper frame, provided with a porcelain scale with large division lines and figures, and costs 15s. It is shown in Fig. 20. Here the frame protects the tube, and the indications may be easily read while the instrument is still under the surface up to the top of the mercury column. It is generally sold for brewers, and therefore provided with a cup, in which some of the liquor may be taken up, so helping to maintain the temperature; but this, however useful in brewing, is a nuisance in cheese-making, because milk and curd must be continually cleaned out from it in order to keep it sweet. The best plan is to remove the bottom of the cup, bending the edge of the frame *a*, Fig. 21, in on each side, as at *b*, to prevent the tube-plate from slipping out, while taking up nothing when lifted out of the liquids tested. The hollow glass instruments, now so commonly used, are not only uncertain, but very liable to be broken in the milk or whey, with danger to those who afterwards handle the curd. Their only merits are that they are cheap, and easily cleaned.

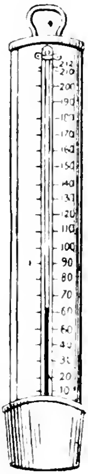


FIG. 20.—CHEESE-MAKER'S THERMOMETER.

A thermometer never should be so tipped as to have the upper part of its mercury lower than the bulb, or the column will be likely to separate, after which it will be difficult to reunite it. If this does happen, the instrument should be firmly grasped at the top and swung with a sharp jerky motion; by doing this, reunion may generally be effected. The fact that the thermometer is going into fermenting milk and whey continually, will point to the necessity of its being carefully cleaned and scalded after every process in which it is used.

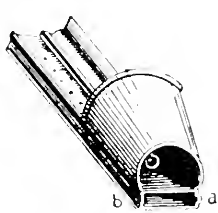


FIG. 21.—THERMOMETER PREPARED FOR USE.

The method of heating milk for coagulation differs according to the apparatus used. One plan is much followed in the smaller cheese dairies of Britain, in which a proportion of the whole supply is heated in a vessel (Fig. 22), plunged in the hot water of an ordinary house boiler, and heated to a point at which, when added to the remainder, it will bring it to the right temperature. This involves a litt'e calculation, not only to fix upon the right limit for the milk heated in the boiler, but to avoid a higher point than 130° F., beyond which it is dangerous to go because of the influence on the albumin, which, though it does not coagulate, undergoes a preparatory physical change in the near degrees above that point. Albumin coagulation differs in nothing in principle from that of casein, and although it takes place quickly at 163° F., it is distinctly affected at 140° F., and tends to separate. Now, although free albumin is of itself a valuable food, it is a very undesirable addition to a cheese, for it does not behave under the ordinary forms of fermentation as casein does, but putrefies early, whether under the action of C.F. or a special ferment is not known. We know enough, however, to avoid its separation from milk and whey in cheese-making. Moreover, it takes on a burnt flavour when over-heated. Examples of the proper calculations accompany the description of practice.

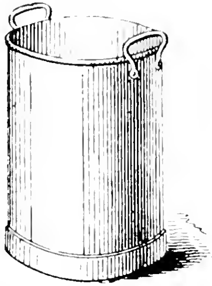


FIG. 22.—WARMER.

Better than this is the heating in a double-cased cheese-making vessel, the space between the two parts being filled with hot water or steam. Here the whole supply for one making can be treated at once, and no part unduly heated to serve the rest. The economy in time and labour also is considerable, especially in large dairies.

It has been urged against hot water and steam, that there is a danger of cooking the albumin by the contact of the milk with the hot metal; but this is absurd, for there cannot possibly be so great a risk as with a small quantity plunged into boiling water. In any case there is danger, if the milk is not stirred; this attended to, and the limit of temperature observed, there can be none. Any liquid which is being heated, not only gains in temperature, but cools whatever is used to heat it; so the heating-water loses a good many degrees to heat the milk but a few (in its proportion to the milk quantity), and steam condenses against the inner case and drops off as water. How little force there is in the objection, is shown by the fact, that after removing the heating-water, or cutting off the steam, the temperature of the contents will only rise one degree F., and this probably represents from a half to a fourth of the difference between the metal temperature and that of the moving contents. It would seem to be foolish to notice the cavil, but that it is continually trotted out by some writers and lecturers, whose sole justification appears to be found in the results of ignorance or carelessness, either in their own or other people's dairies. With a wide experience in the various methods of heating, we have had no difficulty whatever with hot water or steam; and with persons who have no knowledge of any way, we find it distinctly easier to teach them to avoid mishaps with either of these than with the old boiler-heating plan.

Ripeness and a correct temperature having been secured in the milk, the rennet is added, and carefully stirred in, the stirring being maintained until coagulation takes place. The first stirring may be vigorous, but after the rennet is safely distributed it should be no more rapid than is necessary to the second purpose. If this be continued too long, the coagulum, instead of being in one body, will separate into tiny particles, and great loss will ensue in the after-processes. Most makers fear to venture with their stirring beyond a

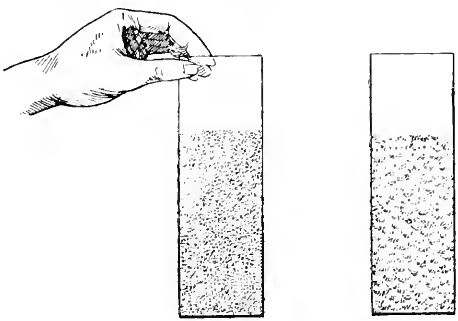


FIG. 23.—COAGULATION TEST.

third or half of the time usual to coagulation, and almost invariably find a little cream on the surface of the curd. This, in spite of all notions to the contrary, is lost in the whey.

Coagulation manifests itself to the eye soon after it has taken place, but this is not sufficiently certain as a basis for calculation. A tin bowl is left by many makers floating in the milk, the lifting of which when the curd has formed will show it on the metal, and in the dent left on the surface. This also fails to show just when the change occurs. A perfect test is made by dipping a piece of clean glass into the milk, and holding it between the eye and the light, as in Fig 23, where *a* shows the appearance of the milk as it smoothly works downwards, and *b* the change which marks the curd formation when the casein becomes clotted and droops in its downward movement into loops and angles. This taking place, marks the *coagulation* or *curding point;* but for a minute or two before, varying with the state of the milk, an increase of viscosity is noticeable, and should lead to caution in stirring; indeed this latter should be gradually reduced as curding is expected, so that when it actually takes place there may be no motion. For the same reason, it should be confined to the upper section of the milk as this point is approached. The glass should be free from grease and cream, or it will show a clotting which will hinder from proper observation, and probably deceive the user. It should also be frequently dipped, so as to have fresh milk at the correct temperature, for the cooling which that obtained at each dipping gets from exposure to the air tends to check coagulation.

This valuable test was brought to our notice by Dr F. T. Bond, and has enabled us to stir long enough to prevent loss of cream without the least danger of breaking the coagulum.

The next business is to preserve the curd from changes of temperature. This is most easily done in a double-cased vessel, which gives greater protection in any case; and, if necessary, allows of some water being kept in it,—either the space full, at one or two degrees higher than the milk temperature; or a small quantity, not reaching the bottom of the inner case, and at a temperature 20° F. higher. The cover should be capable of cutting off the influence of the air temperature completely, and be made of wood lined with felt, which is a good non-conductor of heat, and this again faced with tin, this surface being next to the milk. The purpose of all this care is to have the curd uniform throughout. If the surface be allowed to cool, the rennet and ferment actions are slower at that point, and so far downwards as the cooling extends in its various degress. In this way the great majority of makers err daily. A light cloth supported by a strip of wood is generally thought to be sufficient; but in any, save the warmest of weather, such will not serve.

(3.) *Separation of the whey.*—During the time from coagulation until the curd is ready for the next process, it is constantly growing firmer; and this, although unnoticed by the eye, is really a beginning of the separation of the whey. If allowed to remain unmolested, it will be seen to shrink from the sides of the vessel, leaving the clear greenish-yellow whey in the space. This might proceed to any length but for the rennet and ferment action, which would reduce the mass to a putrid condition long before it had completely separated. So, as we cannot leave it to its own course, we have to help the separation by (*a*) mechanical means, and in some systems by (*b*) heat.

The former may take various forms, and it is in these that the greatest differences can be seen in the practice. In the simplest, the curd is lifted out in small quantities into vessels which will allow its expressed whey to pass off by draining; in the most elaborate, tools of various kinds are employed to divide the curd in one vessel into small fragments. In either case, and in all those which come between them in character, the aim is the same. But the results are very different; for from this point, at which those systems which are most alike diverge more or less, they keep on their distinct courses to the end. There is but little difference in their curds at the end of the coagulation period, compared with the striking diversities in their final products, and these latter are in the main due to the means used in this section of the work. The extent to which separation is carried is regulated by the aims of the makers, and has a great influence on the flavour, keeping quality, and texture, of the cheese. Whether it is effected by draining or by tools, and when by the latter, then by what kind, has something to do with the rapidity of the manufacture, the proportion of cheese made, and of fat in it. The use or non-use of heat also touches all the qualities in one way or another. These and other points will be best understood by a comparison of the systems in detail, these being considered in the light of their aims. But we may point out, that according to the extent and speediness of the whey expulsion, fermentation in the curd and cheese are in a large degree determined. If of two cheeses one retains more whey than another, the one which holds the most will be the most highly fermented. The larger quantity of water is the first item of importance; the more of moisture a substance holds, the larger are the limits of fermentative possibilities within it. The sugar converted into lactic acid will favour the life and operations of the other ferments (even though it modifies their influence on the casein), and especially after the limit of acid production has been reached. This ferment will also counterbalance rennet action, and prepare the way for the B.A.F. with its work on the fats. In every sense the more whey the more fermentation, and the less *proportionate* rennet action. That some of the ferments help the rennet in reducing the casein to solubility is true, but their help may be a hindrance to the best results. In so far as fermentation checks the work of rennet, it also reduces digestibility; and in so far as it effects its own kind of digestion, it breaks up the proteids into the forms common to putrefaction, NH_3 and its kindred, with ptomaïnes, of which more anon. In any case, the decomposition of proteids, fats, and sugars, with their after-recombinations, commences in the curd, and their power and tendency have direction given to them by the management, especially in this item of the work. Therefore, though the standard of milk ripeness may not be high in any instance, it is possible to arrange for a great amount of after-fermentation by the retention of whey in the curd by various devices. Of these, the most effectual, in several leading systems, belongs to the earlier part of the separation process; for if heat be applied in certain conditions of the curd (as to the size of its particles and the proportion of whey left in them), then no after-treatment can suffice to put aside the consequences in any satisfactory degree. Finally, though a cheese may lose much of its moisture after it is made, it will lose water and not whey, leaving behind the solid constituents of the latter in a state more or less changed by fermentation. These silent forces are more powerful in some systems than in others, according to the practices followed; and however much we may have occasion to note the immediately economical effect of the manipulation in the proportions of cheese made from the milk, we have as much or more need to estimate their natural effects on the extent and character of the chemical and physical changes wrought in the finished product.

(4.) *Curd ripeness.*—This is but the extension of the earlier milk ripeness; and just as this last was the stage at which coagulation could be best brought about, and the earlier work of the system carried on, so curd ripeness is an advanced stage on which the closing practices of the system most properly follow. Here we may note that even in those systems in which only a very low degree of fermentation is allowed for coagulation, the second stage is as advanced as in any. This is not merely a compensation, nor is the time at which fermentation is brought to its maximum a matter of little consequence. These variations are all planned to operate harmoniously to the desired result; the lack at the first, as much as the fulness at the last, is right in such cases, as we shall presently see. Our special purpose just now is to point out that sooner or later that fulness is secured, and in every variety of cheese the ferments have a large share in making it what it is.

This influence must be uniformly exerted. The main separation of the whey has left us a body of curd still holding a great deal more than the cheese must finally contain, and the whey will tend to sink through it downwards, so that at any time it will scarcely be distributed evenly in it. If it was kept in one position, the fermentation in its lower part would be much more powerful than in the upper and drier part, and this would tend to a cheese of uneven character. So also with heat; for although the upper part may be covered, it will be liable to lose its temperature more than the lower, and such variations also tend to uneven ripening. Therefore it is necessary to turn the curd frequently, so as to redistribute its moisture, and make its fermentation uniform. Its general temperature must also be maintained at a point favourable to ripening at the rate set by the system.

As in milk, so in curd, the ripeness must be determined by a safe test. The smell is of some value when educated, but is never safe, because it is affected by every passing cold. The best test, by way of acidity, is the litmus paper, which can be passed into a slit cut in the curd, and the sides pressed together against it. A very common practice in America, and to a small extent in England, is to press a piece of curd against a hot iron, and slowly draw it away. If it adheres to the metal, and draws out in fine threads to a length varying from a quarter of an inch to two inches, according to the demands of the dairyer, it is judged to be ripe. What is it in the curd which makes this test possible? If a curd which will respond to it be examined, it will be found to have lost some of its original character and become more or less stringy. Torn in its grain, it will separate into thin flakes; and the more fully it does so the longer will it draw on the hot iron, and in the finer threads. This state is the first evidence seen of the peptonising of the coagulum, and thus is a test both for the rennet and C.F. action. It is to that extent valuable, but should not be taken alone, because the proportion of L.A.F. influence is of some consequence, and cannot always be known by the physical state of the curd. It may be thought that if it be proper to judge of the C.F. by the L.A.F., it can be no less reasonable to reverse the process; but the rennet is in the reckoning now and must be allowed for. This increasing the difficulty of correct estimation, it is best to associate the litmus with the iron, if the latter be used at all. But is the last necessary? To the observant maker, the acid, taken with the flakiness, tells as much as the iron with its smell of burning casein, and necessity for skill in use. For, however simple it may seem to be, we have known expert users try two or three times before satisfying themselves; and in the hands of less experienced persons have too often seen misleading results, mainly in the form of failures to draw, when this could be readily done by others more familiar with it. Though having no objection to the iron, so far as it is reliable, we distinctly prefer for all purposes the litmus test, with the flakiness of the curd—as found by tearing a little.

(5.) *Preservative treatment.*—Having been encouraged so far with a view to their best service, the ferments must now be checked, for the preservation of the cheese. If left to them and to the rennet, the curd would soon be peptonised and fermented, to an extent which would ruin it for trade purposes, for it would be too soft to bear carriage or keeping, and too pungent in flavour or odour to be fit for the strongest stomachs. There can be no doubt that the ferment products, of some kinds at least, and in the proportions in which they would appear under such conditions, would be positively injurious to health or even poisonous. The latter result occasionally occurs even in cheese treated for preservation, where that treatment has been defied by more than usually numerous and powerful ferments; how much more surely then in our supposed case? Since then, cheese should be portable, palatable, and preservable, for a reasonable time, in the hands of the tradesman and consumer, we must do something at this point to bring fermentation within the limits proper to our purpose. A similar course is pursued in other manufactures—*e.g.*, in bread making, in which the dough, at the right stage, is exposed to such a heat as destroys the yeast, drives off the alcohol and CO_2, and leaves a food which can be held long enough to meet all the uncertainties of trade.

In our case the *destruction* of the ferments is not attempted, but only their *control*, and that by the presence of conditions unfavourable to their multiplication and action in the higher, though permitting these in the lower, degrees. This is distinctly better and safer than to allow the fermentation to proceed to the dangerous limit, and then to destroy them; for that would involve constant watching and testing, and the use of far more of the germicidal material than would be desirable either for health or economy. Nor would the results be the same in the two cases. The chemical changes, and the combinations of the various stages of fermentation, would be different where the anti-ferment material was present from those which would occur in its absence. The cheese-maker's practice, therefore, is to apply the preservative treatment at a point when the ferments have proceeded so far as to ensure the continuance of their action at a rate desired in view of his ends, and in the presence of a small amount of the preserving material. Each system has its own practice consistent with this general purpose, and with its own variations.

Any antiseptic would be effectual in checking the ferments, but only a few are fit for use in foods. The Boron preservatives might be generally employed but for their cost; and indeed they are used to a limited extent. But common salt (NaCl) is the material universally used, and answers the purpose admirably. The quantity necessary to any system, under proper—or even unusual—conditions, and when properly applied, is not enough to give its own flavour to the product to a noticeable extent. Salt should be of the purest, for $MgCl_2$, or "pan scale" of $CaSO_4$, are very mischievous to the cheese, giving a bitterness by direct action and checking fermentation unduly. In the salt blocks usually sold, veins of "pan scale" can be easily discovered by their hardness, and carefully removed, even to the sacrifice of a little of the surrounding salt; anything is better than putting it into the cheese.

But of late years manufacturers have put on the market a salt in a loose state in bags, and this, as saving time and labour, has been and still is much used in the dairy. In this lurks a danger. The pan-scale is no longer in a form which allows of ready detection and removal, but so intimately mixed as to make such removal impossible. Therefore, in the absence of any other security, it is best to buy the best block salt obtainable, and to take the trouble of rubbing it down to looseness, casting away all separable substances. There are, however, salts which do not contain these impurities in any influential proportion, and one make, at least, in which the pan-scale is excluded by a patent process. It is therefore still possible to buy "factory filled" dairy salt in bags, which is safe in use, and from which the objectionable substances are either absent or present in harmless proportions. These latter may be stated as under .05 per cent. for the compounds named above.

The money value of a salt depends to no small extent upon the amount of moisture it contains. The tendency of $CaCl_2$ to absorb it from the air makes its presence in salt a practical difficulty, because the antiseptic strength of wet salt is less pound for pound than that of dry salt, and the loss is proportionate to the excess of water; but salt will absorb more or less of this in any damp situation, and should therefore be stored in an exceptionally dry spot, such as over a boiler-house. So far as we have observed, the manufacturers one and all send out their salts in dry state, and well protected for travelling by rail. The absorption takes place in the hands of the retailers and dairyers, the latter especially being given to storing it in very unsuitable places. The inevitable consequence is, that the actual salt influence, which is to control fermentation, varies much; and the regulation quantities estimated for curds do not effect that which they are expected to do.

In view of the importance of having pure salt for our work, we recommend its purchase by guaranteed analysis. There should be no more difficulty in this than with cattle foods, and manufacturers who have confidence in their products will not hesitate to comply with this reasonable demand. By this means the reader may judge for himself which, of all the makes offered him, is best for his purpose, and we can assure him that the best is the cheapest. It is foolish indeed to take a salt containing 2 or 3 per cent. of impurities in preference to one containing a half of 1 per cent., because the former costs 6d. per cwt. less. Even estimating the damage to the cheese at 1s. per cwt., the loss would be more than a hundred times the saving in the cost of the salt.

The size of the grains is of some moment. The larger they are the better for such cheeses as retain the higher proportions of whey, for, taking longer time to dissolve, there is less loss with the whey, which may be drawn or pressed from it. For dry curd a finer make will answer better, this having little or no loss, and requiring the distribution of the preservative influences as early as possible, in view of the low proportion of moisture and its corresponding action in dissolving the salt.

The proportion of salt must be calculated by certain varying conditions :—

(*a.*) By the proportion of the casein to the fat in the curd. The salting is done for the sake of the former, which is more immediately subject to fermentation than the latter. Besides this the B.A.F. and other fat-attacking microbes, if such be present, do not commence their operations until the way has been prepared by the friendly ones. Therefore to check these latter is our aim, the others being also checked at the same time, and to a greater extent. The more casein, the more casein fermentation—other conditions being favourable,—and the more salt is necessary to control it. The variations in milk quality point to corresponding differences in the salt quantities as necessary to safe results. More is needed, on this account, towards the end of the milking season than at its beginning, and to meet other changes.

At times, when the milk is lowest in quality, the main loss is in the fats, the casein being but little reduced. When the milk improves it is mainly by the increase of fat. Hence in the former case, while the curd falls off in quantity, it really needs more salt because of the increase in the relative proportion of casein. This may be illustrated by examples :—

	1	2	3
Fat - - -	3.25	2.80	3.75
Casein - -	3.40	3.30	3.45
Total - -	6.65	6.10	7.20
Ratio of fat to casein	1 to 1.046	1 to 1.178	1 to ·92

Here are three milks, No. 1 being of an average quality, and Nos. 2 and 3 poorer and richer respectively. The proportions of fat and casein to each other are shown in the lower figures. With equal care, the fat and casein in the curd should stand in the same relations. Then No. 2 will require more, and No. 3 less, salt than No. 1 ; and in proportion to the increase or decrease of the casein ratio.

(*b.*) By the total yield of curd. It ordinarily happens that when the casein ratio is at its highest, that the total yield of curd is at its lowest ; and the reverse is true in the other case. This may be seen by comparing the totals and the ratios in the table above. Therefore while No. 2 needs more salt because of its higher casein ratio, it also needs less because of its lower yield; while No. 3, requiring less because of its lower proportion of casein, requires more because of its own larger quantity. It may seem, in view of these facts, as if the calculation for salting must needs be very complicated and troublesome; but there is a method by which these opposite requirements are met, and the whole matter reduced to a simple and fairly reliable basis. Our calculations have been based on percentages, and the totals of fat and casein represent approximately the yield of dry curd from 100 lbs. of milk of each quality. The curd actually loses a little fat and casein in making, and contains more or less of whey. This does not interfere with the soundness of our argument, for the three milks under similar management will yield curds *in proportion* to the total of casein and fat, whether they be in larger or lesser quantity than the totals given, they will all agree in retaining their *original* relative *proportions to each other*. This is all we need. We have only to set the increase required by No. 2, because of its high casein ratio, against the decrease necessary because of its lower total yield of curd, and calculate by the *milk quantity* to reduce the whole matter to a proper balance of interests. We may therefore calculate that No. 2 will need as much salt for its yield of 6.10 lbs. with a casein ratio of 1 to 1.178 as No. 1 does for its 6.65 lbs. with its 1 to 1.046 ratio, because what No. 2 needs more than No. 1 on account of its higher casein ratio, it needs less than No. 1 because of its lower yield. The same is true of No. 3, and of all other milks of nearly average quality. If the weight of the *curd* is made the basis of our calculation, as it is with the great body of English makers, then its frequent variations in casein ratio must be taken into account with accurate tests for its determination; but if the salt is calculated by the quantity of *milk*, no such constant testing is necesary. It is not claimed that the results of the two bases of calculation balance each other absolutely, but it is certain that the salting is much more correctly done than when the curd is weighed without the variations in the casein ratio being taken into account.

(*c.*) By the proportion of moisture. As this varies with different systems, and very commonly between the practice of different makers by the same system, and the daily experiences of the same maker, it must be considered. Each system has its own proper standard in this respect, included among the points which give to the product its characteristic qualities; and must therefore be a law to itself. But variations in the same dairy are undesirable. They sometimes arise out of causes beyond the dairyer's control; but there is far too much carelessness on the point, carried even so far as neglect to allow for excess of moisture when calculating the salt. But it must be evident, that as the whey still contained in the curd dissolves the salt when applied, whatever of that whey is lost by draining or pressing must carry its proportion of the salt with it. The one loss will be in keeping with the other, so that the wetter the curd, the larger must be the allowance of salt to ensure the retention of a sufficient proportion.

Salt is applied either (*a*) from the outside of the cheese when moulded into its final shape, or (*b*) by mixing with the curd. In the former case, it is necessary that the cheese should be small enough to allow the salt to penetrate to all parts, otherwise the outer and inner sections will be unlike in all respects. The other method is suitable to all the larger makes, but the curd must be specially prepared for it. This is done by tearing the curd into small pieces by hand (called *crimming*, where most practised), or by grinding through a mill. The latter differs according to the systems, but these agree in desiring a small and regular size to the ground curd, in order to an intimate and uniform mixing of the salt. Large pieces do not receive their due proportion of salt so early as they ought, and at their centres fermentation continues vigorously after it has been checked in the smaller fragments. The influence of salt on the curd is soon observed,—the fermentative changes fall back to a slower rate of progress, and a dryness follows.

(6.) *Moulding and pressing.*—Curd is not strictly cheese until it has been moulded, and—if necessary—pressed, into its destined form. This comes before salting, wherever that is done on the outside, and in some systems follows immediately on the completion of curd formation. In most English systems it comes as soon after salting as the suitable temperature is secured. Pressing is only necessary where the curd will not consolidate sufficiently without it. Both are ruled by the needs of the various systems.

The temperature at which these processes are carried out is of great moment. The fermentation is not so checked but it will go forward too rapidly if that temperature is too high; nor is it able to make proper progress if the curd is too cold. Now, when the air influence is to be so largely excluded from the inner parts of the cheese, a few degrees will make all the difference between success and failure. The best point for any system will depend upon its standard of curd-ripeness, the proportion of whey retained, and the provision made for completing the manufacture.

(7.) *Curing or ripening of the cheese.*—The previous processes convert milk into cheese, but at this stage the latter is unfit for food. Its peptonisation has proceeded some little way, according to the relative and combined influence of the rennet and fermentations; but the contraction of the casein has brought it to a state in which it is able to resist the action of the digestive juices, to an extent which was impossible to it in its original milk form. For all practical purposes, therefore, curd is more indigestible than the casein was in its diffused state. Until the rennet and C.F. have done much towards rendering it soluble, it is of little food value. It must be stored under conditions which will favour the peptonising process, so far as this is consistent with the preservation of the article. The dairyer has two aims,—the one, to get it ready for use as soon as may be; the other, to have it as firm and free from risk in carriage or keeping as is desirable for the trade and the consumer. These aims have to be reconciled, and in this systems differ, and local conditions too, so that the dairyer's judgment must be wisely exercised in determing upon a right course. This he can safely do, in the light of all the facts,—both those which relate to his earlier processes, and those which rule his later needs.

The work of the rennet and the ferments in curing, must first be considered separately. Of the former, suffice it to say that it simply goes on to do its main work of reducing the casein to peptone, as quickly and as fully as circumstances will allow. That it has any share with fermentation in other changes, such as flavour-producing, cannot be said with certainty, because we cannot make cheese entirely free from ferment action ; but at present it seems as if the latter can account for all but the one special work of the rennet.

The fermentation also proceeds with its characteristic changes, modified by temperature, heat, and moisture ; and dependent, in no small degree, on the kinds of ferments which are present. Whatever the conditions may be, the ferment varieties have a powerful share in determining what the cheese shall be. The friendly ones have the first place.

The L.A.F. does but little if anything in the way of lactic acid production in the made cheese, but the acid is present, and affects the life and vigour of other ferments, some of them favourably. So far as the ferment itself goes, its hardening tendency puts back the peptonising in proportion to its relative power ; and when it is in unusual proportion to the rennet, and, as it sometimes is, to the C.F. too, the cheese is hard and generally crumbly, and the casein does not adhere, as it should, to form a good texture.

The C.F. is as influential as conditions will allow, and works away, as far as can be known, to the end of the story, breaking down the casein something like the rennet does, but with a more direct effect of chemical decomposition. All that we have observed tends to the conviction that rennet—if it could act upon the casein with only the modifying action of the L.A.F.—would produce a different series of results to those which would follow on the friendly ferments together, *i.e.*, if all other microbes were excluded. Nevertheless, there can be no doubt of the usefulness of the C.F. in producing digestion in a limited sense and degree.

These ferments, however, as in milk, prepare the way for others; and although these, by good management, may not have been allowed a chance to do anything in the milk and curd during the making processes, they now come into operation. The contraction of the curd has given some protection to the fat globules, the envelopes of which by the C.F. action are doubtless reduced to a common state with that of the casein formerly diffused in the milk. But as the C.F. goes on to break down the casein, the B.A.F. not only finds the friendly conditions for its work, but can reach the fats more freely, and, by acting upon these, help to form the cheese flavour. There is no reason to believe that the B.A.F. action is so influential as that of the other remaining ferments.

A more powerful factor is the formation of volatile fats from the proteids, and, not unlikely, from the fixed fats as well. The former is well established, and accounts for the due proportion of casein and fat in comparison with their original relations in milk. In any well-made cheese there will be more fat to casein than in the milk from which it was made; and the reduction of the casein ratio is consistently explained, both in fact and in degree, by the operation of the natural laws governing fermentation. The residue of casein elements can be shown to have recombined in new forms, the P and S discovering themselves readily when the fermentation of this kind is unusually rapid, or in the presence of some taint ferments, in certain gases given off from the cheese; of which more yet.

Here is found the butyric acid already described, as formed in part from the albuminoids; combining with glycerine at first, but afterwards liable to separation from this. The fatty acids, both of fixed and volatile fats, when set free, combine partly with the CaO of the ash, and partly with the NH_3, according to the supplies of these materials in an available state.

Ammonia (NH_3) is given off, and, combining with such of the residuary elements as are at hand, forms the ammonic salts,—which explain the fact that over-salting within the narrow limits of experience tends to an apparent lack of salt, while under-salting gives the effect which we should expect to follow on an excess of salt. For the excess of the preservative hinders the fermentation, and the formation of NH_3 salts, proportionately; while, with the deficient salting, the ferments have full play, and form the more pungent salts from the decomposed casein. The presence of ammonic butyrate, caproate, caprate, and caprylIate, with the aids of the volatile fats, has been proved by analysis. To these, in whatever proportion, is due the return of the cheese from an acid to an alkaline condition.

The ptomaïnes of the friendly casein ferments are always present, and bear their share in producing flavour; but this is small in comparison with that borne by the products of the mischievous kinds, which are both more evident, and more dangerous to health. Even those of friendly ferments when excessive—and this means a proportion so small as to be scarcely capable of expression in figures—are probably unwholesome, for in many stomachs they create resistance and nausea. The taint ptomaïnes are sometimes poisonous, and without much doubt unwholesome in any case. In 1886 a definite case of poisoning was fully investigated and reported on by Dr V. C. Vaughan, of the Michigan (U.S.A.) State Board of Health. This was traced directly to cheese, in which—as also in highly fermented milk, and in ice-cream which had produced poisoning symptoms—he found crystalline matter, which, when separated, was used in experiments, effectively demonstrating its character. Minute doses of this substance caused violent vomiting and diarrhœa in human subjects, and killed small animals with symptoms like those of cholera. This is identified with the *diazo* compounds, which are formed out of the fermented materials of the volatile fats by the action of nitrous acid (HNO_2), this latter being a recombination product of the casein decomposition. It is easy to see that only when the fermentations of the casein and fats are excessive, and most probably caused by special ferments, such results will arise; but the possibility points afresh to the importance of excluding the bad ferments, and controlling the good ones. The toleration of ignorance and carelessness is a menace to public health. The accumulation of ferment products steadily increases with the age of the cheese, but the amount varies with different systems, and the individual products of each system. Besides these changes, there are also (*a*) a formation of CO_2 and (*b*) a number of recombinations of elements and compounds separated by fermentation, and which—as they depend on changing conditions affecting the proportion of their materials—are altogether too intricate to follow.

Cheese, when ripe enough for eating, and later, consists therefore of—(*a*) the casein in a more or less peptonised and fermented state; of (*b*) fats, the fixed kinds originally in the milk being probably somewhat changed by fermentation, and the volatile kinds certainly so changed, while the latter are increased by casein decomposition; with (*c*) traces of albumin, also fermented in the later stages of curing; some (*d*) lactic acid, salt, and sundry chemical compounds, as NH_3 salts, &c.; and finally, (*e*) a proportion of water, ranging from one-fourth to one-half of the whole cheese, according to the producing system. The proportion and influences of each item above is fixed by the system and the management of the maker; and combined, these determine the character of the product to an extent which is impossible to any other agency concerned in the matter in ordinary experience.

Curing is therefore to be carried on under conditions which tend to the production, in the curd, of the changes described, and these at a proper rate. It is easy to spoil the finest curd by errors in this part of the work; and we believe that if there is one point in which British cheese-makers fail more than in any other, it is in curing. This is mainly because its importance is not realised, either by themselves, or by those who provide the accommodation. We have seen many dairies, but cannot recall a dozen in which this process can be properly carried out, and generally have found the dairyer content with his curing-room, unless he had to complain of the lack of labour-saving conveniences. Let the conditions be considered in order.

The Temperature.—This must be fixed according to the system, but in every case will need more warmth at times than the air can give. Some means of heating must consequently be provided; and whatever this may be, it should be capable of regulation. No expense or trouble is too great to be taken in order to secure this power of control. Any apparatus which will not meet the greatest cold to which the cheese is liable, and maintain the necessary temperature, is a practical failure, and more may be lost in a single season by its use than has been gained by its cheapness. The effectiveness of any provision will depend much upon the construction of the curing-room; the more perfectly it excludes or controls the influence of the outer air, the less will be the demand made on the source of heat. The ventilation of the room should therefore be planned to operate with its heating so that the two may work harmoniously to the best ends. The constructive arrangements necessary to these points will be shown in describing the dairies of the various systems.

The higher the temperature is, within proper limits, the more rapid will be the fermentation. In the case of excess, the cheese will dry unduly, even to the waste of fat; and while at first the ferments will be helped, the rapid removal of moisture will tend to check them later. Against this limiting of the flavour production must be set the great encouragement given earlier, and the tallowing of the fats, which gives a vile flavour. The exposure of the best curd to excessive heat is to ruin it. On the other hand, too low a temperature checks rennet and ferment action, and slow curing will result; while other ferments, finding favourable conditions, produce bitterness, and other ill flavours. The slow-drying causes dampness and discoloration, particularly near the outside of the cheese. The range within which these ill effects are avoided is narrow for any system, and the dairyer must watch the variations with unwearying carefulness. His greatest help in this will be the self-registering thermometer, Fig. 24, which consists of a bent tube *a* with two bulbs. In the bend lies the mercury, above which spirit fills the branch *b* and its bulb entirely, and partly the other branch *c* also. When the temperature rises, the spirit in *b* expanding, forces the mercury downwards; and this rising in *c*, and itself expanding, shows the increase of heat on the scale. With the increase of cold, both the mercury and the spirit in *b* contract, and the spirit in *c* drives the mercury upwards in *b* to the limit of the spirit contraction in that branch, so that the rising of the mercury in this case is the same as its falling in an ordinary thermometer. Registers of metal, *d*, *e*, rise with the mercury in either branch with changes of temperature, and when the column sinks remain behind, showing the point which had been reached. The register *d* shows the minimum point to which the temperature has fallen, and *e* the maximum point to which it has risen, since last they were set. A magnet *f* is used for drawing them down to the tops of the mercury column.

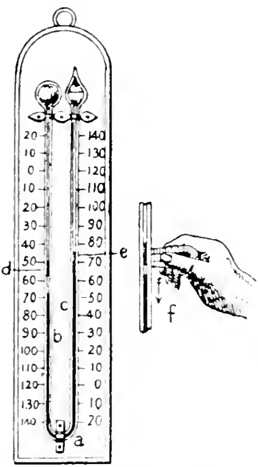


FIG. 24.—SELF-REGISTERING THERMOMETER.

Moisture of Air.—Scarcely less important is the proportion of moisture in the air. Cheese, especially in its earliest age, gives off much moisture. If the room be not properly ventilated, this will load the air until it ceases to take up that which continues to be thrown off; and this, lodging in the outer parts of the cheese, helps fermentation there and causes discoloration and soapiness of texture. If the air is too dry, and its passage too rapid, it will tend to dryness of the outer part and cracking of the skin. In either case, uniformity is sacrificed, and food and trade values are reduced. The state of the cheese, as it is moist or dry in proportion, serves roughly as an indication of the state of the air, but it is best to employ a hygrometer, thus securing accuracy.

As in the working process, so now, the cheese needs frequent turning, so that its moisture may be evenly distributed, and its drying and curing be equal throughout. According to the amount of moisture, so will be the fermentation; and if a cheese is allowed to remain too long on one side, the result must needs be a difference of condition in several respects. The contraction of the casein still continues, and though it is now very slight, yet it helps in the expulsion of the moisture; and as this proceeds, the distribution of the latter is not so quickly disturbed as in the earlier stages. The cheese does not therefore need turning so often, and as time passes the labour decreases.

Moulds.—These fungoid growths, which are common to moist organic substances, find a home on, and sometimes within, cheese during the curing process. They include, as a class, objects as large as the mushroom and kindred growths, and others so minute as to need the microscope to show their form and character. They have points in common with ferments, but these are also common to most plants; and moulds are unlike the microbes in certain important respects. For one thing, the microbe lives an independent existence; the mould grows from a species of root, which penetrates the surface of the substance on which it depends. There are several kinds which grow on the cheeses, of different systems, and under varying conditions. The most common of these is *Penicillium glaucum* (Fig. 25), which gives the cheese a greenish-blue colour, growing lighter with low temperatures. The range within which it thrives is from 50° to 60° F. It feeds upon the moisture and decomposing matter which gathers on and below the surface of the cheese, and increases by the formation of seeds called *spores*, which in time are cast off to germinate wherever they can find a suitable soil. Their propagation, under suitable conditions, is very rapid. They are not, however, of more than trifling importance in comparison with ferments, for though in the course of their feeding they effect certain changes in the materials of their cheese soil, such as the saponification of its fats, the acids of which form salts with NH_3, and possibly others, they only affect the cheese in the way in which plants affect the earth, by taking up what they need, and leaving remainders when the decomposition for feeding purposes is not wrought within themselves. So far then as they are found on the outside of a cheese only, they do but little harm. There are one or two varieties which are very mischievous, a black mould especially, which causes erosion or wasting of the cheese surface, and production of a bad flavour. With this we have had

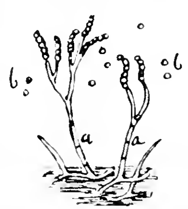


FIG. 25.—PENICILLIUM GLAUCUM.

some experience, and found it very difficult to get rid of. Red and yellow moulds, varying in their shades of colour under different temperatures and variations of moisture, are found occasionally in most curing-rooms, but especially on soft cheeses, where the appearance is watched for as an evidence of cheese condition, and the right state of the air for its needs. When seen on the hard cheeses of most English systems, they usually point to too much moisture ; but their distribution depends somewhat on that of their spores, which may at any time be brought in from other sources and form a temporary settlement.

When opportunities occur, moulds find their way to the insides of cheeses, and grow within their cracks. If a cheese be cut, and the boring allowed to remain open for a few minutes before returning the plug (part of which will have been used for tasting), the spores are almost certain to enter, and spread wherever they can find free space. They feed in such case just as on the surface, but they and their products are eaten with the cheese, and add greatly to the enjoyment of the majority of consumers. Scarcely any luxury exceeds "blue-mould" cheese in the estimation of the gourmand. Hence the internal growth is purposely encouraged in some systems. The effect on the palate is not unlike that of the mushroom, to which the mould is, of course, related. Wherever this is desired it must be introduced and encouraged. The makers who follow the systems referred to commonly assert that their kinds of cheese cannot be successfully made in the dairies of other systems. This is true as to a beginning in many cases, but there is nothing in the world to hinder the introduction of the appropriate mould by some old cheese. A very little time and trouble suffices to secure the supposed monopoly.

It is desirable in other cases to keep the harmless moulds well under hand, though not necessarily to banish them. This can be very well managed by rubbing the cheese surfaces with the hand or a brush. When, however, the troublesome ones make their appearance, it is necessary to use boiling water in a quick application to the brushed cheese, and for washing the shelves and the brush afterwards. This will be effectual in time if the fresh colonies are watched for and attacked at sight. The shelves or floors on which mouldy cheeses have stood require such washings after every clearance of goods, otherwise they not only spread the moulds too liberally, but themselves damage by rotting.

Insect Pests.— These, though outside of cheese-making when strictly considered, have to do with the product, and can be properly described here.

(*a.*) The *Cheese fly* (*Piophila casei*), Fig. 26*a* (magnified), is a tiny insect which lays its eggs in cracks in the cheeses, and the shelves or floors on which they rest, also under the folds of any cloths with which the cheeses are protected. They especially select moist spots for this purpose. The maggots (*b*), which hatch out a few days later, are nearly white, and thrive well with such good fare, meanwhile spoiling the surrounding cheese by their excretions. By curling as at *c*, until they

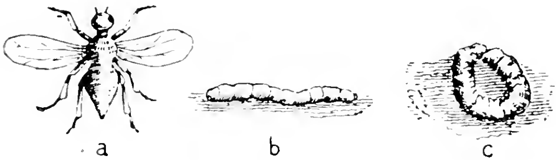


FIG. 26.—CHEESE FLY AND MAGGOT.

literally can "make ends meet," and then straightening themselves out with a vigorous action, they can leap several times their own length. They can only be removed for destruction; for while there are numerous insect powders that will kill them, few, if any, of these would be safe to use with a food. But such preparations may well be used to destroy the flies.

(*b.*) The *Cheese mite* (*Acarus domesticus*), Fig. 27 (magnified), generally appears in large numbers as a brown dust on the cheese; but, when seen under the microscope, as an almost colourless insect. It prefers dry surfaces, and especially those of cheeses made from creamed milk, and which are generally drier than whole milk goods. They have no special objection to the latter, however, and when once they have taken possession are long visitors. Their increase is rapid. The best way to get rid of them is to scrape them into a vessel and subject them, the cheese, and the shelves, to boiling water with salt in it.

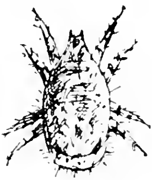


FIG. 27.
CHEESE MITE.

Colouring of Cheese.—It has long been the practice of the makers in certain districts to colour their cheese in various ways. This is not essential to any system; nor, however ancient the custom, can it properly have anything to do with the naming of any variety, popular notions notwithstanding.

If the substance of the cheese is coloured, *annatto* is generally used. This is a material obtained from the seed pods of a tropical bush, the *Bixa Orellana*. There are two colouring matters, one red, the other yellow, and these are prepared in a liquid form by steeping in an alkaline solution, in oil, or spirit, according to its purpose. There is possibly no danger to the health from any of the preparations by respectable firms, but the taste and smell are both vile; and, though used only in very small proportions, are calculated by so much to alter the flavour of a cheese. The quantity used varies from a drachm to two ounces per hundred gallons of milk, the latter giving an orange-red hue. The different preparations show more or less redness or yellowness in result, pointing to differences in manufacture.

Annatto is liable to produce irregularities in cheese. If it is not properly mixed with the milk and at the right time, it will not be distributed evenly. Worse than any patchiness of colour due to neglect, is that arising from its fermentation. Being a vegetable substance, it is liable to be attacked by special ferments, which would probably be otherwise harmless. In tainted cheese the annatto generally "flies," leaving weak spots, and these join with the ill flavour to condemn the article to a low price. Some districts have suffered much in this respect of recent years. They have most likely always so suffered more or less, but in these times such matters obtain a notice which they formerly did not. We have always heard of the trouble as belonging to the days of our fathers, who groaned and bore it, and still coloured their goods. Personal inspection of stocks in a certain famous dairy, temporarily afflicted with "colour flying," satisfied us that, in that case at least, the cause was special fermentation; for the flavours and other evidences of taint were distinct, and in proportion to this was the loss of colour. Other observations, though not so complete, confirm our belief that the evil is mainly due to this cause, and that there is only one way to avoid it, viz., by ceasing to colour at all.

Why is annatto used? Because the British cheese consumer is ignorant and gullible. He knows that the yellow milk of the Jersey is richer than the whiter milks of other breeds, and so gets the notion that the butter or cheese which is yellow or red must be richer than the paler products. He will eat a cheese made from partly creamed milk, and rejoice in its "richness" because it is coloured! The trade then bows to his demand for a coloured cheese, and when the demand is passed on, the dairyer bows to the trade. So the consumer is gulled to order. There can be no mistake about the folly of the whole proceeding. Not one particle of food value does it add to the cheese; it is troublesome at times, and always nasty. We sincerely hope that it will speedily disappear from the dairy.

Uniformity of System Needful.—The various practices of every system must be brought into such relations as will, with proper care, give the best products possible to it. If an error or evil condition arises anywhere, the whole of the processes following after are liable to be affected prejudicially. From the beginning, where the health and management of the cow control the state of the milk, to the end, where the finished product passes out of the dairyer's hands, there is not one solitary point that is unimportant, or that can be slighted without penalty. Compensations for error may be made to some extent, but they can never give the finest results.

We must not only carry out our chosen system as perfectly as possible, but also aim at uniformity in the product. This would be comparatively easy if the daily conditions were alike; but as these vary, scarcely ever repeating themselves on following days, any hard line of repetition of practice in detail must necessarily make uniformity in the cheese impossible. How can it be otherwise? To bring uniformity out of varying conditions, we must plainly meet these by varying our practice within the limits of our system. The work of the cheese-maker will therefore depend for its success in no small degree on his familiarity with the facts relating to his material and conditions, his quickness to perceive changes, and his soundness of judgment in meeting them consistently; and these powers can only be acquired by study, practice, and observation. Therefore, though we shall endeavour herein to advise for common contingencies, all the many minor variations must be left to the reader. To anticipate them all would need a bulky volume.

For the same purpose of securing uniformity in the cheese, all mingling of the practices of various systems should be avoided wherever the grafts are in any sense or degree out of harmony with the main stock. Many makers adopt all sorts of ingenious suggestions indiscriminately, especially for the saving of time and labour; but the results are rarely, if ever, of the finest. It is better to hold to one system, and consider the possibility of improvement only in the light of its essential principles.

The Factory System.—The factory system must here receive attention. By this we mean the manufacture of milks from various sources in one building and under one management, and not any special system of cheese-making. This usually involves the mixing of milks with a view to that economy of building space, appliances, and labour which the factory system rightly claims to effect.

What are the effects of this mixing?

It has already been shown that so far as the "character"—which is the product of soil and feeding influence—is concerned, the mixing of milks tends distinctly to uniformity, and the confinement of variations within a narrow range. This is proved by experience, and makes possible the more uniform management which obtains in the factories everywhere. It is not asserted that the factory managers all work alike or produce like results, but simply that both work and results are much more alike among them than among home dairyers ; and the narrowing proceeds steadily, year by year, as any painstaking observer cannot fail to see. This uniformity is not the same thing as a high average quality. Whether the latter is attained or attainable in factories, does not rest merely with any advantage which such blendings of milk may confer, though this in some degree helps to the best results ; but a general uniformity is a natural outcome of the factory system, as is admitted by its stoutest opponents, and can only be sacrificed by bad management. Even when the cheese of the factory is inferior, its range of value is quite narrow compared with that of the average farm dairy.

In the other matters the factory and farm dairy are equally subject to the laws which govern quality, and error in either case has a like effect. Given an equal knowledge, skill, and familiarity with local conditions, the same person shall make equally fine goods in a farm dairy as in a factory; and *vice versa*, provided the proper conveniences be at his hand, and the milk of proper quality and character. The influence of *quantity* is distinctly in favour of the factory ; for with the larger body of milk the temperatures are better sustained, and the extremes of the heat limit are unnecessary. The concentration of one person's energy and judgment on the work, which would otherwise have been distributed among a dozen or two of home cheese-makers, may be a benefit or a disaster, according as he is capable and careful, or the opposite ; but the qualifications, personal and acquired, of the dairyer-in-charge, touches the home dairy as well as the factory, and the possibilities of failure at that point has nothing to do with the soundness of the factory system. One might as well argue against any of the best cheese-making systems, because it will not secure the best goods under an ignorant or careless hand. If this question is divested of all matters which are not concerned in it, and reduced to common-sense, it is easy of settlement. What there is to hinder a factory being as well designed and constructed, and as well managed as a farm dairy, nobody has ever yet shown, and we may take the two as on a level in that respect.

But attempts have been made to show that the mixing of milks is mischievous, and preventive of success. This has been set down to interference with the proper course of fermentation. We fail to see how the mixing of any number of sound milks together, in clean vessels, and under the pure air only, can cause any such interference ; but since it has been asserted, let the matter be examined. The introduction of a tainted milk may be admitted to account for any amount of irregularity, but this is not necessary to the factory any more than to the farm dairy. It happens as often, we firmly believe, in the latter as in the former, but is inexcusable in either. If the factory manager must needs take the milks sent to him without questioning their fitness for his purpose, then the factory must become the dumping-ground for the bad milks of careless farmers; but this is no essential part of its management. Wherever, through unwatchfulness or moral cowardice, such milks are received, these defects in the manager must be blamed for the results, and not the system; for in what would the consequences differ in his case from those arising from the use of such milk in a farm dairy, saving in their distribution through a larger body of milk, the contents of one making vessel? One bad cheese in ten is no better than ten such among a hundred, so far as the comparative damage is concerned. Therefore the possibility of damage from bad milks cannot be laid to the factory system as one of the dangers peculiar to it, until it is shown not to exist in farm dairying.

In the blending of sound milks there is no danger. If any milk is capable of injuring another by being added to it, that milk is manifestly an unsound one, and incapable of making a fine cheese by itself. Does the mixing of milks bring new ferments into existence out of nothing? It certainly cannot. Such a belief would be but the "spontaneous generation" theory, which has been shattered to its foundations, and can never be rebuilt. A ferment can only be produced from a germ, and if the germ is present it is capable of germination and increase under certain conditions, and if these be absent the germ remains inactive. Therefore to produce bad cheese by any interference with fermentative processes, must involve the germ and its proper conditions. If, then, separate milks, containing no ferments capable of doing mischief in them, are mixed together under like conditions, no harm can ensue. If one is much warmer or more highly fermented than the others, it will by so much encourage the ferments found in the mixture, or modify their proportions and influence; and even the friendly ferments may be in excess, as we know. But this case is precisely as the other—a matter of management. Every experienced dairyer knows that such effects follow, and avoids the causes, even when he does not understand their nature. The city milk trade is always urging the separation of milks varying much in temperature, and this consistently with our teachings on fermentation.

What does experience teach? Many farmers have brought milks from separate holdings to the same home dairy, and mixed them without damage. In what does such a custom differ from that of the factory? If blending is bad in the latter, why not here also? But the factory system can speak for itself. In different parts of the world, under great disadvantages, it has taken the supplies of the less successful farmers (for those who are doing handsomely do not sell their milk), and out of these it has made goods the average of which is considerably above that of the goods made from corresponding milks in the farm dairies, or even than that of the whole market, taking all kinds and qualities of cheese in their proportions. This would have been impossible if there had been some inherent mischief arising out of the mixing of supplies. It may therefore be accepted, that there is nothing in the factory system, or inseparable from it, to prevent the cheese made from any milk, or mixture of milks, being the best possible to it, or equal to the average of the best possible products of the same milks separately manufactured.

CHAPTER IX.

THE CHEDDAR SYSTEM AND ITS PRODUCT.

THE Cheddar system has been selected to occupy the first place, because, of all British systems, it is the most completely reduced to form and rule; and because it illustrates more principles, and includes more diverse practices, than any other. It is therefore peculiarly fitted to exhibit the general principles already laid down. A careful study of so comprehensive a system will be beneficial even to cheese-makers who follow others in their own dairies, enabling them to understand the better the influence of each practice concerned in the methods of their choice.

While the system is more widely known than any other, it is specially practised in the county of Somerset, where it first saw the light, and derived its name from the village of Cheddar, which is situated at the southern foot of the Mendip Hills. The northern part of the county, to which the manufacture is mainly confined, is occupied by the soils of the Carboniferous Limestone, the New Red Sandstone, and the Lias, with younger rocks on the east, stretching into Wiltshire. It is not, however, confined to that district, but is practised in Dorset, in south-west Scotland to some extent, and here and there throughout the world, on almost all soils and under very different climatic conditions. In so saying, we do not include the American or Canadian systems, which, though their followers defer to Cheddar teaching so far as pleases them, are not identical with the Cheddar system, excepting in so far as they have grafted certain Cheddar practices to their own stock, and profited thereby.

Cheddar cheese, when well and truly made from sound milk of average or better composition, is of rich quality, perfect solidity, mellow or plastic, and of specially mild and pleasing flavour, reminding the eater of a ripe hazel-nut. It will keep, under proper conditions and with continual improvement, from one to two years; and yet—such are the principles of the system—it may be consumed at three or four months old; and though scarcely possessing sufficient flavour at that age to satisfy lovers of the piquant, will be more digestible, and therefore more valuable, as a food than any other English hard-curd product of similar age. The long-keeping capabilities of the Cheddar are well known and quoted by all writers, but the early digestion is not usually referred to.

The composition of Cheddar cheese is variously stated, but the best account we have seen is that of the late Dr Augustus Voelcker, in the *Royal Agricultural Society's Journal*, vol. xxii., part 1. Such is the value of the analyses there given, and of his notes thereupon, that we quote the former in part, and the latter at length :—

	Average of Six Analyses.	No. 1. 11 Months old.	No. 4. 6 Months old.
Water	34.60	30.32	33.92
Fat	31.03	35.53	33.15
Casein	27.60	28.18	28.12
Sugar, Acid Extractives	2.94	1.66	.96
Salt	1.04	1.55	1.15
Ash	2.79	2.76	2.70
	100.00	100.00	100.00

"The rich appearance of old cheese is by no means attributable to a very large proportion of butter; nor is the poor condition of new or badly-made cheese referable solely to a deficiency of butter. One of the chief tests of the skill of the dairymaid is the production of a rich-tasting and looking, fine flavoured, mellow cheese, from milk not particularly rich in cream. That this can be done, is abundantly proved by the practice of good makers. One of the finest Cheddars that I have ever examined is that mentioned as No. 4 in the above table. This was made by Mr Harding, Marksbury, Somersetshire, and analysed by me when six months old. Like all good cheeses, it of course contains a large amount of butter; though, as I found by experiment, not so large an amount as its appearance, rich taste, and fine mature condition, seemed to imply. Though only six months old, it had a much more mature appearance than the Cheddar cheese No. 1, which was at least eleven months old when analysed; and, thanks to Mr Harding's skill and experience, had a much fatter and more mellow appearance, and richer taste, than a specimen which actually contained 2½ per cent. more butter.

"Thus we see that the proportion of butter does not entirely determine the value of cheese, since a high-priced Cheddar or Cheshire cheese does not necessarily contain more butter than another which fetches eight or ten shillings less per hundredweight in the market.

"In the opinion of good judges the Cheddar cheese No. 1, notwithstanding a larger amount of butter, and the smaller amount of water which it contained, was worth less than No. 4 by one penny per pound—no inconsiderable difference in the returns of a dairy to remunerate capital and skilful management. The peculiar mellow appearance of good cheese, though due to some extent to the butter which it contains, depends in a higher degree upon a gradual transformation which the casein or curd undergoes in ripening. The curd is hard, and insoluble in water, but by degrees it becomes softer and more soluble—or, speaking more correctly, gives rise to products of decomposition which are soluble in water.

"Now, if this ripening process is improperly conducted, or the original character of the curd is such that it adapts itself but slowly to this transformation, the cheese when sold will be, comparatively speaking, tough, and appear less rich in butter than it really is; while in a well-made and properly-kept cheese this series of changes will be rapidly and thoroughly effected. Proper ripening thus imparts to cheese a rich appearance, and unites with the butter in giving it that most desirable property of melting in the mouth. On examining some cheeses deficient in this melting property, and accordingly pronounced by practical judges defective in butter, I nevertheless found in them a very high percentage of that substance,—clear proof that the mellow and rich taste of cheese is not entirely, nor indeed chiefly, due to the fatty matters which it contains."

Both theory, as already given, and experience entirely confirm Dr Voelcker's judgment as to the cause of the superiority of sample No. 4, which was simply a better-made cheese than No. 1, though from a poorer material. In No. 1 the ratio of fat to casein was 1 to .793, and in No. 4 to .848.

The relation of casein to fat gives the higher proportion to the latter in all three tables, which is contrary to the case of such milks as are usually employed in the Cheddar dairies. Of the examples given by Dr Voelcker we know nothing with the exception of No. 4, and there is the best reason for believing that the milk out of which that was made did not exceed the average of Chapter IV. in composition. There are then good grounds for asserting that any average milk properly manipulated will make a cheese in which curing changes will reverse the relations of casein and fat, by converting some of the former into the latter. This change, which is shown in the analyses, must not be confounded with the peptonising which Dr Voelcker refers to as accounting for the mellowness observable in the better-made article.

The composition of a good and well-ripened Cheddar may be roughly stated at one-third of (*a*) water, (*b*) fat, and (*c*) casein and other materials, including the added salt. The Cheddar system is calculated to produce such a cheese. The chief points aimed at are the mildness, fine flavour, and keeping quality; but with these are secured the other qualities desired, and especially the characteristic texture and digestibility. This happy combination is provided for in the system, and, wherever this is properly employed upon good milk, will not fail to give it.

It must not, however, be supposed that all cheeses made by this system, and entitled to be called by its name, are necessarily of such quality. Errors in management may greatly alter the composition and qualities of its products, and that without involving any departure from its essential principles. Such errors will be pointed out in their proper connections. The effects in the main are apparent to the tradesman and consumer, and pay the penalty of loss in price. The best makers recall regretfully the days when these goods realised from 75s. to 90s. per cwt., but such times will return when the value of cheese as a food, and the special value of the Cheddar among English varieties, are understood by the people.

CHAPTER X.

THE CHEDDAR DAIRY.

Importance of a Good Dairy.—The construction and arrangements of the dairy exercise a considerable influence on the results of cheese-making. However favourable other conditions may be, however good the milk, however skilful and conscientious the maker, the faults of the dairy may prevent success, and British dairies do their part to that end in numberless instances. Observation shows that they are generally defective in those points which affect the work done in them, and we can count all the really good dairies within our ken on the fingers of two hands. This includes the costly and elaborate structures, as well as the roughest and most inconvenient; for not a few of the former are built in utter disregard of the processes to be carried on in them.

Often the dairy which has been recently built, and at considerable cost, is worse than the old one. Fine to look at, and well built, as if it had been intended for a dwelling-house—large and lofty, and the pride of the owner—it fails just where it should have been at its best, and succeeds only in points of less consequence. Generally speaking, therefore, the dairy needs reforming, and the dairyer should be fully informed on all points in relation to the matter, and know for himself what his accommodation ought to include. The present state of the dairies is mainly due to ignorance of cheese-making by those concerned in their erection. The estate agent, the architect, and the local builder, generally know nothing about the art and its requirements. They probably think it is no business of theirs, but of the farmer's, who should be able to advise them. But while this may be to some extent reasonable, it is still highly desirable that those responsible should be able to appreciate the advantages claimed by the farmer, and understand how best to secure them. It would well serve the purpose of everybody who may be called upon to prepare designs for dairies, to take a course of instruction in dairying, with practice.

The farmer, however, should be ready to point out and explain intelligently the points which should be secured in any case of building or alteration. He should know in what respects his previous work has been damaged or hindered by structural defects, and how these may be remedied; and wherever he is not also his own dairyer, that personage should be able to advise with him. When estate agents know what makes for successful dairying, they will care more about providing perfect dairies from the maker's point of view; and when the farmer or his dairyer can really help them in making such provision, their guidance will be more readily sought. Here knowledge is power, and tends to mutual confidence and satisfaction.

Among the points involved in the question are some which are common to all systems, and others in which the dairy is specially adapted to the particular system pursued in any case. We will therefore first consider the former, and afterwards the latter,—as special to the Cheddar system,—and illustrate both, as they relate to that system, by typical dairies; dealing with the accommodation for other systems as they arise, and making this chapter the basis for the descriptions then given.

Location and Aspect.—The farm dairy will generally be a part of the dwelling-house, and there is no objection to this if it does not entail conditions of an unfavourable character. The convenience for which this arrangement is made, is also served by grouping around the house all the other farm buildings; and unless this is carefully planned, so as to place the dairy beyond the reach of the homestead, that convenience will be bought at a high price. It is, of course, possible to cut off such sources of damage by a high wall, or some building not occupied by cattle or anything objectionable; and wherever this can be *effectually* done, the dairy may be as near to the farm-yard as is desired. In many cases the relations of the two can only be made tolerable by such a course. But wherever the dairy can be placed at a good distance from the cattle-sheds, piggeries, and yards, and on the same side as the direction of the prevailing winds, so that these may carry the odours and germs away from it, and not towards it, it is well to do so, and thus to give the greatest degree of safety. There are no better surroundings than lawns, gardens, and pastures; and even with these there will be times when the windows looking out upon them must be closed, even for days,—as when manures are being applied, compost heaps turned, or rubbish burned.

The best position for a dairy attached to any house having the traditional south-east aspect is behind it, facing north-west, so that the sun may cross it during the day; or it may be set against the house, on either side, and to face with it. But there are advantages in the other case when butter-making is part of the business, when a south frontage is unsuitable ; and while warmth is a help to cheese-making in some respects, it is always wise to shelter the south windows with a verandah roof, and so prevent direct sunshine reaching either milk or curd.

Suitability to the System Pursued.—This is the most important point in the arrangement of the dairy. Each system aims at certain results by a certain course, and nothing must be allowed to interfere with its purposes. The dairy must be brought to the system, and not the system to the dairy. It is, of course, true that a Cheddar cheese may be made in a ploughed field or on a mountain top, or anywhere under the blue ; but while the system may be pursued with all faithfulness, the product will not be of the best under other than the best conditions. This will be appreciated when the typical dairy, and the practice pursued in it, have been described.

Separation of Departments.—The conditions suitable to some of the processes are unsuitable to others, and certain necessities arise out of them which must be provided for. It is therefore necessary to separate the dairy into sections, devoted to their special uses. The cheese-making department, for instance, must have its temperature fitted to the state and needs of the milk or curd ; and the heat of boilers, or the cold air of a butter-making room, would be objectionable. First, then, a making apartment must be secured ; and, if possible, nothing must be kept in this but the milk and its coagulum, and the apparatus proper to them. An adjoining room should be provided for hot water,—and even here it is well not to have the coals, ashes, and dust inseparable from the fire, and to arrange for these to be in yet another room or an open shed. In this last all the washing of milk pails and other vessels fouled on the farm should be done, and only the dairy appliances proper cleansed in the hot-water room. Presses which, with whatever care, must needs carry the odour of whey and lubricating oil, and whey if kept for creaming, should occupy another room ; and if butter-making is carried on, it will need its own provision. These will properly be upon the ground floor. Over all there should be a curing-room, unless indeed there is room enough on the ground level for it. In the latter case, the cost of building would be greater, but the cheese would be more easily stored and despatched.

It would seem as if this dividing of the dairy must necessarily make it unduly large and costly. That it would cost more than a simple shell of two floors is certain ; but the only difference in size would be that required by the partitions, and the extra cost would be small in comparison with the great advantages to be enjoyed by the separation recommended.

Convenience and Economy. — These are considered together, because the former is often the source of the latter. The rooms should be so related as to allow of the readiest passage between those which have most interests in common. The hot-water room should be close to the making vessel, the room for whey and presses where the former can be most easily run into it by gravitation, and the cheese carried the shortest distance in reason. The butter room should adjoin the whey room, but may be more remote from the making room ; and as its work would not need hot-water so frequently as the cheese-making, the latter should have the preference in nearness to the supply.

The rooms should be no larger than is necessary to contain the apparati proper to them arranged in the best way for use, and allowing space enough between them for the dairyer to move and work comfortably. If they are larger, the cost in building must be greater in proportion ; the time, toil, and cost in going over the ground, and keeping floors clean, will follow suit,—and these without the least benefit in the work or its results to compensate. There is also an important item in the saving of time during cheese-making, the processes being such as to require the greatest expedition at certain points, and then the shorter the distance to be travelled to reach the desired tools, water, or what not, the better.

Control of Temperature.—This must in every case be secured, but the cost need never be unreasonable. Of all the structural conditions on which the cheese dairyer depends for success, none is greater than this. Without it his work cannot be perfect, for occasions will continually arise when the building which is defective in this respect will expose his milk or curd to the unfavourable influence of too great heat or cold or draught, and not even the best of makers can fully counterbalance these evils by variations in management.

Construction and Materials.—In order to the last preceding point, the dairy must be built with proper materials, and especially on correct principles of construction. The roof, of whatever character, should be whitened every spring with a wash which contains abundance of size, this colour causing it to cast back the sun's heat, while a darker surface would absorb it. Inside, the roof should be boarded substantially, and the ceiling of the curing room made also of board, and covered with six inches depth of dry sawdust. By this means there will be above the cheese the treble protection of the whitened roof, the sawdust, and the large space between these. The temperature of the air in this last will often rise or fall below that suitable to the cheese and making, but it will not affect the air in the dairy interior to anything like the same extent.

The walls can be built either of brick or stone ; if of the latter, it must not be of a kind inclined to dampness. Bricks are decidedly best, and can be lined with board at two inches distance from the wall, nailed to pieces of scantling laid on their broad sides, as in Fig. 28, where the dotted lines show the position of these and the continuous air-space enclosed. Good walls may be made of timber, a frame-work being covered on both sides with matched boarding, and weather boarded on the outside. To our British notions this would be unlikely to afford much protection from changes of temperature, but only in permanence are such structures inferior to those of brick or stone. Doors should fit well, and be provided with rubber draught-tubing; and windows should have second sashes, which can be buttoned into place, making air-spaces between the two sets of glass.

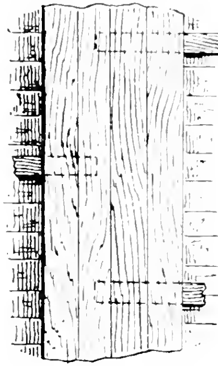


FIG. 28.—WALL LINING.

For brick or stone walls nothing is better than whitewash, renewed every spring; or, on wood lining, a light paint. All dark colours should be avoided; their tendency to hide dirt, and for which they are praised in matters of dress, is a sufficient reason for their rejection in the dairy. Let the colours be such as suggest and reveal purity, and give proof of scrupulous cleanliness in management. There is, moreover, no small advantage in the cheerfulness of the dairyer's surroundings; a moral and mental brightness arises from it, and as it costs no more to employ light than dark colours, this help may well be given to him.

Floors.—These are best made of concrete, all joints being thereby avoided; but if ill laid, such floors are of the worst, cracking and crumbling after a little wear, and giving much trouble. Therefore none but the most reliable constructors should be employed on this work, and in their absence it will be wise not to attempt this material. Various artificial pavings are in the market now, made under better conditions than those attending the laying of permanent floors, and therefore more dependable. They are also of such large size as to reduce the joints to a minimum; and as these are so many weak spots which wasting and wear will make into crevices, either to be kept constantly mended, or to collect dirt and moisture, the less of them the better. Failing these, good flagstones will serve; but bricks, even the best vitrified, are to be avoided. The difficulty with all cements is that they waste under the action of acids; and although sour whey and milk ought not to be spilled in the dairy, the fact remains that they are so spilled, and unless they can be removed at once a small amount of mischief is wrought, which with repetition leads to the spoiling of the floor. Whatever be the dairyer's care, then, let the floor joints be as few as possible, and these well looked after. The foundation of any floor should be of the best, and deep enough to prevent any settlement. Pillars which have to carry weight should pass through the floor, and rest on heavy stone foundations.

In every case the floors should have a sufficient inclination to lead washing waters towards a gutter or outlet, so situated as to conduct to the drainage system. This fall must depend on the character of the floors,—if of concrete, 1 inch in 8 feet will be sufficient; but if of flags, as much as 1 inch in 5 or 6 feet will be necessary.

Drainage.—Two absolute rules should here be observed,—(*a*) that no drains should pass under any part of a dairy, and (*b*) that no trap be open within it. The former, because at any time such drains may become foul and require opening, with inevitable danger from putrefactive gases; the latter, because traps are ineffectual safeguards from these same gases as they accumulate in ordinary drains. The common notion that the water which lies in the bend of a syphon trap stops the upward motion of drain gases is an erroneous one. Moreover, when gases in a drain are confined by obstruction, every passage of water into the drain from above causes the ascent of a body of foul air in proportion to its bulk, which enters the dairy when the trap is within it. This will be constantly happening, and the rule given is the only source of safety. This does not by any means condemn the trap as useless, but only as insufficient by itself.

The syphon kind shown in Fig. 29 is the best and simplest, but needs frequent removals of solid matter settling in the bend. Here the gutter *a* is shown emptying into the pipe *b*, which should be so set as to drain the gutter completely. The sliding door *c* cuts off the outside air when the immediate use of the drain is over; a brick sink-well *d*, 18 inches square and a foot deep, receives the waters, which then pass through the strainer *e* into the trap *f* and away. At the head of every branch drain there should be a ventilating pipe, which will carry the gases far enough above the windows of the lower floor to make sure of their complete dissipation at a safe point; and this should end in a revolving cowl, which will discharge

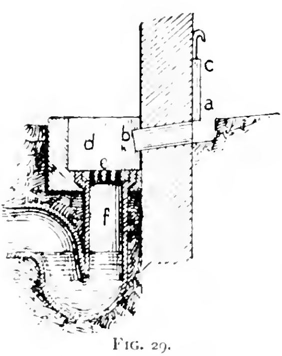


FIG. 29.
GUTTER AND DRAIN-WELL.

the escaping gases in the direction of the wind from whatever point it may blow.

At convenient intervals openings should be provided for reaching and removing any obstructions. Whenever a stoppage occurs, water poured down may be followed at these inspection holes, and the section of the drain in which it is will be known by the water failing to appear at the inspection hole below it. These holes should be large enough to admit of a drain-clearing tool being put together, section by section, within the drain, as shown in Fig. 30, and this tool should be long enough to reach half-way between any two holes, so that if the claw does not strike the obstruction from the point of entry above, it may be sure to do so from the one below it. The cost of this provision is not more than any probable year's expenses in curing the stoppages in ordinary drains, therefore it is but a foolish economy to withhold the provision on the ground of cost. Every dairyer should know where

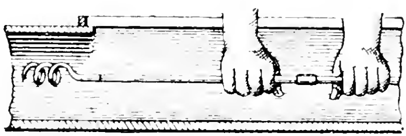


Fig. 30.—Using Drain Clearing-Tool.

the drains connected with his dairy are, and be able to deal with any difficulty promptly. For this he should have a plan of the drain system. We have known the drains of a large factory abandoned, and a new set laid, because they could not be tracked and opened up without an expense which would have been nearly as great as the new undertaking. All drains should be laid with glazed stoneware pipes, and set—not with cement as is often done—but with well-puddled clay, care being taken to remove any which rises above the joint on the inside, for anything of this kind tends to create obstruction by stopping solids in their downward flow, and causing their steady accumulation. Cement is useless, because it is soon eaten away by the acids of dairy drainage waters, after which the latter escape into the soil, and soak into the foundations of the buildings.

The outlet and disposal of drainage are troublesome matters, and can only be dealt with satisfactorily at some little trouble and expense. Sewage containing the washings of cheese-cloths and appliances, greasy, caseous, acid, and ready for rapid and noxious putrefaction, cannot properly be discharged into any open place within a considerable distance from the dairy or any dwelling-house, nor into any watercourse. We therefore advise the collection of each day's drainage waters into a small tank, where it may be treated in the evening with ferrous sulphate, or some other cheap chemical, which will coagulate the albuminoid material, which in turn will carry down with it any suspended impurities, and leave the water so cleared as to make it harmless to discharge next morning through a pipe placed above the surface of the precipitated solid matter, which at proper intervals may be removed by another pipe opening from the lowest point of the tank.

The **Lighting** of the dairy must be sufficient to enable all the work, and the corners of the rooms, to be seen well in dark days. In the lower rooms clear glass will best serve the purpose. Wherever the frequent opening of windows is desirable for drying and airing, the best arrangement is a well-made sash (with chains to carry the weights), for the air current can then be regulated according to need. In curing-rooms, where the windows should be double, with an air-space between, hinged casements are better for the outside; and for the inside, frames buttoning into place, with draught-tubing to make a close joint.

Heating and Ventilation.—These should be provided for under a combined arrangement, the one only serving effectively in company with the other. For the lower rooms, the air temperature as affected by boilers and heating processes is generally favourable to the work, but not always; and the loss caused by insufficiency of warmth in spring and autumn, would more than cover the interest on any reasonable outlay to meet the case, to say nothing of satisfaction and reputation. In the curing-rooms a complete system is needed, giving perfect control of the temperature, and not suffering a greater range than two or three degrees above or below the best curing point. This being indispensable, it is easy to supply from the heating source whatever is required at any time for the lower rooms. With each heating centre an inlet of air, also under control, should be associated, so that the air in entering may be warmed if necessary, and be conducted in its rising towards the opposite end of the room, and allowed an egress at a point which will best serve the purposes of its distribution. Helps to its passage out of a room are sometimes necessary, and should then be provided. These will be better understood when described as in typical dairies, the necessity in its different degrees being met in different ways, according to the system. The common foundation of all the systems is the fact that warm air, like a warm liquid, rises, while cold air sinks. This we shall watch in application.

Water Supply.—This should be of the best, and of two kinds, according to use. For steam boilers, rain water should be collected, because having no more mineral matter than can be washed from the roof it will give the least trouble with calcareous deposits ("rock") on the inside of the boiler. All other may be pure spring water, and for certain important purposes it cannot be too cold (naturally) in the warmer portions of the year. Whenever the source is much higher than the dairy ground-floor level, the supply can be directly discharged at all convenient points ; but otherwise a sufficient supply should be secured in a tank by pumping. Fetching water by the pailful as wanted, is a great waste of time and hindrance of the work ; and there are so many occasions where a constant supply by gravitation is a great convenience, and at others needful, that we recommend it to all and sundry.

Heating for the Processes.—This may be provided by steam or hot water. It is seldom economical to employ the former in farm dairies, for the only services worth considering which can be rendered, are the supply of steam to the making vessel, and the grinding of curd and pumping of water, if an engine is added to the equipment. The pumping is the most laborious of these, but there need be no difficulty about raising the quantity of water needed by hand or wheel pump, or with the aid of a horse gear. The care of a steam-boiler, however small, is a responsibility which should not rest with a dairyer, whose whole attention is needed to his cheese-making ; and this means that a second and reliable person must be kept to bear it. We therefore recommend hot water for the farm dairy, and shall design our dairies accordingly. On the other hand, no factory worthy of the name can be properly and economically managed without a steam-boiler and engine. These, with the manner of distributing steam and power, will be better described later. So far as we are at present concerned, the choice depends on the quantity of work to be done. When it exceeds the capabilities of the dairyer and one or two occasional helpers from the house or the farm, then it is well to employ steam and a proper caretaker. It must be a very large farm dairy to make that provision necessary.

The Cheddar Dairy.—We will now describe such a building as we could desire that every maker of Cheddar cheese should have, combining the best applications of the foregoing rules, eschewing everything but proper construction, suitability to system, and economical convenience, and capable of being built and furnished at a reasonable cost. The dairy shown is designed to receive the milk of from fifty cows upwards, but it will be easy to reduce the proportions of the different rooms to meet lesser needs. The plans of the building are drawn to a scale of 16 feet to the inch, and the whole fabric is 35 feet in length by 20 feet in width on the outside.

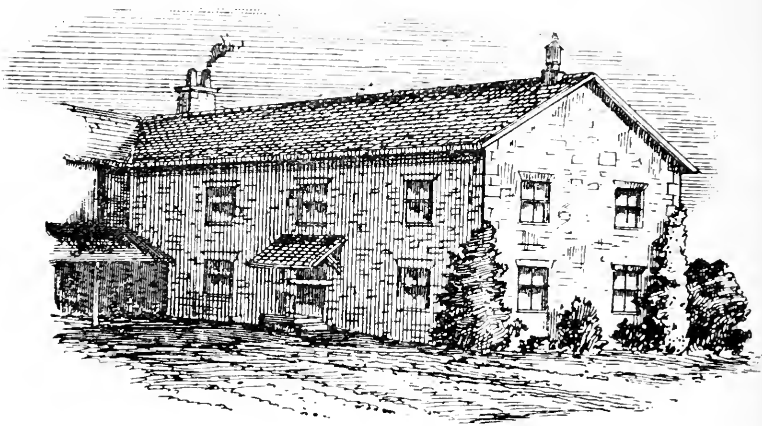


FIG. 31.—FARM CHEESE DAIRY—ELEVATION.

It is (Fig. 31) a north wing of the farm-house, from which it can be reached by the back door under shelter of the verandah. This is better than having a direct connection with the farm kitchen. It is divided (Fig. 32) into five apartments, —A being the hot-water room, B the furnace-room and coal store, C the making-room, D the whey and press-room, and E the butter-making room. Entering the first-named, which measures 9 feet by 8 feet, we find a hot-water boiler 1, so built as to have its fire front within the next room B, so that the dust is shut out of this room, which may be kept as clean and sweet as the making-room itself; the position of the flue (2), which connects with the chimneys in the south wall, is marked by the dotted lines. A hand-pump (3) supplies this boiler from a tank (4), of which more anon.

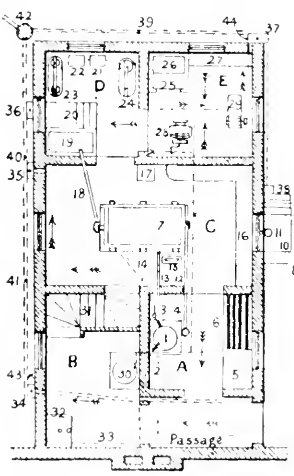


FIG. 32.—FARM CHEESE DAIRY—GROUND PLAN.

The manner of setting the boiler is shown in plan in Fig. 33, and in section in Fig. 34, where the letters denote the same parts in each. The boiler *a* rests on brick walls *b*, and beneath is the fire on the grate *c*, the smoke and heat passing behind and around the boiler (see arrows) and so into the flue *d*, thus giving as large a surface to the heat as is possible. The arch *e* bears the partition and flue wall. A soot door *g* allows the flue to be easily cleaned.

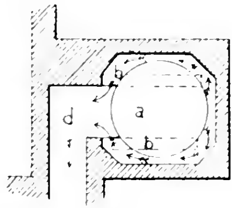


Fig. 33.
Farm Dairy Boiler—Plan.

On the other side of the way from the boiler are a tub (5), and a rack (6), the former for washing the utensils used in manufacture. The rack (Fig. 35) is much better than any plain shelf, because when vessels have been washed they can be turned upside down upon this, and more quickly and effectually dried and aired.

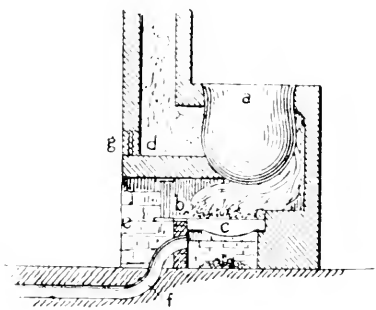


Fig. 34.—Farm Dairy Boiler—Section.

The Making-room C (17 feet by 10 feet) follows. This is mainly occupied by the cheese tub or milk vat (7), and is exclusively devoted to the keeping of milk and the making of cheese. The making vessel may best be described here, though most of the appliances employed will await their place of use in the system. The old form is usually called a *tub;* it was formerly made of wood, and retains the name which suggests this; but as a *vat* is a vessel to contain liquids, the term may as well be used for this as well as for the oblong vessel generally so called.

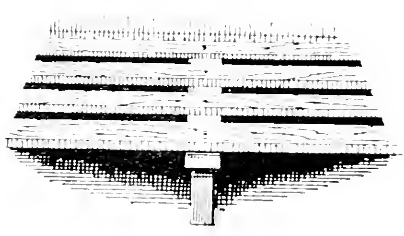


Fig. 35.—Airing Rack.

The circular vat here shown (Fig. 36) consists of a tinned copper vessel *a*, which rests partly within a lower case *b*, a strong beading *c* of ½ inch thickness being provided to support it in the proper position. This case slopes inwards from the perpendicular enough to allow a space between the two of $1\frac{1}{4}$ inch at the lowest point; and under is a space of 2 inches, filled with hot water when heat is desired. Heating-water is poured into it by the funnel *d*, and can be drawn out as required by the tap *e* or the spout *f*, the latter being only used when the space must be cleared after a heating, and such may be done in a minute by removing the plug. The tap *g* is generally made with a loose plug; its chief objection is that it affords an inch or more of pipe, opening into the vat, in which curd lodges, and from which it must be continually cleared, that it may share in the treatment of the whole. The wooden stand *h* is made to hold the vat in place by grooves, and to tip it by a block *i* (hinged to the stand) being raised under it (Fig. 37), when lifted by the handle *j*; and by the handles *k*, *l*, the duplicates of which are on the other side, the inner can be removed from the outer case, or both carried from place to place. It is common to make the inner case with a convex bottom, partly for strength, and partly because it is intended that the curd should be piled in the middle and so drain into the angle from all sides. But it is better to pile at the side, not only for the greater protection to the curd, but because it is more easily reached for after-processes, and a flat bottom which will give free drainage directly to the tap on being tipped is therefore preferable. Moreover, the angles formed by the old bottom are difficult to reach to keep the curd stirred out of them. The one real advantage that it does not settle into a concave shape, may be secured to a flat bottom by a simple circular frame of 12 inches diameter supporting it in the middle, but allowing free passage of water. A wooden cover should be provided, fitting closely at all points, and jointed as in Fig. 38, to allow of an inspection of the vat's contents without entire removal. This cover may be drawn up by a cord and pulley when out of use, and its space so saved elsewhere, as well as much lifting.

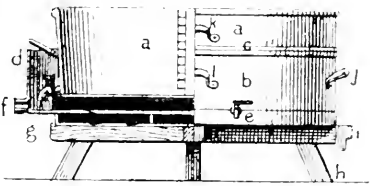


FIG. 36.—CIRCULAR HOT-WATER MILK VAT.

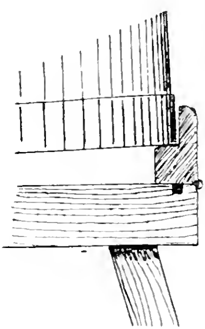


FIG. 37.—TIPPING BLOCK.

The round vat is only to be recommended for small quantities of milk, when it would be difficult to work it in the other kind; in every other case the oblong vat is superior. It has sometimes been asserted that a round vat is essential to the system; but it is impossible to show either that any principle of the system is involved in the shape of the vessel, or that any practical advantage is gained by the cheese from it. Just as fine cheese can be made in the one as in the other by a person fully accustomed to either, but any beginner can much more easily procure high quality and uniformity of the curd in the oblong vat than in the round one.

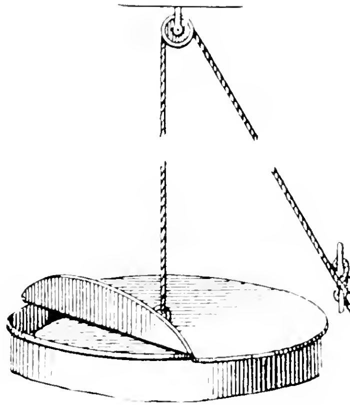


Fig. 38.—Cover for Round Vat.

The oblong vat, Fig. 39, is constructed on the same lines as the circular one, but the outer case is not unfrequently made of wood, and when it rests on legs this is best. The fore-legs are made by $1\frac{1}{2}$ to 3 inches shorter than the hind-legs, according to the length of the vat;

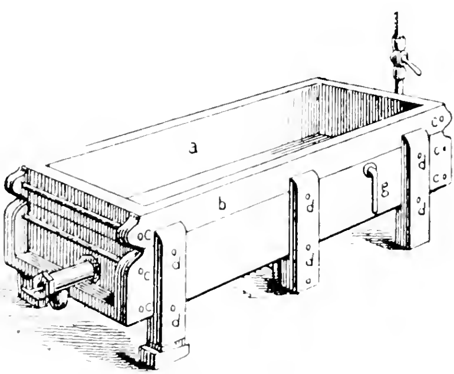


Fig. 39.—Oblong Milk Vat.

and are supported at level by wooden wedges, easily made and replaced, and superior in use to any device we have seen. These removed, the vat can be tipped, and the wedges placed under the hind legs, when the whole will have a good incline for the removal of the whey or draining of the curd. This arrangement is much better than the provision of a sloping bottom to the inner case. The size, measured at the top inside, ranges from 27 inches to 36 inches in width, from 22 inches to 25 inches in depth, and from 4 feet to 9 feet in length, according to capacity. As will be seen in Fig. 40, the space

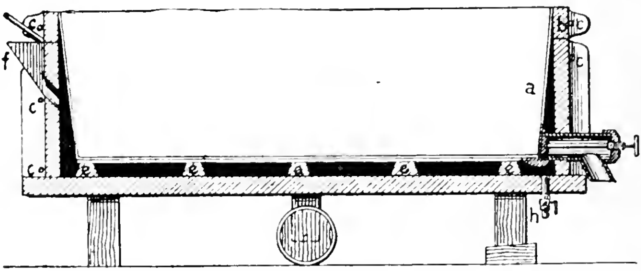


FIG. 40.—OBLONG MILK VAT—SECTION.

between the lowest point of the inner case and the outside opposite to it should be $1\frac{1}{2}$ inch, and the loss of containing space must be taken into account in estimating the capacity of a vat. It amounts to $\frac{3}{4}$ inch on the average, on each end and side; or $1\frac{1}{2}$ inch on the width and length. As the dairyer may wish to obtain a vat of proportions suitable to his milk quantity, he may calculate capacity by selecting the most suitable width and depth from the following table, and dividing the total number of gallons of milk by the corresponding figures in column 4, which will give the requisite length in inches as if calculated for cubical measure. But as a mean of an inch and half of loss arises from the sloping of the vat to that extent in its total width and length, so much must be added to the result obtained. The depths as stated are calculated to allow two inches above the surface of the milk for working room; if more be thought necessary it must be added, but a lower margin should not be attempted.

1 Suitable to	2 Width.	3 Depth.	4 Divisor.
130 galls.	30 ins.	22 ins.	2.24
160 ,,	32 ,,	23 ,,	2.50
200 ,,	34 ,,	24 ,,	2.78
300 ,,	36 ,,	25 ,,	3.06

Example.—A vat to hold 150 gallons should be 32 inches wide × 23 inches deep, and the calculation for length (150÷2.5) will give 60 inches, to which adding $1\frac{1}{2}$ inch, the length may be fixed at 5 feet $1\frac{1}{2}$ inch top inside measurement.

The inner case *a* is fastened to the upper edge of a separate frame *b*, by screws, the heads of which are soldered over. This frame, and the outer case generally, should be made substantially, not less than $1\frac{1}{2}$ inch in thickness, and well bolted together at *c c*, with all joints made watertight. To prevent the upper frame from slipping, iron studs should be fastened to the lower part, with corresponding plates on the under side of the frame into which they may fit, as the tendency is to slip towards the tap end when the vat is tipped.

The legs should be of 2 inches thickness above, and $\frac{1}{2}$ inch thicker below, the body, and bolted at *d d;* the ends of the fore-legs iron-bound to prevent wear by wedging; and the wheels of the middle set fixed on an axle running in metal bearings.

The inner case should be made of one sheet only for each part, so avoiding seams; and, to prevent its losing shape, should be supported beneath by three strips of wood $\frac{1}{3}$ inch thick, resting on and secured to blocks of wood *e e;* and the whole outside of the tin, and all parts of the outer case, should be well covered with a non-corrosive paint. At the back, a funnel *f* receives the heating or cooling water, which fills the space between the cases to the height of the pipe *g*, then overflowing; and, when done with, removed by the tap *h*, at the lower end.

The peculiar character of the vat makes a special tap necessary, one that may be securely attached to, and easily detached from, the inner case to allow of the removal of that part, and yet making a water-tight joint in use. Finding none in the market which met this need properly, we designed, some twelve years since, a tap which has given us great satisfaction. It has never been patented, nor have we any monetary interest in it, and may therefore describe it for the benefit of all concerned. It consists (Fig. 41) of a collar *a* which is riveted to the inner case, and a tube *b* with a nozzle *c*, of 2 inches to $2\frac{1}{2}$ inches diameter according to size of vat, and which screws into the collar. On the outside of the tube a wide flange *d* bears a thread upon which a collar *e* runs, screwing against the vat a rubber ring *f*, well coated with a mixture of white and red leads to make a tight joint. Finally, a plug *g*, fitting into a seat, is held in place by a spindle *h*, which screws into a cover *i*,

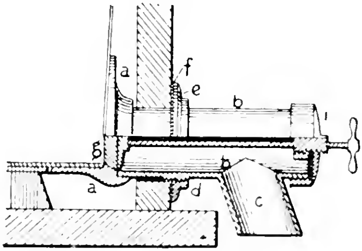


FIG. 41.—FACTORY VAT TAP.

being withdrawn in a moment, and giving ample passage to the whey. The whole cover and plug may be removed for cleansing.

The making-room has two windows, giving a through draught when needed, and plenty of light at all times. The east window is protected without by a projecting roof (8, Fig. 32; see also Fig. 31), and

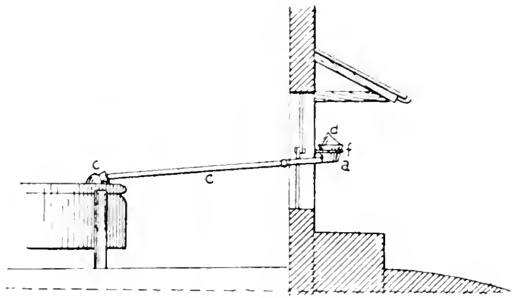


FIG. 42.—MILK CONDUCTOR IN PLACE.

under it are steps (9) leading to a small platform (10), where the milk conductor carries to the vat the milk brought from the cow-houses without the milkmen entering the dairy. In Fig. 42 the conductor is shown in place. The receiver is a pan of the shape shown in *a*, Fig. 43, having 12 to 15 inches of pipe *b* projecting from it, and fitting into another tube *c*, which, after a few inches, becomes an open shute, kept in shape by occasional bands across it. This is better than a complete tube, because more easily cleansed. In the receiver rests a strainer *d* of fine perforated brass, which can be removed to shake out anything which may be caught in it. It is not wise to have a fixed strainer in the receiver itself, and this separate one can be used for other proper purposes. A bag *e* of strainer cloth is fastened over the end of the conductor to prevent splashing, and to divide the milk afresh for aëration. The conductor is supported by an iron frame *f*, which closes round it and fastens with a catch *g*, and the pipe *b* passes through a wooden pane in the sash, the aperture being closed by a

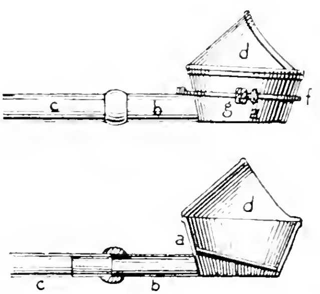


FIG. 43.—MILK CONDUCTOR IN USE.

cap when out of use. The pipe should fit so as to prevent a draught. The conductor serves a second purpose, by conveying hot water from the boiler 1 to the vat (Fig. 44), its receiver *a* resting in an iron frame *b* attached to the side of the former, and its other end on the funnel *c* of the latter (also 12, Fig. 32). This puts an end to all carrying. When the water has reached the level of the overflow pipe *d*, it runs into a similar conductor *e* (also used for whey removal), and by it to a tank *f* (under 4, Fig. 32), from whence it is raised again into the boiler by the pump *g* (also 3, Fig. 32). The whey conductor *e*, after occupying the position shown in the dotted lines to receive the overflow, can be drawn to the other position to receive the rest when no longer needed (14, Fig. 32). The tank *f* holds 250 gallons, and serves a very important economy in water and time, for that which

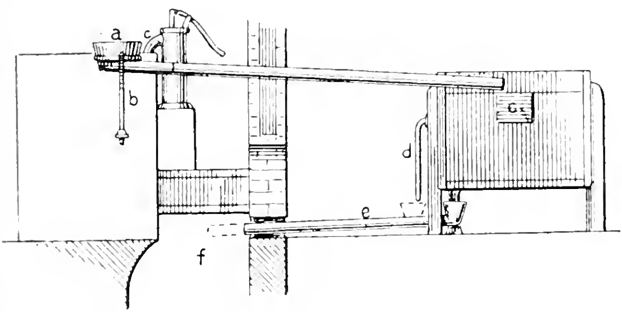


FIG. 44.—METHOD OF SUPPLYING HEATING WATER.

returns is always much nearer to the boiling point than any supply from without, and saves both fuel and time in getting heated afresh. This secures the using over and over again of the same supply, for it will be twice heated for this vat, and afterwards part will serve for washing utensils, the remainder being used for cleaning floors at the close of the day. The quantity provided for is ample for the work in view. Before the curd is ready for first operations, the conductors can be put in place; and the dairyer will only need the attention to the fire by a household servant, and her help in pouring water into the conductor and pumping a fresh supply into the boiler, and there is therefore a saving of labour to the house. A shelf 16, and sundry pegs for hanging implements, with a desk 17 for records, and a locker beneath for small dry stores (as rennet, litmus, &c.), complete those furnishings of this room which require notice.

The floor of this apartment should, at its eastern end, be raised six inches above that of the rooms A and D, and a foot above ground level. This gives the necessary incline for the delivery of whey by the conductor (18, Fig. 32) to the *creaming tank* (19) for whey, shown also in Fig. 45 as in use, where the steps (20) by which the dairyer goes down to skim it are seen. In the whey room is the *cheese lift* (Fig. 46), which may be of the simplest description, but should not be missing. It is quite as much to the advantage of the goods as of the dairyer that they should be raised in this way rather than carried by hand, with the risks of injury, which will hereafter be shown to be much more than is usually supposed. Two guides *a a* bear a roller *b*, on the end of which a wheel *c*, with spikes at intervals on its circumference, is made the means of raising and lowering the table *d* by an endless rope *e*, which is simply gripped between the spikes and draws the wheel round when it is pulled. A partition *f* surrounds the floor opening, and is covered by doors, one of which *g* is shown raised. These fit closely when in place, and should only be opened for the few minutes necessary to actual use. The table *d* need not be larger than will serve one cheese of the largest size. The turning table 22 (Fig. 32), and presses 23, 24, will be described later, as also the movable furniture of the butter-making room.

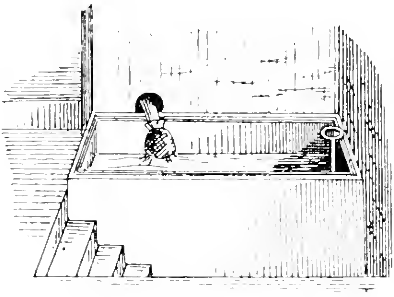


FIG. 45.—WHEY TANK.

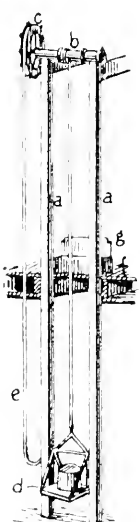


FIG. 46.
CHEESE LIFT.

There is, however, in the last-named apartment a provision in which the cheese-making is concerned; the water tank, which covers a part of it its whole width, and 7 feet of its length, with a depth of 3 feet, and a capacity of 1000 gallons or several days' supply. This is preferable to a small tank holding only the supply for a day or two, if only for economy of time. A pump which will raise 350 gallons per hour can be bought for £3, and three hours' use would meet the needs of nearly twice as many days. In Fig. 47, the tank *a* is shown as resting on iron girders *b*, ceiled beneath, where it covers a small butter cellar (also 25, Fig. 32). A double wall and door *c* of boards, with a lining (as in Fig. 28) against the main wall, confines the cold air descending from contact with the tank, and passing over and around the shelves *e e e* finds egress under *d*, where a space of two inches is left for the purpose. The warmer air of the room, rising through holes in the ceiling, passes under the tank and, being cooled again, sinks. This will therefore be

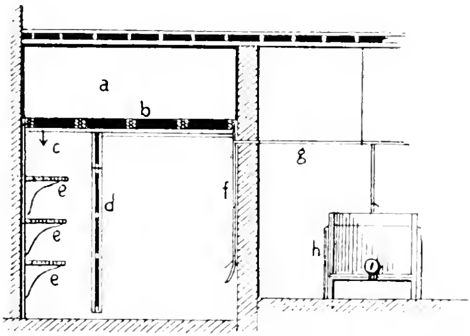


FIG. 47.—WATER TANK AND BUTTER CELLAR—SECTION.

the coolest room in the building. A pipe *f* descends to a point convenient for use with the butter-making; and another branch *g* passes over, supplying the vat *h* (7, Fig. 32), to the boilers and washing vessels in rooms A and C when necessary to supplement the supply from the tank. The course of the pipes is shown by the single dotted line (Fig. 32).

The stairs (31, Fig. 32) leading to the curing-room start from the making-room, and are enclosed within a board partition, with a door at each end. In the boiler-room B is placed the heating apparatus (32), with its flue (33) rising to the main chimneys.

The inclination of the various floors is shown by arrows pointing to the lowest ends. It will thus be seen that water used in cleansing the floor of room A flows towards the doorway, where a gutter (dotted line) gathers with this all discharged from the washing vessel (5) and that used on the floor of the passage, and carries it forward to the drain well (34), which serves room B as well. In the making-room C the flow is towards the west wall, where a gutter, shallow at south end, grows deeper towards the outlet (35); while room D has a double slope towards a common point (dotted line), and all waters flow to the outlet (36) by way of the stairs (20), which are therefore last cleansed. The butter-room has a double slope too, emptying into a gutter and outlet (37), the drains serving these and the trap (38) to receive the washings of the milk delivery platform, which naturally becomes foul from the boots of the milker, and should be kept carefully clean. Outlet 36, by reason of its low level (2 feet below ground level), determines the inclination of the rest, and this will be more than is necessary to secure rapid clearance. As outlet 37 is a foot below ground level, the drainage from 38 may empty into its side, and so need no inspection-hole ; while one at each of the points 39, 40, and 41 will serve for the rest, with a common gathering and inspection-well at 42, from which the main drain will carry all to the tank or final point of discharge. Ventilation pipes at 43 and 44 will serve the whole system.

The curing-room, Fig. 48, is constructed as earlier described in regard to its walls and windows, and its heating and ventilation may now follow in detail. The sources of heat (45), and of air ingress (46), are placed at the south end of the room, the heating apparatus being placed with most convenience in the room B (Fig. 32) below. The outlets 47, for air are therefore at the other end, and the warm air is caused by this arrangement to distribute itself equally over the *width* of the room. In Fig. 49 (the reference figures are the same in both) the distribution in height is shown. The natural tendency of the warmed air to rise will ensure its reaching the upper part of the room, and if the outlets were close to the ceiling the cheese stored at the highest levels would have most heat. But by making these outlets in the form of simple shafts, rising to the roof ridge and discharging in common, and their lowest points to be not more than two-thirds of the height of the room above the floor, the main currents of warmed air must necessarily fall to this point in passing out ; and thus, while occupying the upper part of the room, also pass more directly towards the outlets, covering the middle part of the room between the two upper dotted lines in Fig. 49. No air being admitted excepting at 46, if the inlets and outlets be closed, the whole air of the room must needs be warmed, the lower colder air passing southwards to the pipes as the warmed air rises and spreads northwards by natural

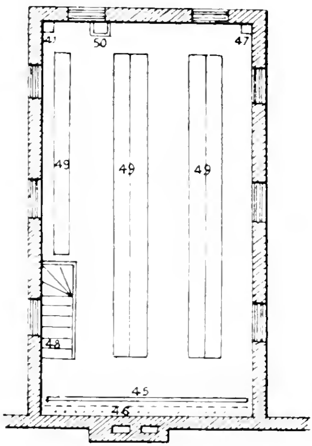


FIG. 48.—CURING-ROOM—PLAN.

action. With the general rise of temperature that circulation would become slower, and the distribution of heat more even, as could be proved by comparing correct thermometers at different parts of the room. On opening the air inlets and outlets to an extent suitable to the existing needs, the warmed air would naturally pass out, and fresh

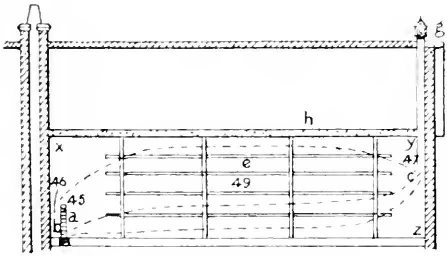


FIG. 49.—CURING-ROOM—SECTION.

warmed air would continue to follow it, occupying all of the room excepting the angles *x*, *y*, and *z*, and raising the temperature even of these. The actual course of the air would be as shown between the highest and lowest dotted lines whenever the current was properly controlled. If it was too rapid, the warm air would be drawn into a narrower body, and pass more directly towards the outlets, so leaving the upper and lower parts of the room, and especially the latter, without much benefit. Frequently the difference between the actual air temperature and that proper to the curing would be but a few degrees, though too great for the best results; and, in such case, the heating necessary would only cause feeble currents, which would tend to the higher space and but slightly affect the temperature of the lower space, failing also to clear the moisture of the room sufficiently for the good of the cheese. At such times a more rapid current should be induced by some provision which can draw out the internal air by mechanical means. At the point of discharge of the air shafts 47, a revolving ventilator, Fig. 50 (*g*, Fig. 49), will serve the needs of Cheddar cheese. This device consists of a tube *a*, part of which is cut away, showing the screw *b*, which—as attached to, and drawn by, the upper part—draws up the air below, discharging it through the spaces between the plates *c*, the whole being propelled by the wind

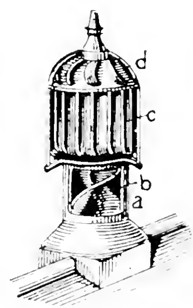


FIG. 50.—"HOWORTH" REVOLVING VENTILATOR.

catching the cups *d*, and the rate of propulsion therefore varying with the wind. This introduces an element of uncertainty, and makes it necessary to provide means of control. The many slight variations in the ordinary rate of the wind may be disregarded, because they give within the highest and lowest experience an average which will be as useful to our purpose as a steady rate of motion ; but when we have to deal with broader difficulties, as between a gentle breeze, a rapid wind, and a hurricane, we have to provide for the average action of such states of the air, and control the exhaustion of internal air accordingly. With the heating so fixed as to provide for a proper temperature with a slow passage of air, a change to a greater speed of the wind and the ventilator would mean that the air would be drawn out too rapidly to be properly warmed at its entrance, and the cheese would be exposed to a too low temperature. If this difficulty should be met by increase of heat the economy must be touched.

At all noticeable changes of the rate of the wind, then, the removal of air by the ventilator must be regulated, and in Fig. 51 a simple appliance for this purpose is shown. It consists of a shutter *a*, swinging on an axis *b*, to the end of which is secured a steel spring handle *c*, which catches in the notches of a rack *d*, and can be made to change the position of the shutter by being drawn towards the user and released into another notch. The dotted lines show the position of the spring when the shaft is fully open, as at *e*, and closed as at *f*, strips of wood *g g* meeting the shutter in the latter case and stopping it at a level point. The shelves 49 (Figs. 48, 49), the lift 50, and the stairs 43, are shown in their respective positions, and it will be seen that the windows give ample light for examining the goods—a matter of great importance. They may be easily darkened by shutters. The ceiling *h* (Fig. 49) is covered with saw-dust as earlier advised.

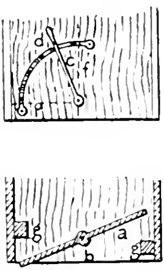


FIG. 51.—APPLIANCE FOR CONTROL OF AIR SHAFT.

The heating may be provided for in various ways. The use of a stove in the room is objectionable, because it is scarcely possible to maintain a proper temperature in cold weather, with a passage of air sufficient for the removal of moisture, without overheating the nearest cheeses. If, on the other hand, this is avoided, the cheeses farther away from the stove will suffer from cold. We have seen much of this direct heating, and have never seen it give the best results. In dairies where fine goods are made during the summer the early and late makes are usually inferior, and to no small extent because of such error in the curing-room.

A stove may be used, however, if it be kept in another apartment, and the heated air distributed properly. In Fig. 52 a suitable stove is shown, consisting of a double-cased frame of iron, the inner case lined with fire-bricks, and containing the grate *a*, and ash-box *b*, fed and emptied by the doorways *c* and *d*, and discharging its smoke by the flue *e*, these openings being made with fast joints to both cases. The top of the inner case has an opening with a tight-fitting cover, allowing of removal when occasion arises. This case rests upon narrow iron supports shown at *f* in Fig. 53 (section), the upward extensions of which keep it in place. The bottom plate of the outer case has a large opening in it, through which air entering is warmed, rising (see arrows) between the two cases into the dome *g*, and thence in any upward direction by the pipe *h*, a continual supply of fresh warm air being thereby maintained. The best method of employing this stove is by carrying its hot-air pipe *h* into another *i* set, as in Fig. 54, between the floor of the curing-room *j* and the ceiling *k* below it, with numerous apertures *l* in the pipe and floor to distribute the rising air. These last should be collectively equal in area to the pipe; if they exceed this, they allow the air to rise through the nearest apertures, and so prevent evenness in distribution. A tongue *m* divides the air into two currents, and a convex check *n* can be raised or lowered, reducing or enlarging the air passage, and being held at the height desired by a pin *o* in a simple frame *f*, so regulating the heating as well as it can be done. The pipes can, with a view to economy of heat, be covered with felt or other non-conducting material, and the space around *i* packed with the same, so also saving the timbers from danger of overheating. If the air is thus made too dry for the cheese, shallow troughs of water may be set immediately close to the air-holes *l*, so as to take up a supply of the vapour rising under the action of the heat. By regulating the fire, as well as the air passing, this apparatus may be made to answer fairly; but it is not so controllable as a hot-water circulating system.

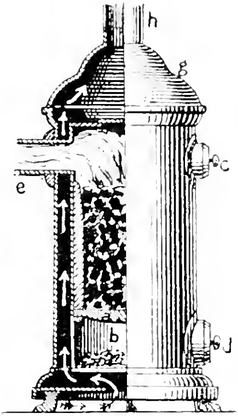


FIG. 52.—HOT-AIR STOVE.

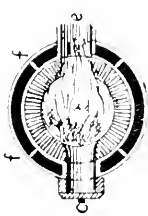


FIG. 53.
SECTION OF STOVE.

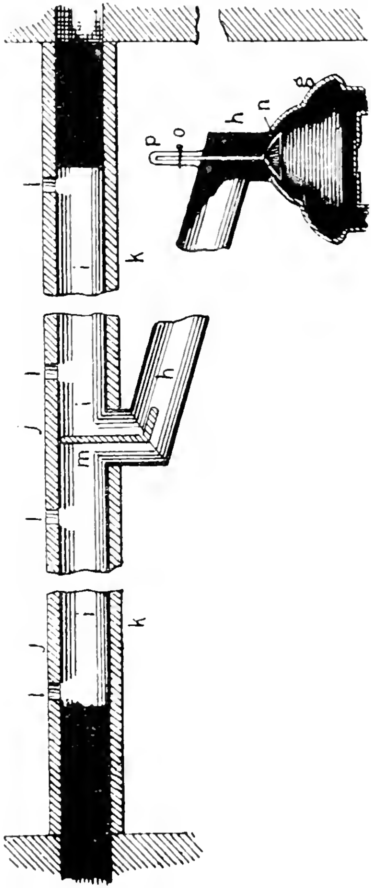


FIG. 54.—HOT-AIR APPARATUS.

For hot-water heating a double-cased boiler is needed, the space *a* between the two cases, as in Fig. 55, being filled with water, as also a set of pipes which connect with it at the collar *b*, and a similar one opening into the side at the lowest water point. The principle can best be explained by a diagram, Fig. 56, in which the water circuit is shown complete. From boiler *a* the flow-pipe *b* rises through the ceiling *c* into the room to be warmed, and passing to the other side of it bends back to the return-pipe *d;* the water in the boiler rising as it is warmed, and colder water from *d* taking its place, to be warmed and ascend in the same way. So a circulation is set up which soon becomes rapid and continuous, and the pipes being heated give off their heat into the room. There will be, of course, expansion, and this must be allowed for or the pipes will burst, so a small tank *e* is fixed against the wall of the room, and connected by a pipe of ½ in. diameter with the highest pipe. This is kept half-full of water, which rises with the expansion of that in the pipes, and sinks when heating ceases. This is the simplest form of the matter; but it may be applied in various ways, by coils of pipe turning back and forth upon each other, and increasing the heating capabilities to any extent necessary in a curing-room. The expansion of the pipes should also be provided for by joints which allow of this occurring without damage. Such devices are common in the trade, but generally covered by patents. The main body of pipes can be set permanently with an iron cement. They need proper supports, which should allow them to rest on rollers so that they may have free movement when expanding, otherwise they would drag their supports out of the perpendicular.

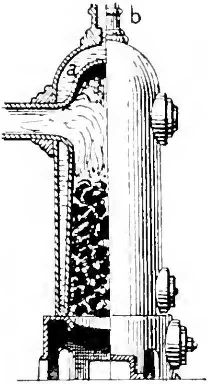


Fig. 55.
Hot-water Boiler.

The rapidity of the circulation and extent of the heating will depend somewhat on the quantity of fire, and therefore on the size of the fire-box, and also on the surface exposed to the flame. As the water gives off its heat it necessarily comes back colder, and this in proportion to the distance it has travelled, and the time it has taken in going and returning. There-

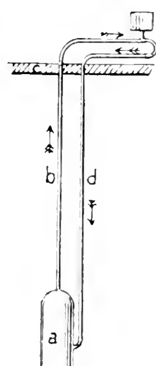


Fig. 56.
Diagram of Hot-water Circulation.

fore the greater the fire-heat the quicker the circulation, and the greater the heat given off on the way.

An independent boiler, Fig. 55, may be used in farm dairies, but needs a covering of non-conducting material. Here, however, the economy in fuel is not so great as in that shown in Fig. 57, and which must be set in stone or brick. This boiler has pipes *c* within, which greatly increase the heat surface. The fire-heat after acting on these passes out through a hole, *d* in Fig. 58, where the boiler is seen in side elevation; and following the course of the arrows in both illustrations, passes beneath the plate *e*, around the sides under the plates *f* and over the top into the flue *g*, having attacked the water at every available point, and made the most of whatever fuel may be employed. The economy justifies the expenditure on setting, as against the original cheapness of the independent boiler.

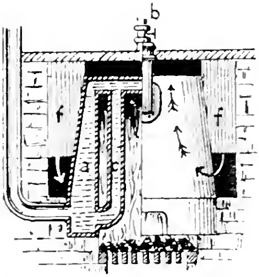


FIG. 57.
HOT-WATER TUBULAR BOILER.

In our case we have need of a more than usually controllable source of heat, such as will avail to keep the temperature within five degrees of the best point for the cheese; and as the air without artificial heat may fall in a cold night, and even in a room constructed as described, twenty degrees below that best point, we should have the means of raising the temperature at such times by fifteen degrees at the least. We do not mean that such a fall would come in a single night, but that in a continuation of cold and the absence of internal heating the internal air will steadily sink towards the external temperature, and will not recover itself in the warmer part of the day. Probably twenty degrees of difference is the outside limit; but as this is always possible in experience with autumn-made cheese, before it is ready for the market, it must be provided for. But plainly the heat necessary to keep the room right under such conditions, would be far too great for weather which, though milder, would still be too cold to dispense with heating, and it is proper to provide for the regulation of the heat by stages, so that the loss of a few degrees may be met without excess, as well as the extreme of need without a failure. This may be

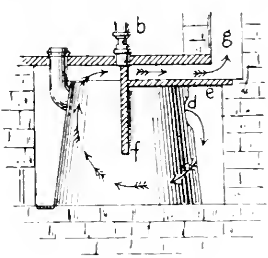


FIG. 58.—HOT-WATER TUBULAR BOILER—SIDE ELEVATION.

effected, as shown in Fig. 59, by the use of a coil working in four sets, —one, two, three, or all of which may be employed at a time,—with corresponding variations in the extent of the heating. From the boiler *a*, the flow-pipe *b*, rising, ends in a series of T-sections *c*, connected by expansion joints *d*, and with the circulating pipes *e*, which are in four bends or sets numbered by nearness to the boiler. A series of elbows *f* joins the lower pipe of each set with the upper one of the next set, and a series of valves *g*, *h*, and *i* are employed to open or cut off communication between them. In Fig. 59, *g* and *i* are all open, and *h* closed, so that the circulation is, as shown by the

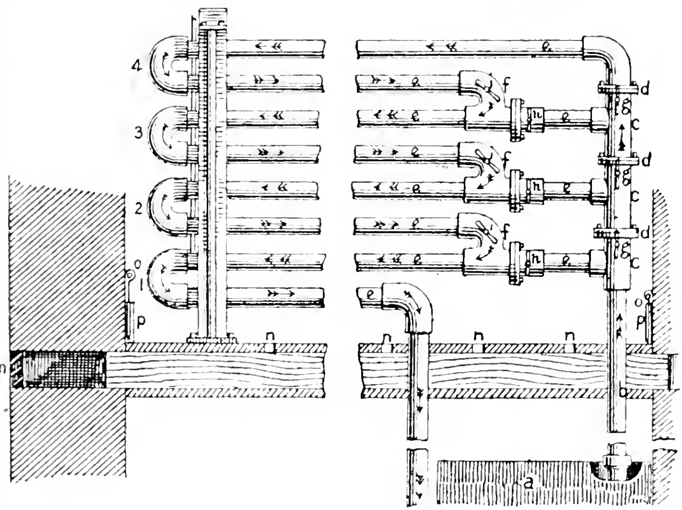


FIG. 59.—HOT-WATER COIL.

arrows, occupying all the coil. But by closing the uppermost *g* and *i* valves, and opening the corresponding *h* valve, the circulation in bend 4 would cease, and be confined to 1, 2, and 3; and in the same way bends 2 and 3 could be cut off from use, and bend 1 alone employed, so giving entire control over the temperature. If the internal air should fall four or five degrees below the best point, one bend would be sufficient to restore it; at a few degrees lower, a second would be needed,—and so on; and there could be a corresponding though not equal economy in firing, for one bend would not need so large a fire to maintain its heating power, as two or more; or, with an equal fire, one would throw off more by radiation alone than it would do in proportion if working with a second. The effectiveness is still somewhat dependent on the stoker; but, with no more attention than a stove needs, the regulation of the temperature is easier and more nearly absolute.

The supply of air is brought from without through *louvres* (Fig. 60; and *m*, Fig. 59) in the walls, opening into a space between the floor, the ceiling below, and the two joists, with perforations (*n*) in the floor. On the inside of the walls shutters (*o*) are provided, sliding in frames (*p*), and by these the ingress of air can be regulated,—that one being generally opened which is on the opposite side of the building to the direction of the wind, and the other closed. This matter will need watching in practice, with the guidance of the thermometer, hygrometer, and experience. The system recommended is, however, the best known to us, and the cost justified by the benefits. The commonest steam coal, with coke and any combustible rubbish, will serve as fuel, unless when the heaviest demands are made upon

Elevation. Section.

FIG. 60.—LOUVRE VENTILATOR.

it, which in our climate is not often or for a long time. In some farm-houses the boiler is put in at the back of the kitchen grate, but while this gives an advantage during the daytime, it fails at the very time when it is needed—during the night,—for even if the fire be banked down to keep it in, it gives but a slow heat, and does not meet the case. It is best to have a separate fire for the purpose, and exercise the economy in the kind or quantity of fuel.

A factory for Cheddar cheese-making is shown in Fig. 61 in elevation, and its ground-plan in Fig. 62. We will follow the latter in our description, which we shall confine to those matters in which it differs from the farm dairy, the two being alike in general construction. At the west end will be seen a projecting roof, which shelters the delivery platform. The last projects a couple of feet outside of the building, and five feet within the outer wall-line. Two heavy doors close it, falling within to right and left at time of delivery. This platform should be of concrete or stone, for it will have much wear with the cans dumped and rolled upon it daily. But at the front a

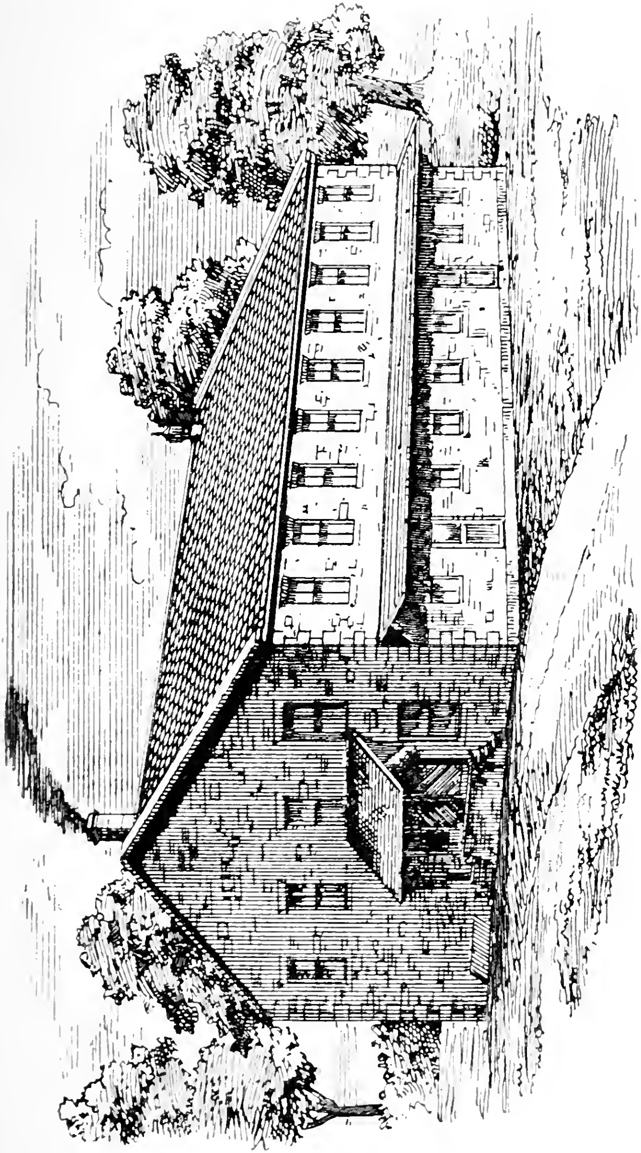


Fig. 61.—Cheddar Cheese Factory.

strong beam (*a*)—Fig. 63—or stone, supported by a beam (*b*) and block (*c*) embedded in the concrete foundation (*d*), should bear the

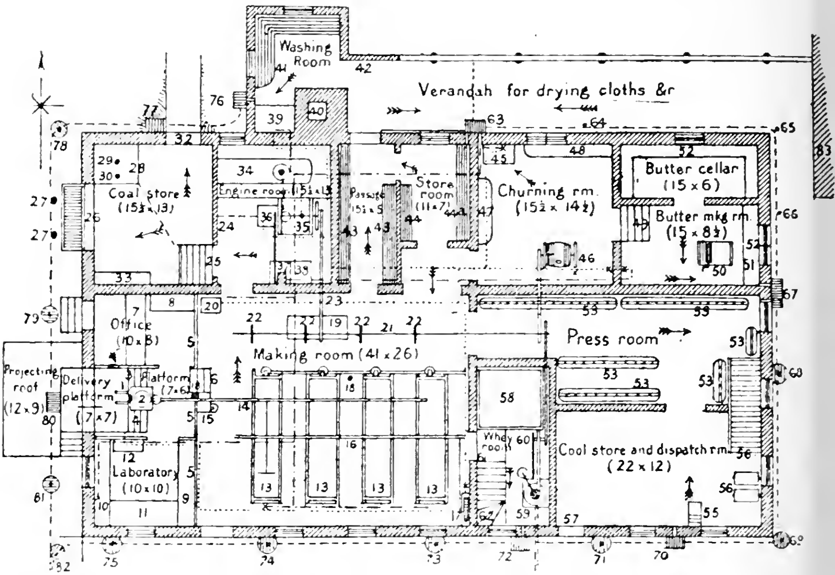


FIG. 62.—CHEDDAR CHEESE FACTORY—GROUND PLAN.

strain of the vehicles set against it, and this and the whole front wall from the ground upwards should be protected by pieces of wood, which when worn can be replaced, leaving the main fabric uninjured. To this platform the roadway should rise, so as to allow of compara-

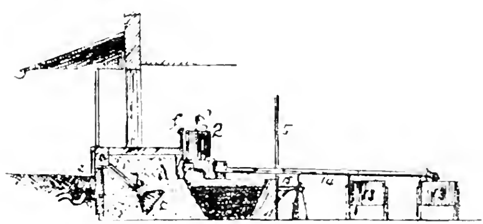


FIG. 63.—DELIVERY PLATFORM.

tively low vehicles delivering their milk-cans with as little lifting as possible; and if the road in front can be of stone paving it will be better, for, in turning, the wheels make sad havoc of a macadamised surface, and create much mud in wet weather. A drain-well (*e*) (and 80, Fig. 62) is needed to receive the cleansing waters used on the platform, which after a delivery will be one of the dirtiest places on the premises. A barrier (*f*), with a leather cushion on its top bar, allows of the cans being tipped without bulging, and with trifling labour; and a pair of iron-bound skids (1, Fig. 62) should be provided, to raise them a couple of inches from the floor, to give the lifters clear handling. We have seen all sorts of devices for milk delivery, but none which allowed of such expedition as this one.

The milk receiver rests on a lower platform, with its edge at two inches below the cushion top, so escaping any contact with the cans. Where milk is bought by measure, this should be gauged with a brass strip in imperial gallons, and the platform made absolutely level. Where purchase is by weight, the scale should be allowed for in determining the height of the platform, and any of the best scales of the various makers will serve, preference being given to such as most quickly give the correct result, and the balancing of which is least liable to interference from the milk carriers. The bottom (*a*) of the receiver (Fig. 64) is made to slope towards the discharging valve *b*, which is lifted by the chain *c*, and held up by hooking to the side so as to allow of a safe flow. Two hooks at a half-inch apart will allow for the variations in flow, which are safe with larger or smaller quantities, avoiding waste. The end of the chain is secured to the edge of the vessel. On either side of this small platform, steps 3, 4 (Fig. 62), lead to the lower platform, office, and laboratory, the whole of which are enclosed by a partition 5, which is boarded up to the height of three feet, and glazed above, giving those occupied in either a clear view of the cheese-making room, at the same time cutting off the external air from it.

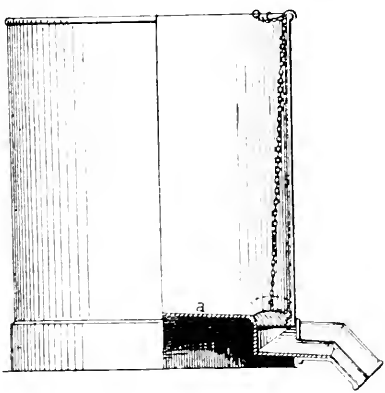


FIG. 64.—MILK RECEIVER.

The office is so placed as to be convenient for booking milk figures as given from the weigher, and for ready access to any persons delivering milk who have also other business to transact. It contains a counter

(7), with nests and lockers, and a private desk (8) for the manager. The laboratory is also conveniently placed for receiving samples, and provided with two wide shelves (9, 10), high enough to work at while sitting, and a hot water and washing bath (12), with sundry shelves and pegs for appliances used.

By the steps (6), we reach the cheese-making room. Here are four vats (13), of the same form, but larger than those recommended for the farm dairy. Their total working capacity determines the outside limit of milk supplies, unless some other manufacture, besides cheese-making or the milk trade, is continually carried on. Space is allowed in the plan for the greatest length used in practice, but the three sizes used in factories are as under, viz. :—

Capacity.	Width.	Depth.	Length.
400 galls.	38 ins.	26 ins.	129 ins.
500 ,,	41 ,,	27 ,,	146 ,,
600 ,,	43 ,,	27 ,,	166 ,,

The largest size will seldom be required, and the smallest is more generally used in British factories than any other. The economy of the former in cost is not wholly gain, because with the Cheddar system only a strong and tall man could manage a 600 gallon vat properly.

These should be fitted for steam-heating, and connected with the pipe *a*, Fig. 65, from the boiler by a piece *b* of the best rubber steam-

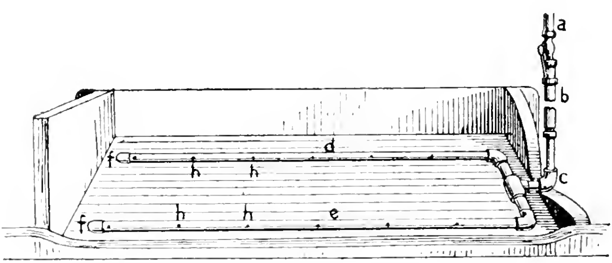


FIG. 65.—STEAM HEATING PIPES IN FACTORY VATS.

tubing, secured by copper wire or a screw union, a thread being turned on the pipe ends in either case. Where the pipe *c* enters the vat, the joint must be made watertight. Within, *c* divides into two branches *d e*, which extend the length of the vat, and are closed by caps *f f* to prevent steam escaping at their ends. The steam is distributed by small holes *h*, bored at intervals of a foot on either side, or one in six inches of the whole length.

The milk conductor (14) has no strainer in its receiver, because the discharge must be so rapid as to risk splashing or overfilling if one were used. Milk delivery is sharp business, and must not be hindered. A bag strainer on the end of the pipe therefore serves the double purpose of retaining solid matters accidentally found in the milk and preventing splashing. Fig. 63 shows that the platform carries the receiver high enough to give the pipe a good fall towards the vats; and also that the pipe is made in sections, the first reaching a few inches beyond the partition, the second to the nearest vat, the third to the next vat, and so on. In distributing the milk the farthest vat is supplied first, then a section is removed and the next receives supply, the first vat coming last. This also has the advantage of preventing waste, because each of the joints is over a vessel, and any droppings are caught. Against the partition is the second receiver (15), of the same capacity as the first two, from which milk is run into it for filling railway cans when milk is to be sold (Fig. 66). The city suppliers are frequently glad to purchase large quantities from the factories to meet emergencies, and such a provision is important to facilitate speedy despatch, for by this simple means the cans can be filled as fast as milk comes down, and without hindering the first delivery for a moment. When the last can is filled the pipe can be put in place and the next discharge made into the vats. Such milk will be despatched by the south door opposite. The objects 16, 17, 19, and 20 will be described later. The pillars (18) support the main girders, which have here to carry a great weight in cheeses and shelves on the floor above. The shaft (21), bearing four pulleys (22), provides motion for grinding the curd, being connected with the engine by the belt (23), and this shaft is carried by journals bolted to the cross girders of the ceiling.

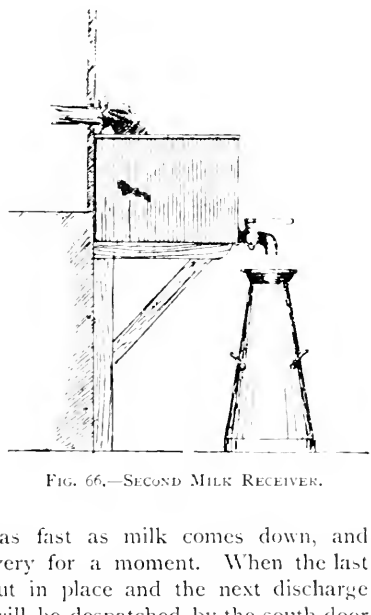


FIG. 66.—SECOND MILK RECEIVER.

The engine-room adjoins the making-room, and this nearness gives ready communication with the driver, while no trouble arises from dust or heat; for all the former, and most of the latter, is cut off by a partition (24), which enables the engine-room proper to be kept clean, and comparatively cool, the boiler being covered with a non-conducting material, and the engine discharging its waste steam into the boiler supply or the chimney. In Fig. 67 this is shown in section. The boiler is so set as to rise but a foot above the floor-level of the engine-room, and steps (25) lead down to its front. Immediately before it the floor is level, but further back slopes to a lower point under the coal gates (26), which give a draught to the fires and admit of a load of coals being discharged at once into the store, the blocks (27) stopping the cart-wheels at a safe point. The curbstones of the shute are supported by stays. The hot-water boiler (28) for heating the curing-room, with its flow-pipe 29, its return-pipe 30, and flue 31 leading to the main chimney, is placed in the best position for the purpose. By the door 32 ashes are removed, and a bench (33) is handy for repairing work, of which there is always much to be done in a factory.

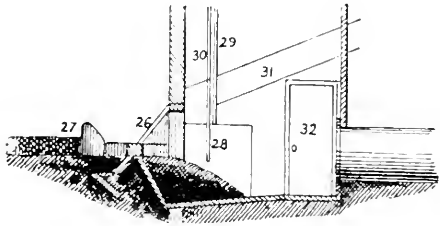


Fig. 67.—Boiler Front—Section.

The best steam-boiler for a dairy is the single-tube Cornish, Fig. 68, in which the fire-grate is set in the front part of the tube, the heat passing through and coming in contact with a considerable heating surface. Multitubular boilers give steam more quickly, but are scarcely so safe in most hands. From the dome rises the main pipe, which

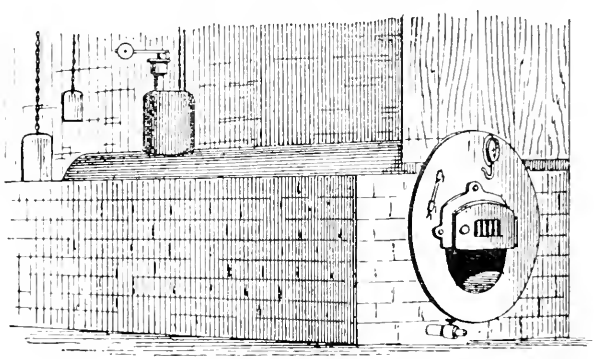


Fig. 68.—Cornish Boiler.

carries steam wherever it is wanted, as shown by the dotted lines, Fig. 62. Taps suitable for this, and for water, are shown in Fig. 69; where *a* is the best for all water use, and for steam wherever it is used free, as in heating vats and boiling water. The handle, which should occupy the position shown when the tap is closed, can be more easily and quickly turned down, and the supply more quickly cut off, than with the *wheel-valve b*,—which, however, is useful when accidental interference with a handle would be too great a risk. The pipe below, in *a*, is shown as connected with a vat distributing-pipe.

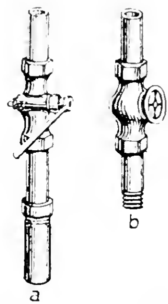


FIG. 69.—STEAM AND WATER TAPS.

The engine (35) may be of any reliable make, but that shown in Fig. 70 has special advantages, and in practice has proved the best with which we have had experience. Set upon a foundation of stone-work, its cylinder *b* and pump *d* are placed conveniently for attention, and in the full light; while the pulley *f*, being on the crank-shaft, is so high as to carry the belt *g* above the heads of passers-by. If desired, the main water-supply pump *i* can be worked by an eccentric *h* direct from it,—*i.e.*, if the well is near enough to allow the pump-pipe to reach it with sufficient directness. In other cases that pump must be separate, and worked by a belt and pulley. In the plan, Fig. 62, the engine is made to draw only for the boiler from the tank (36), while the pump (37) is fixed against the wall opposite, and made to draw from a well situated under the man-hole (38), this well being either supplied by its own spring, if one is found there, or from a distance by pipes. The pipe (— — ·· — — ·· — — in plan) should rise directly to a point from which the water can flow by gravitation to the tank over the butter-room, a fall of two inches sufficing for this. Rain water should be collected for use in the boiler, hence the tank 36; but for emergencies, a pipe should supply this with well water from the general distribution.

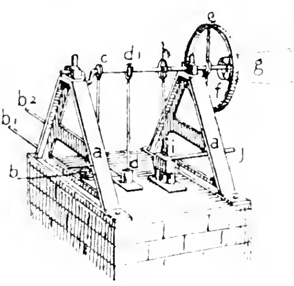


FIG. 70.—VERTICAL ENGINE.

A hot-water tank (20) is useful in the making-room, and two other such are found in the washing (39) and churning (45) rooms. These have one common form, though varying in size according to use; they are all kept strictly for clean hot water only. The heating is done by free steam, which, as generally distributed, creates a great noise, which is very inconvenient. This may be largely prevented by a simple device, shown in Fig. 71, and which consists of a cylinder *a* secured to the pipe *b* by a screw collar, and perforated as closely as is consistent with its strength over three-fourths of its circumference, the remainder being turned towards the tank side, where steam escaping would cause rapid wear of the timbers, and is therefore undesirable. On this cylinder is fastened a thick and coarse hemp bag *c*, through which the steam passes with but little sound, and causing but little ebullition as compared with that arising in an ordinary steam heater. In the illustration a piece of the cylinder is cut away showing the pipe, which ends at two inches above the bottom. Various devices have been brought out for this purpose; but this combines durability, cheapness, and effectiveness beyond any other known to us, the bags, though wearing out often, being easily replaced at trifling cost. An extra thickness of wood (*d*) lines the bottom of the tank, to receive the wear, and be replaced when worn nearly through, so leaving the real bottom in good condition. The capacity of this tank should be twenty gallons or more, according to demands, a considerable and ready supply of boiling water being required in the general cleaning-up of each day, as well as at other times.

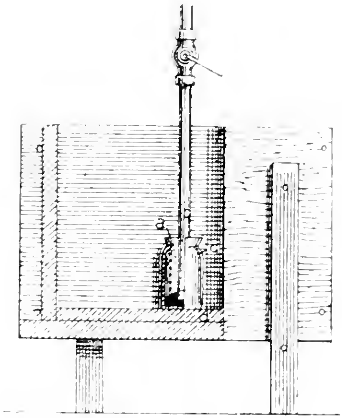


FIG. 71.—WATER HEATER.

In the washing room a larger tank (39) is found, capacity 40 gallons or more, and here all the utensils are removed for cleansing as soon as they are out of use. Wide racks (41), narrower shelves above them, and pegs on the east wall, provide for placing the appliances brought here, conveniently for the time being. A wall (42) protects the doorway from the wind, and a verandah supported by pillars gives a good drying and airing place, in any state of the weather, for the many cloths used in cheese-making.

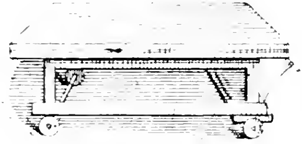


FIG. 72.—CHEESE TABLE.

The passage admits air, in conjunction with the south windows of the making-room, for the airing of the curd, and of the front part of the building generally after the day's work is over, and this is a very necessary provision. Along its walls are racks (43) on which the cleaned utensils are stored in readiness for use, and on hooks are hung the milk and whey conductors, with an inclination which allows them to drain and dry completely.

The store room is similarly provided with a rack (44) and shelves, a rack platform (44*a*) raised a foot from the floor on substantial supports to carry the salt stores, and here should be kept cloths, brushes, soaps, and other washing materials. A doorway into the passage gives ready access from the washing room, another—at the south end—from all other parts.

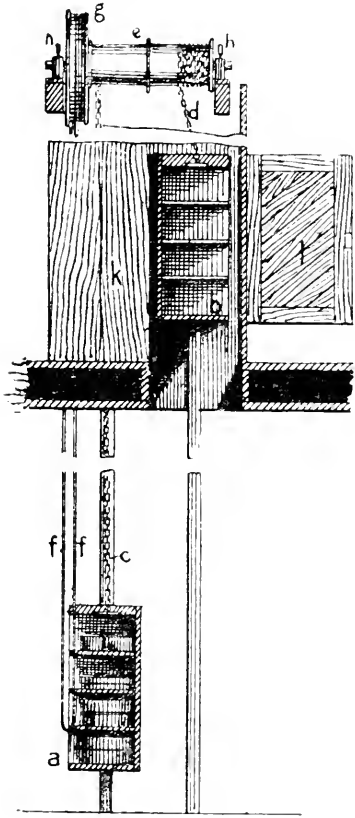


Fig. 73.—Factory Lift.

The churning and butter rooms and butter-cellar will be described under that manufacture. Over the two last, however, as in the farm dairy, is placed the water tank. A tank measuring 14 feet in length by 10 feet in width and 3 feet deep, would hold 2500 gallons with proper margin, and this would supply such a dairy as we have in mind for several days. By pipes (............) this is conveyed to all parts, and taps (×) are fixed wherever free water may be required for cooling or washing.

The press-room is arranged to allow of the cheeses, when made, being drawn on the table (19) to the presses (53); and the same table serves for bandaging, emptying, and conveyance to the lift (56) in the cool store. It is shown in Fig. 72. The lift, having to do more work than in the farm dairy, is, for economy's sake, made to carry heavier loads. It has two cages *a b* (Fig. 73), strongly built, and the strain of their loads is borne by an iron bracing which surrounds the woodwork as shown in Fig. 74. In each cage is a middle fixed shelf, and two others which rest upon side strips, and can be removed to allow of the largest cheeses being carried. They are raised by chains *c d*, which wind around a cylinder *e*, which in turn is caused to revolve by the endless rope *f* drawing on the flanged pulley *g*, the whole winding apparatus resting in metal bearings *h h* on strong beams. The rope pulley *g* is divided by a flange in the middle ; and one of the rope ends being secured in one of the divisions, and the other in the remaining one, so as to draw in opposite directions, the cylinder may be worked either way, raising one cage while the other is being lowered. The cylinder is made of slightly larger diameter at the middle flange than at the two ends, so causing the chains to wind closely by their tendency to work towards the lowest points. The cages are kept in place while in motion by rollers which travel against the guides *i i*, and are seen in Fig. 74. From the ground-floor ceiling upwards, the track and apparatus are enclosed by a partition *k* (which is cut away to the right to show the cage *b*), while a door at each side allows the cheeses to be removed, but is closed at all other times. The measurements for all purposes depend on the size, shape, and quantity of cheese to be carried, and no figures would be of general use. At the beginning of any season, when the old season's goods have been cleared, the labour of raising new goods will be at its greatest, the return cage descending empty until the first cured goods are ready, after which the loads will balance each other ; but at no time will it be difficult to raise a load of separate cheeses of cylindrical shape, or flat goods piled two deep, the weight being only with the cheeses (for the cages balance each other), and the leverage of the flanged wheel being as great as its chosen diameter may make it.

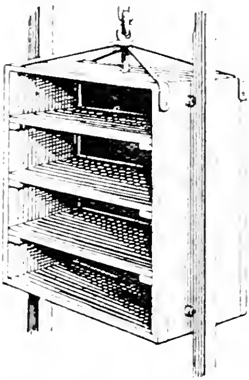


FIG. 74.—CAGE OF LIFT.

This room serves a double purpose—providing a convenient place for effecting sales of all cured goods, and for packing and despatching them. The scales (55) are used for weighing new cheeses as well as stocks sold, and furnish important figures for manufacturing and commercial guidance. Stairs (56) ascend to the curing-room, and are enclosed by a partition with doors ; and the vehicles which remove cheese to the rail are set against the doorway (57) to receive their loads. If a station is near, a railway track could be laid to the south front, and trucks loaded with milk or cheese in the most convenient manner.

The whey-room may be furnished as in the farm dairy with tanks of equal capacity with the vats (13), but here the arrangements are for mechanical separation, the tank (58) holding from half to two-thirds of the whole quantity of whey and supplying it to the separator (59), which is driven from a pulley of large diameter on the shaft (21) by an intermediate motion (60). As the top of the tank is nearly level with the floor of the making-room, and the separator feeding pipe proceeds from its lowest point and must have an inch of fall in its length, it is evident that the floor must be lower than that of the making-room by the depth of the tank, the fall of the pipe, and the height of the separator and fittings, combined. A platform (61) is convenient for cleaning the tank, and steps (62) lead to the floor. A strong railing should be placed here. The creaming of whey will be dealt with under butter-making.

The floors of these ground-floor rooms are made to fall in the direction of the arrows, and where two arrows are shown on one floor it inclines towards a common point, or a gutter shown by a dotted line. There is no trap within the building ; shallow open gutters and wall pipes carry all waters to the drain wells, which are covered with gratings, because they lie in the line of movement. The head of one line of drains is at 63, where is a ventilating pipe. This branch proceeds eastward, with inspection openings 64, 65, and 66, getting drainage at 67 from the butter and press rooms, at 70 from the cool store, and at 72 from the whey-room,—the latter is the lowest point of the system, being five feet below ground level. This marks the necessity for a good fall of the land in some convenient direction, and shows that man-holes, with cover plates, must be provided for inspection purposes at 68, 69, 71, 73, 74, and 75, at a depth varying from four feet to six feet in that distance. At the back of the washing-room the other branch begins at well 76, also with a ventilating pipe, and gathers the washings of the coal store at 77, which also serves for inspecting the section above it ; going west and south it collects from 80, and joins the other branch at inspection-opening 82, thence going forward to a tank or discharge. The inspection holes of this branch, 78, 79, and 81, are all more or less beyond easy reach from the surface because of the rising roadway and their rapid fall. But it must be remembered hat whatever the drainage system may be, it cannot be effective f it does not meet the need at all points; and while the plan given is purely an imaginary one, it exactly illustrates what in one form or another has to be faced in any case where a true economy of building and management is demanded. Moreover, the very difficulty which makes such a system of drainage necessary, and so more than usually expensive in the first outlay, makes the economy of that outlay the greater, as saving the cost of all possible openings of the ground to reach drains in case of stoppage.

There is probably no item in the construction described which

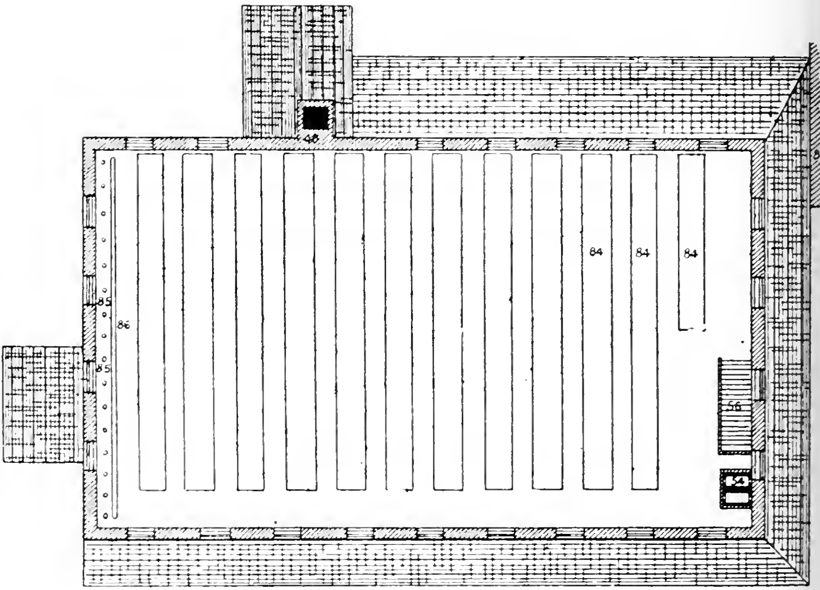


FIG. 75.—FACTORY CURING-ROOM—PLAN.

most factory owners would be so inclined to neglect in view of its apparent unprofitableness as drainage, and none is more important. It does not make money, but it prevents the loss of it; and the prospective builder is urged to secure himself from such loss at the outset, when the cost of laying down such a system is lightest, because the work is then most easily done.

The windows on the east and south sides of the building are shaded by a projecting roof, which is particularly desirable to the latter, and useful on both; and the manager's dwelling will be well placed at 83, where he may enjoy the greatest privacy practicable in such a business, with nearness and economy of time.

The curing-room, Fig. 75, covers the whole building with the exception of the washing-room; and may be provided with shelves (84) to hold over three months' stocks, from the aggregate of four 400-gallon vats filled daily, with the floor beneath them besides for an emergency. Hot water is recommended as well-nigh indispensable for heating this room. No present stove arrangements at the same cost will give equal satisfaction in working. In all other respects the details are as in the farm dairy.

These designs are offered, not to be copied unless the conditions are entirely suitable, but to give suggestions in a practical form which may be adapted to meet such conditions as exist on the site chosen as the best within the area from which milk is to be drawn. A set of conditions better than those supposed to be at command here it would probably be hard to find. But the dairyer will have no difficulty, if he has a good site at all, in bringing his plans to suit the location, aspect, water supply, drainage, &c., and to make the best of his case. The next two chapters will still further illustrate the principles kept steadily in view in this one, and the remainder of the furniture of the cheese-making department will also be given where the use of each item can be best described.

The cost of such buildings as these depends so much upon local supplies and possibilities as to make it very uncertain at best; and in preference to quoting experience and calculations, we advise the intending factory builder first to carefully resolve upon his system of manufacture; the extent, immediate and future, of his undertaking; the site and conditions; the most economical and convenient general arrangement for the work; and then to sketch his ideal, and, with all details on which he has determined, to submit his facts and designs to one or two reliable contractors and obtain their estimates, with the understanding that the construction is to be of the soundest and best.

The reader will now be aware, if he has not previously been, that there is nothing in the construction and furnishing of a factory to prevent any success possible in a farm dairy if the milk and skill in handling it are equal.

CHAPTER XI.

THE CHEDDAR SYSTEM IN PRACTICE.

In describing the manufacture of Cheddar cheese, it will be convenient to suppose that the dairy and conditions are such as have been already recommended; adding, as occasion arises, directions suited to other conditions under which the dairyer may have to labour. We will take as a basis the matter of Chapter VIII.

The receipt of milk in a farm dairy is a very simple matter. The conductor being placed in position, with a bag of strainer cloth fastened to its end, the supplies from the cow-house can be poured in as fast as they arrive. If a sample of the milk is required, it should be taken as soon as the delivery is completed, with a previous thorough stirring.

In the factory the work includes the examination of milk and cans, and the weighing or measuring, sampling, and booking of the former. The person in charge of the laboratory should inspect all supplies, and none should be discharged into the receiving-vessel until he has passed it as fit for the purposes of the business.

The evening supply requires special management, in view of the state of the air and the morning's needs. The aim of the dairyer being to secure as much ripeness as is consistent with entire safety, it is necessary to determine on a treatment by considering the temperature of the milk on arrival, and the probabilities of the night. The use of a capillary cooler is admissible, for even if the water is unnecessary, the passage of the milk over the fluted surface will aërate it, and reduce its temperature nearer to that of the air. It can be hung by a wooden frame (*a*, Fig. 76), and supplied with water by a rubber pipe (*b*), with another (*c*) to carry off the overflow. This is better in thundery weathery than any slower cooling; but excellent results may generally be obtained by running

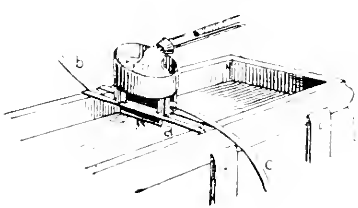


FIG. 76.—COOLER OVER VAT.

cold water into the space between the cases of the vat, freely at first, until the heat is reduced from 65° F. to 75° F. (according to the weather), and afterwards more slowly, with frequent stirring.

In order to thorough aëration and the prevention of cream rising, the stirring should be kept up all night, but in such case only so far as will effect our purpose. A movement through it once in two minutes

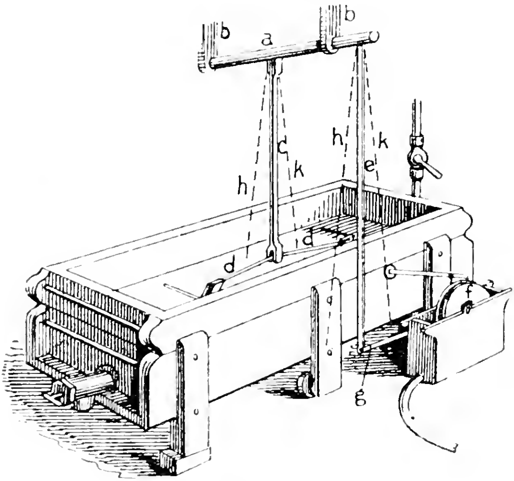


FIG. 77.—AUSTIN AGITATOR.

will serve for this, and can be provided by a mechanical device known as Austin's agitator, after its American inventor. There is no British patent on this, and it can be made by any intelligent craftsman. It consists, as best made (Fig. 77), of a wooden beam two inches in diameter, borne by hangers (*b b*) secured to the ceiling, and carrying, at a point directly over the middle of the vat, a light ash rod (*c*) 1½-inch wide by ½-inch thick, excepting at its extremities, where the thickness is equal to its width, to allow, at the upper end, of a proper joint with the beam, and, at the lower end, of the attachment of the floats (*d d*), which is done by a bolt and thumb-screw. The floats are made as in Fig. 78, and when in use have the upper

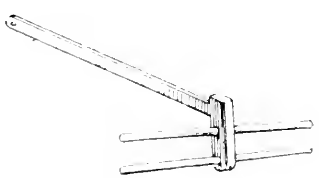


FIG. 78.—FLOAT.

cross-rod resting on the surface of the milk, and the lower one at three inches below. From the end of the beam a second rod (*e*) hangs to the level of the crank of a water-wheel (f), to which it is attached by a similar rod (g), the attachment being made with bolts and thumb-screws as before, and easily effected. The wheel may be made of zinc,

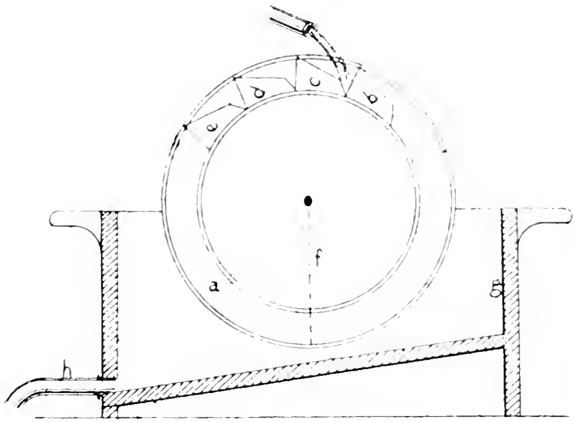


FIG. 79.—WATER WHEEL—FIRST POSITION.

with its sides projecting beyond its circumference, as seen in Fig. 79. Between these flanges (a) the buckets (b, c, d, and e) are so fixed that when the wheel is at rest and its crank at the lowest point (dotted line), the first of them (b) is in a position to receive water from the source provided. By the time it is full, the wheel will have moved forward, so as to bring the bucket c under the stream, as in Fig. 80, and d and e follow in turn. The crank has then been raised to the position of the dotted line f_3, and no further resistance being offered the wheel turns over, emptying its buckets, and returning to its original position. It will be seen that the milk resists this motion by way of the floats, and this, with the weight of the crank and rod (g, Fig. 77), must be overcome by the slightly greater weight of the water in the

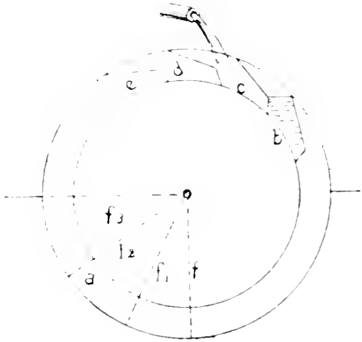


FIG. 80.—WATER WHEEL—SECOND POSITION.

buckets when full. To regulate this accurately, a balance-weight of lead may be secured to the flange opposite the crank, when needed. The wheel-axle rests in bearings on the edges of a box (*g*, Fig. 79), the bottom of which slopes towards the outlet *h*, from which a pipe conducts the water to a tank. As the crank rises it thrusts the rod *e* (Fig. 77) towards the position *h*, and the floats follow; then by the turning of the wheel they are carried to the opposite extreme of the motion limits (dotted line *k*), and the length of the cranks and floats are calculated to allow of the latter covering between them nearly the whole length of the vat at every such turning. These measurements must therefore be fixed according to the length of the vat, and the float-rods to its width, allowing two or three inches only of margin around their track. The elasticity of the ash rods gives a gentler motion, and longer continued, than stiffer ones would do, for they bend in following the motion; and after the wheel has come to rest, float to and fro a few times with decreasing distances—being helped by the waves of milk which they have caused—before their motion ceases. This action should occur at intervals of two minutes, and the stream of water regulated accordingly. If the contents of two or more vats are agitated from one wheel the size of the latter must be increased, so that the water-weight may be sufficient to overcome the greater resistance.

The water may be brought from the vat side, by the pipe *g* (Fig. 39) being lifted and fixed at a proper height for the purpose, so that the one supply may serve for cooling and motion; or it may come direct from a branch of the main; but in any case a very small stream will suffice, from one-eighth inch with one vat, to three-eighths inch with four vats being ample.

This apparatus, by preventing the rising of cream, prevents also the sealing down of odours, which would otherwise happen with warm milk slowly cooled without motion, and in the morning the better condition of the milk is noticeable in comparison with the milk unstirred. Moreover, we have never seen loss of fat so fully avoided by skill in heating and stirring in cream which has risen, as by the use of this device for its prevention. The floats should be daily immersed for some minutes in boiling-water after washing, and longer after the least suspicion of a taint in the previous making, and the parts overhanging the milk should also be kept carefully clean. The wheel box may be made removable for convenience.

The agitator, as used in the farm dairy, with water round the milk (supplied after the first half-hour only at the rate necessary for the motion), will answer admirably as a rule; and if the capillary cooler is at any time required, it can be used in addition to the ordinary cooling, and the water used in it economised by requiring it only to reduce the milk to a temperature at which the vat water can be trusted to complete the work. The agitator can be used in the round vat, but not so well as in the oblong vessel.

Where no provision for cooling and stirring is made, the separation of the milk in risky weather will greatly increase security from over-ripening. It may be partly or wholly set in shallow vessels, and frequently stirred until bedtime, but this is not so good for the cheese as the other arrangement. The milk should be brought from the farm to the factory at a temperature of 60° F.,—not higher when the air temperature is the same, and but little lower at any time. In such case the water need not be used with the vats, but served directly to the wheel, and the floats of each vat set in motion as soon as sufficient milk is in to allow them to clear the bottom.

The temperature of the night's milk will largely determine the progress of ripening. It is not possible to give figures always and everywhere applicable, because changes of weather may occur, and fermentation be helped or hindered by unsuspected causes. With the care of the milk earlier demanded, the following figures should be of practical value, as showing the temperature to which milk may be reduced during the night for safety :—

Air.	Milk.
70° Fahr.	50° Fahr.
65° "	53° "
60° "	57° "
55° "	60° "
50° "	63° "

With these it should be remembered that the larger the body of milk the longer will it take to reduce its temperature, and the means used must be estimated accordingly.

The value of a free passage of pure and cool air at this time is apparent; but the air within the dairy, if pure, is preferable to any supply, however cool, coming from contact with any fermenting matter or objectionable odours. This should be carefully considered in connection with the direction of the wind, and its possible dangers, when determining on leaving the windows open or shut. The use of perforated zinc will not prevent mischief. Millions of germs could float through the finest perforations known to the trade, a hundred abreast, and with room to spare, and those borne by the air from manure heaps, &c., will not be hindered in any serious proportion.

The state of the milk and of the weather should be the inquiries of the early morning, and calculations based on the facts made for the day's management. Too much can hardly be said in favour of this, for the leaving of these matters until the milk is coming in gives too little time for thought about it. Ten minutes' consideration of the conditions existing at or before six A.M. saves an hour's thinking at a later time, and enables the dairyer to go about his work with a clear idea of his bearings all day. If, for instance, he finds that the milk does not show the degree of ripeness which the air temperature at night and morning, and its own, would warrant him in expecting, he will know that something is amiss ; possibly some ferments checking the L.A.F., or a deficiency of the latter in number and influence. He will prove his first fact by litmus. If this confirms the backwardness, he will further test with rennet; and if this causes coagulation in a time proportionate to the apparent state of the milk, then he will use means to encourage the L.A.F., heat being best ; and a few degrees at an early hour being better than a considerable increase later, because the risks are less. The fermentation may advance more rapidly than he expects, and it may be necessary to check it by a reduction of temperature. This is more easily done when the heating has been slight, and the time for cooling is ample, than under the opposite conditions. If the rennet gives quick coagulation, this—with the acid tests—will show that some ferments are at work, not only checking the L.A.F., but hastening the casein towards curding at an unsuspected rate ; and he will check them by cooling until nearer to the time for the rennet, and then with a rising temperature help the L.A.F. by sour whey in a suitable quantity. To introduce the whey at once would unduly hasten coagulation, and make more trouble than it cured. This by way of showing how important it is to "take time by the forelock," and have leisure for contingencies. If, on the other hand, all is well, then the dairyer is happier all day for knowing it, and pursues his duties with a contented mind.

If the cream has not been hindered from rising, then what has risen must be removed before any new milk is allowed to mix with it ; but if the milk has been set in pans, it may be kept until the morning's supply is all in the vat, and heated, or, if that is not suitable, poured through a strainer set under the end of the conductor, so mixing with the warm milk as it enters the vat. The cream when skimmed is often returned in this way, and if it is well mixed in, and the milk stirred gently but constantly afterwards, it may be largely secured in the curd. But whatever method is followed, the stirring is more important than the heating ; and if it is neglected, the cream will be found on the surface of the curd, and finally pass off in the whey. We have known makers turn a creamy curd over, to "get the cream in," they said ; but it invariably turned up in the whey, generally showing itself during the second heating as the greasy scum, "Slut's butter"; or increasing the whiteness of the whey. Any heating done with the cream will affect the ripening, and must be remembered in calculating for that.

As the time for the last milk delivery is approaching, the dairyer should have ready a supply of boiling water, his implements and materials at hand, and his calculations made, so far as they can be, so that when the actual quantity of mixed milk is known he may in a few moments complete his figures and put them into practice. He will find a little tray useful to hang over the side of the vat and carry his measures and other aids.

He must now have a definite estimate of the influence of existing and prospective conditions, and of the relations of the ripeness, heat, and rennet to each other proper to the case.

Ripeness.—The standard of ripeness for the Cheddar system is indicated by litmus as at E (Colour-chart), provided, of course, that the fermentation is of the proper kinds, and balanced as usual. As this is exceeded, or fallen short of, the results already described follow in proper turn; and no other is at present known at which so fine goods can be made with any other combination of temperature and rennet. Other British systems need other standards for their best results. This one is consistent with the aims and practices of the Cheddar system, the practices exercising a great influence on the progress of after-fermentation, and therefore on the effect in general. Now, the standard being fixed, we may consider the various possibilities which arise in experience.

(*a.*) When the night's milk is sufficiently advanced to ripen the whole, as mixed at the temperature suitable for coagulation.—If the morning's milk comes in at 92° F. and upwards, the night's milk needs only to be at the standard for the mixed milks; for although the new supply is so far from ripe on arrival, its mingling with so large a proportion of ripened material (nearly its own bulk), and the influence of its own temperature, will give ripeness by the time the preparations for curding are finished. If the morning's milk falls short of the temperature named, a proportionately advanced state of fermentation in the night's milk is, of course, necessary to the same result in mixing.

(*b.*) When the mixed milks fall short of that point.—This may arise from—(*aa*) the temperature of the new milk being too low, because of the coldness of the air or the distance it has been carried, so that although the night's milk is as far advanced as usual, the addition of the morning's milk does not produce the usual result of mixing; or (*bb*), when the night's milk itself falls short of the necessary stage to effect ripeness with a new milk of favourable temperature. When the dairyer has reason to expect the former, he should increase the fermentation in the night's milk beyond the ordinary stage by warming it proportionately before the new milk is in. By observation he can judge at what temperature the milk will arrive from any point in a given air temperature; and such facts should be found in his note-book, so that he may have his night's milk at such a temperature by the arrival of the new as to ensure the whole being within a few degrees of the coagulating temperature when the supply is complete; and in such cases as that now considered, he may commence his heating at a time suitable to his need. But this time will be short, because, however cold the weather may be, he will aim at a stage of ripeness in the night's milk in keeping therewith, and the occasional failure of the new milk temperature will be compensated for by a very little extension of the time in heating.

But, owing to a proper caution, he will generally come under case *bb*, and find it necessary to adopt one of the plans earlier described for bringing up the whole milk to the ripe point. These are—(*c*) waiting on the milk at the coagulation temperature, which must not exceed a few minutes, or the mass will lose too much heat; (*d*) heating to a higher temperature, and cooling back to the curding temperature by the time ripeness is reached; and (*e*) the use of a ripening material. Only the two last need attention.

(*d*.) This is a difficult method to explain in detail, because no figures can be relied upon to bring the ripeness and proper temperature to coincide exactly; and we can only advise that, where this plan is followed, the dairyer should err on the side of safety. With this in view, the following table is given, in which three leading air-temperatures are given, and those to which the milk can be raised, the heating and cooling not to occupy more than two hours, and probably much less. Here much depends, as to time, on the supply and application of cooling water, air-temperature, quantity of milk, and stirring, so that it is useless to attempt definiteness. The letters under the second heading refer to the Colour-chart, and show the state of the mixed milk at the outset of heating:—

Air.			Ripening.		
	A	B	C	D	E
65° F.	95° F.	93° F.	90° F.	88° F.	86° F.
60° F.	96° F.	94° F.	91° F.	89° F.	87° F.
55° F.	97° F.	95° F.	92° F.	90° F.	88° F.

The intervals between these, and the many variations in application, which experience will suggest, we must leave to the dairyer, for they would fill a book if exhaustively worked out; but we recommend that if it be desired to commence heating before the milks are mixed, the aim should be rather to bring the curding temperature a little before ripeness than behind it. The chief difficulty is the cooling, which uses much water, and takes much more time than the heating; but if this method is used, this must be accepted as a necessity, and faithfully carried out. The high temperatures at which some who heat for ripening add their rennet are not consistent with the Cheddar system.

(*e.*) The use of a ripener admits of much more definite advice, for experience with whey under proper conditions shows that it can be prescribed with great certainty. We will assume three stages of acid fermentation as shown by litmus, those shown at N, O, and P in the Colour-chart; and, making allowance for the temperature as hereafter given, provide the following table for general guidance:—

Whey. Stages of Fermentation.	Milk. Stages of Fermentation.				
	A	B	C	D	
N	20	12	7	4	Imperial pints per 100 galls.
O	17	10	6	3	
P	14	8	4	2	

The lower degrees of acidity in whey, and those which come between N, O, and P, and between the stages in milk represented by the letters A to E (Colour-plate), can easily be calculated, and are given in the tables published separately in the cheese-making records. The proportions do not increase in an equal ratio at each stage, for it is found that while three pints (O) will procure ripeness in 100 galls. at D, twelve pints will not do the same in the same quantity at A as one might expect, but seventeen pints are necessary; for it is not merely to add a given quantity of acid to the milk to make up a deficiency, but to encourage, by favouring conditions, the ferments already present (which at A have done little or nothing), and furnish more helpers, and these must either have time or numbers to enable them to do what is wanted. Therefore at D the rapidly increasing and active ferments need but little help compared with those at stage A, and yet are helped more in proportion; and experience shows that less whey will serve than the proportions which might be calculated according to the needs of the earlier stages. These figures answer also with creamed milk.

When ought the whey to be added to the milk? The quantities given in the preceding table are intended to be put in only so long before the rennet as is necessary to stir it well in, say from three to five minutes. Its effects will not exhibit themselves immediately in a ripeness shade of litmus,—the work will be going on while the curd is forming; but practice proves that a properly calculated measure of whey brings the result at the correct time. If added earlier, a proportionately less quantity must be used.

Temperature.—This is fixed as low as is consistent with the ripeness and rennet standards; and it is found that with higher temperatures, whether with equal or less ripeness and rennet, the cheese is neither so fine, nor keeps so well. This, in view of the influence of heat on ferment life, is quite reasonable with equal ripeness at the outset; and with less, the hardening effect of more rapid contraction when heat is out of proportion to the other factors in the reckoning, gives a lack of the mellowness which is one of the glories of Cheddar cheese. The temperature varies with that of the air, as all such should do in dairying. The temperature of the coagulum should not fall below 78° F. in warm, or 80° F. in cold, weather, or the contraction of the curd and separation of whey will be too slow.

The quantity of milk must also rule, for the smaller this is the more readily does it lose its heat. The following table will usually meet the case:—

Air Temperature.	Milk.		
	2 o galls. and upwards.	100 galls.	50 galls.
65° F.	80° F.	81° F.	82° F.
60° F.	82° F.	83° F.	84° F.
55° F.	84° F.	85° F.	86° F.

Rennet.—The quantity of rennet must be sufficient with milk ripeness and a proper temperature to produce coagulation in twenty minutes, and a curd of the proper firmness in thrice that time, or an hour; and it is found that as that is departed from, whatever other advantages are gained, the mildness, long-keeping quality, and fine flavour are lost in proportion. Here is that balance of influences which lays a firm foundation upon the solid rock-bed of a sound milk. A milk which, under the ordinary treatment, makes a weak curd, will need a higher temperature and standard of ripeness,—a degree or two of the former, and a corresponding increase of the latter, being usually sufficient. The ripening is best done in such a case by whey; if by heating, it is slower, and more uncertain than with normal milks.

The order in which the day's work up to this point proceeds may be conveniently summarised for reference as follows, viz.:—

(*a.*) Examination of milk and weather prospects in early morning; calculations made as to immediate needs, and generally for the day; hot water got ready, and all early helps brought within convenient reach.

(*b.*) If cream has risen on night's milk, this skimmed, heated, and returned, with a few minutes' vigorous stirring, and a gentle after-treatment maintained to prevent any second rising.

(*c.*) Agitator, if used, removed before any heating of milk in vat.

(*d.*) If ripeness induced by heating, may be commenced at any suitable time, according to extent to which it is to be carried.

(*e.*) If no other heating than to obtain renneting temperature, this commenced as soon as last milk has arrived, when the final calculations for coagulation are made, and the work as quickly completed as it may properly be. If heating by old system, a proportion warmed to some suitable point not exceeding 130° F., being stirred meanwhile, and returned to the vat. A degree or two will be lost in returning, and to secure against a failure this should be allowed for according to experience. Example—120 gallons milk at 78° F.; temperature desired, 82° F.—difference, 4° F.; 10 gallons (one-twelfth of whole) taken for heating; difference, $4° \times 12 = 48$ (additional heat required) + 78° (present heat) + 3° (allowance for loss) = 129° F., which will bring the whole body of milk to 82° F. Sometimes the night's milk may be warmed by way of earlier assisting fermentation, but whenever it is near to ripeness it is better to use morning's milk.

(*f.*) If ripener used, should be estimated, with margin for contingencies, and placed with pint measure and bowl close to vat.

(*g.*) Quantity of milk gauged, entered on record, and proportion of night's milk to whole noted.

(*h.*) Rennet estimated by its strength, and the total quantity of milk, to procure coagulation in twenty minutes. If dry rennet, put it into a bowl of clean cold water, and completely dissolve before use. This may be helped by gentle crushing and stirring, after two or three minutes' soaking. If liquid, should be ready in glass measure—Fig. 81—divided for fluid ounces.

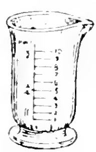


Fig. 81
Measure Glass.

(*i.*) If colour is used, it should first be stirred in before anything else is added.

(*j.*) Next the whey, or other ripener, if such is used, the quantity being fixed according to the then state of the milk as shown by the litmus or other test. This stirred in thoroughly; and

(*k.*) The rennet added, with similar stirring for three to five minutes, according to bulk of milk.

(*l.*) Stirring should be continued gently until coagulation takes place; and after ten minutes from the addition of rennet, it should be confined to the upper part of the milk, and gradually decreased. In a round vat the tendency of the milk to swing around, whirlpool fashion, must be avoided; for it will continue much longer in motion than in any irregular currents, and is difficult to arrest when it is necessary to bring the milk to stillness. A motion across the vat in various directions is more effectual in keeping the globules from rising, and can be stopped in a few seconds.

(*m.*) The curding test should be used, with frequent dipping of the glass, and the exact time from the addition of rennet to coagulation made note of, and multiplied by three to ascertain the time at which the curd should be firm enough for the next process. If the time is more or less than twenty minutes, the work will proceed with proportionately greater or lesser speed throughout. This test is a good pointer to the whole after-management.

(*n.*) The vat should then be covered up, as in Fig. 38 (round vat). The small sizes of the oblong vat can have an entire cover, with a hinged flap; but in the larger, this would be too heavy and awkward. Excepting with high air temperatures, seldom known, no mere cheese cloth covering is sufficient. But such is often used, with the effect of a curd tender at the colder surface, and an uneven working under manipulation, and in final result. Here is one of the points at which

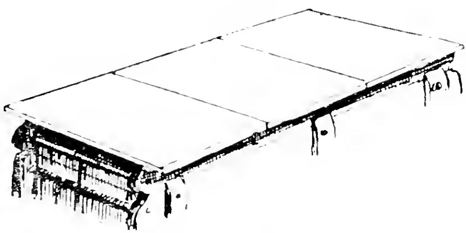


FIG. 82.—OBLONG VAT (COVERED).

waste arises, for no skill can prevent the weaker part from being broken unduly, while the firmer part is being treated in accordance with its condition. It is a choice between wasting some of the uppermost two or three inches of curd; or handling the rest so as inevitably to procure too great hardness, and a final necessity for rapid manipulation, with waste; or imperfect whey separation. Of the two evils the waste of the tender curd may well be chosen; but the need of such a choice ought to be avoided.

(*o.*) During the interval of forty minutes the implements, &c., used up to this should be removed, and such as will be used until whey separation is completed brought into their place.

The time calculation must not be entirely trusted, but checked by an examination of the curd, at ten minutes before the time of expected readiness; for fermentation occasionally makes unexpected advance, and the work must proceed when the curd is ready in any case. The fact that it is firm enough before it is due by calculation, points plainly to a need of quicker handling; and to suffer a delay under such conditions, is to make waste almost unavoidable by the later need of still greater hurry. If, on the other hand, the curd is not firm enough, that condition must be waited for. Generally it will be ready at the time calculated upon.

The condition of the curd is generally tested by putting the finger into it, and then bending and lifting it out again; if the curd clears from it, sufficient firmness is argued; if particles remain on the finger, it is supposed to prove it too weak for handling. But this test is unreliable, as experience has proved; and the reason for its failure is found mainly in the fact that curd has a grain, and splits clearly in one direction, and not in another. The stirring after renneting causes currents, unseen and very irregular, to form, and in these the viscous casein takes direction. They are still moving, though very slowly, when curding takes place, and this fixes them just in the positions they occupy at that time. The fact of the grain may be proved by drawing the finger through the curd in different ways, as in Fig. 83, when it will be found that at any point the curd will break with a jagged fracture in all but one direction. It by no means follows that the clean fracture will follow one direct track,—it very seldom does so for more than a few inches, showing the many varied courses of the currents. Now, while the finger will carry no curd in the line of the clean fracture for some time before the curd is firm enough for treatment, it will do so from all other directions, and for some time beyond the firm point.

Fig 83.
Grain of Curd.

A better test is by pressing the back of the finger upon the surface (Fig. 84) and estimating the resistance, which is soon learned under a teacher, or—with patience—by observation. It is not at present possible to describe the firmness by any standard. The importance of a curd uniform at all points will be seen, in view of this test being required to judge of the time proper for next duty.

Fig. 84.
Testing Curd for Firmness.

Whey Separation.—In the Cheddar system this is effected by a series of manipulations which have a direct relation to each other, and a direct and estimated influence on the character of the cheese; and in whatever this differs from the products of other hard-curd systems, it does so mainly because of the treatment which is now to be described. Several other systems share with it the management up to this point; and so closely alike are they, that the differences cannot account for those observed in results. Here the Cheddar system goes off on a track of its own; and if we are to obtain the peculiar qualities of its product, we must follow it fully in principle, and with no more variations in practice than will tend to an equal or greater value in the same direction.

(*a*.) The curd is first cut into squares of six to eight inches, by a knife which may be a single blade as *a* (Fig. 85) for use in farm-dairy vats, or double-bladed as *b* for factory vats, and the blade as long as the greatest curd-depth in either. The distance apart of the blades in *b* must depend on the width of the vat, and be so calculated that the knife may make the cuttings at its own width, and leave a similar width on either hand against the sides of the vat. This may be done by a knife cutting, as at *a* (Fig. 86),—7.2 inches in a vat three feet wide. The cross cutting may be also made so as to distribute the length between them as evenly as may be, and a single blade can be used to cut away the curd from the sloping sides, where the double knife would leave an angle of curd uncut either at the side or bottom. This cutting is purely for convenience and economy, because the subsequent methods could not be employed to the best advantage without it. It must be so done as to give the greatest practical uniformity in the size of the blocks. In a round vat the

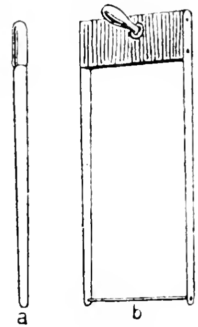


FIG. 85.—CURD KNIVES.

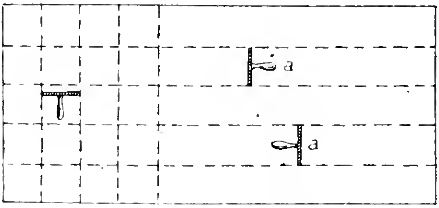


FIG. 86.—CURD CUTTING (OBLONG VAT).

cutting, if done in squares, as is usual, leaves some parts much smaller than the rest; but if cut as in Fig. 87 much greater uniformity is secured.

(*b*.) The next business is to reduce these blocks to smaller size, both by cutting and splitting, so as to prepare them for the third form of treatment; and this is best done by the ancient skimmer (Fig. 88), which consists of a perforated concave blade of a diameter equal to the width of the squares of curd as usually cut, and having a handle 12 to 18 inches long, according to the depth of curd provided for in the vat, so that it may reach the bottom without carrying the hand under the curd surface. It is sunk into the curd edgewise, and so curved to the left as to come under a block, and then brought up flatwise, so raising and pressing the curd until it splits into two or three parts (Fig. 89.), when the skimmer is brought out edgewise, and the action repeated with other blocks. The course of the movement is shown in Fig. 90. This action is brought to bear on every block, the skimmer entering at half the width of one block, and so dividing it on its way to raise the next one to the left. The movement must be slow and steady, so avoiding the waste which always follows haste or clumsiness; and uniformity in the size of curd, as divided, must be the maker's constant aim. This latter is not attainable in the strict sense, especially in the first round of work, for the curd splits with an irregularity dependent on its grain; but at the second, or third—if such be necessary, the regularity in size becomes striking with a skilful handling; for any fragments which are larger than they should be are cut through with the skimmer in its downward movement, while such as are too small are avoided—being only subjected to the pressure of the upward movement.

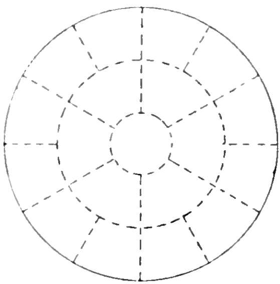


FIG. 87.
CURD CUTTING (ROUND VAT).

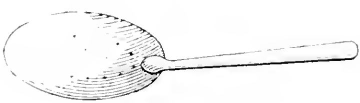


FIG. 88.—SKIMMER.

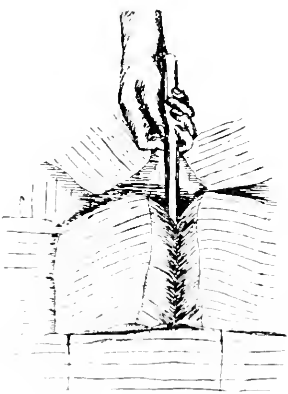


FIG. 89.—CURD SPLITTING.

With the first round, if the curd is deep it may be treated to half its depth, and the lower-half lifted up through the upper on the second round, thus sending the upper part to the lower position. In any case the tendency will be to reverse the relations of the upper and lower parts of the curd, and to expose any larger fragments for special attention, whether of cutting or splitting, as may best fit with the maker's purpose. Before the skimmer is removed all fragments should be of three to four inches across ; and this will be generally reached by two rounds of working, when the whole depth of curd is taken at once in the first round, or in three rounds when it is taken at twice in the first breaking. By the time the proper size is gained the curd lumps will be floating in a quantity of clear whey, and occupy less space in proportion to the separated whey than would have been the case if cutting only had been practised. This is due to the pressure which has been brought to bear upon it, either of the skimmer direct, or of one lump against another in the upward motion, this greatly assisting the natural contraction of the curd and the expulsion of the whey.

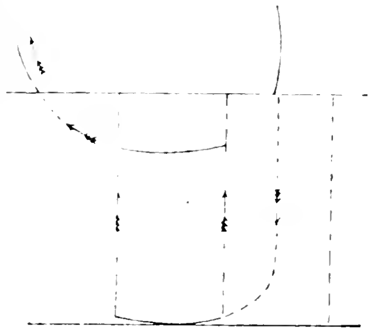


FIG. 90.—DIAGRAM OF SKIMMER BREAKING.

Here also the cutting has been a convenience, because no tool has been yet devised to do the work equally well without cutting ; but the splitting has done its share of the work of division, and is a distinct step in the direction of the later manipulation peculiar to the system. From this point cutting ceases until the curd has reached a point where it is a matter of indifference.

(*c*.) The splitting of the curd is now carried on by an implement called a "breaker," the best form of which is the shovel-breaker (Fig. 91),

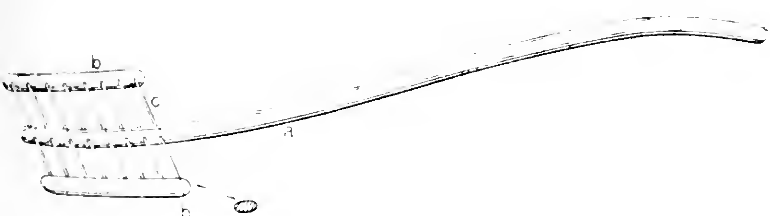


FIG. 91.—CHEDDAR CURD BREAKER.

which can be used in various ways to meet the changing needs of the curd, and more perfectly controlled in its movements than any other implement yet introduced for the purpose. It consists of a curved ash handle *a* varying from 4 ft. 6 in. to 6 ft. in length, and side pieces *b b* from 4½ to 5 inches distant from the handle, and these with round brass wires *c c* form a rack, the size being according to that of the vat in which it is to be used. The handle should be from $\frac{7}{8}$ to 1 inch thick in its upper part, and narrow to from $\frac{3}{4}$ to $\frac{7}{8}$ inches at the lower part, and be of $1\frac{1}{8}$ inch to $1\frac{1}{2}$ inch in width throughout. The side pieces should be $\frac{5}{8}$ to $\frac{3}{4}$ inch in thickness, of the same width as the handle, and 12 to 15 inches long. The wires may vary from $\frac{1}{8}$ to $\frac{3}{16}$ inch diameter, and be set from 1 inch to $1\frac{1}{4}$ inch apart. The highest and lowest wires must be long enough to rivet the whole firmly together, those coming between only passing two-thirds through the side pieces. All parts should be rounded, and as smooth as possible. This tool is calculated to effect the purpose of the system perfectly ; it causes the curd to split in its own grain, and so reduces its size ; at the same time it presses upon it, and assists the natural contraction and expulsion of the whey, while —with proper care—its smooth surfaces prevent waste.

The aim of the dairyer now is to reduce the size of the curd until it has reached that of large peas, about $\frac{3}{16}$ inch through, and to carry on this work so as to continually expose fresh surfaces. If it is not done quickly enough the curd gets hard, and a very vigorous effort has to be made to complete the breaking, with inevitable waste. Beginners generally err in this respect in their anxiety to avoid that whiteness of the whey, which comes of too fast breaking, and shows a loss of fine curd in suspension, with fat globules. In either case waste is the result ; and therefore, of the two evils, too fast is better than too slow; for with the latter there is also loss of time, and the danger of being unable to break the curd fine enough at all, in which case after-mischief will arise. Of this more in its place. For the same reason the breaking must be continuous, for if it is left for even a few minutes it is still hardening by contraction, and settles also to some extent, so as to necessitate a too vigorous action in distributing it afresh, and overtaking the size suitable to the condition. The curd, as it hardens, slips easily between the wires, and seals over its surface in some degree, with a corresponding tendency to retain the whey instead of expelling it, so that stirring without breaking is mischievous. In fact this part of the work must be done without interruption. The care of the boiler must be on other hands, to enable the cheese-maker to give his whole mind to this one duty, without a passing anxiety as to the readiness of his hot-water or steam supply when he will need it.

The curd has been brought by the skimmer-breaking to such a size as to admit of the breaker being used without harm. It is put in against the side, so gently as to avoid breaking the upper curd unduly, and when it reaches the bottom is thrust gently forwards, and moved about through all parts, so as to treat the curd uniformly. There should be method in these movements,—the best results can scarcely be obtained without it. In an oblong vat the work is easy, the breaker track following the dotted lines and arrows in Fig. 92, until the other end of the vat is reached, when the dairyer crosses to the other side and repeats his work. The shape of the vat tends to keep the curd in one place, so that the motion of the breaker is resisted by it, instead of its moving away from it.

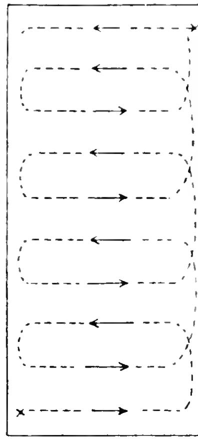


FIG. 92.
TRACK OF BREAKER—
OBLONG VAT.

In a circular vat the tendency is to swim round in front of the breaker; and the dairyer using such a vat must take care to prevent this as much as possible, by breaking from side to centre (Fig. 93), and, after going round, by turning back, so as to ensure equal treatment.

The resistance offered to the breaker is an indication of the hardness of the curd, and must always be watched. The hand can be educated to a high degree of sensitiveness in this matter; and although the resistance is much greater in the tender state of the curd when the lumps are large, than later when they are small and can pass between the wires freely, yet, with an allowance for this, the condition of hardness can be estimated with remarkable accuracy, and the dairyer can be sure at any point whether or not his curd is as small as it ought to be in that condition.

The motion is slow at first, but as progress is made the speed must be increased; and it is well to do this methodically also, going round once at a given speed, and quickening the pace at the old starting-point for another round at the new speed, and so on to the end,—rather than altering speed at irregular intervals. The speed will also depend on the size of the vat; in a small one it will be slower than in a large one, because the area will be covered by fewer movements. The aim should be to break it as quickly as may be, with a clear whey. Fine skill in this work can only be attained by intelligent and painstaking practice, but these given and maintained it is sure. The mind must dismiss all other matters for the short time necessary to it, and give its best attention to the work in hand,—just as a painter on an exhibition

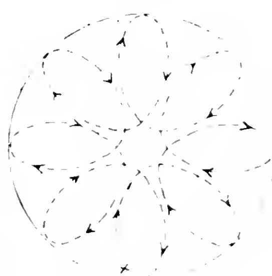


FIG. 93.—TRACK OF BREAKER—
ROUND VAT.

painting, or a musician on a solo before a large audience, would do. There is both science and art in this manipulation; and the ability to carry a curd through this process with a whey well-nigh as clear as wine, and the curd particles themselves so uniformly broken as to make the next part of the work possible to be perfect, is within the reach of anybody who really cares about it and will patiently take the necessary trouble. It will be most easily, quickly, and permanently acquired by adopting the methodical course suggested.

The first position of the breaker is shown in *a*, Fig. 94, breaking the lower part, and resting on the bottom,—this is used for the first

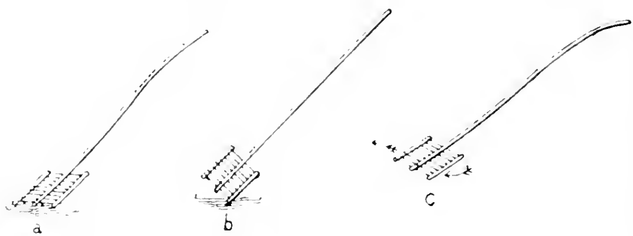


FIG. 94.—POSITIONS OF BREAKER.

two rounds; the second at *b*, which also occupies two rounds; and the third at *c*, which may be maintained, with occasional returns to the second position, throughout the rest of the breaking process. The action at *c* is very difficult to describe, either in words or by a diagram; but it consists in a curve, which is made from one side of the vat to the other, by a thrusting forward and a drawing back, accompanied by a twist of the lower hand, which grasps the handle, as in Fig. 95, firmly but lightly, the upper hand holding it loosely so as to allow it to move as freely as is possible without slipping from it. By this means rapid motions may be made without mischief, while long sweeping movements could not. As with all motions born of intelligence and training, those which are nearest to perfection are also the most easy and elegant; and while elegance may be held in light esteem in such a connection, it is inseparable from the best work.

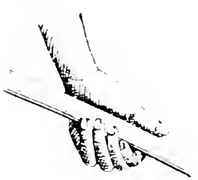


FIG. 95.
LOWER HAND IN POSITION *c*.

When the curd has been brought to pieces of an inch thickness, the sides and angles of the vat should be cleared of any adhering to them by wiping them down with the hand pressed flat against the metal and moved over all parts below the surface of the curd.

If any is left, it will not be properly treated with the rest, and at the next stage will be over-heated. The breaking may take from a half-hour to an hour; no positive rule can be laid down as to time, and it is never safe to attempt any. The condition of the curd must determine in all cases, and this is liable to frequent variations even when the first conditions are allowed for, according to the time of coagulation. During this time it will be tiresome to hold the breaker with the hands in one relation only, and it is wise to learn to break left-handed, so as to be able to frequently change hands, and give the upper hand rest in a lower position. All through uniformity must be kept in view. It is not enough that the largest pieces in the vat are small enough; if any appreciable proportion of the whole are noticeably smaller, the results of the after-treatment will not be uniform; and that, and every succeeding part of the system, is dependent on this and on the others which have gone before them for their success.

The immediate influence of the breaking, as described, is plain: at the end of it, and throughout the remaining processes, the curd contains less whey than that of any system which uses cutting tools throughout. There is an old Cheddar maxim that if too much whey is left in the curd at the end of the breaking it never can be properly extracted afterwards, and experience proves this to be true. The Cheddar system aims at a much more complete whey separation than other systems, because it desires a mild-flavoured and long-keeping cheese, and therefore takes this course consistently with that aim for the reduction of fermentative possibilities. If the use of cutting tools tends to leave a larger proportion of whey in the curd, it also manifestly tends to more fermentation, a flavour earlier and stronger, and a shorter lease of good quality, and therefore violates the first essential of the system. It may be answered that there is an evident gain in weight by the larger proportion of whey secured by cutting implements. We admit it, but the Cheddar system does not seek quantity so much as quality; and when any dairyer takes to cutting tools in order to gain that advantage, he forsakes the Cheddar system and has no longer a right to call his product Cheddar cheese. Our forefathers knew better. Formerly a tool of the kind shown in Fig. 132 was used, but it was of round form and made with round wires. In the middle years of the century an apparatus was brought out for breaking, to be worked by a revolving handle; this has disappeared because it could not bear the test of use,—but it was consistent, for it presented only rounded surfaces to the curd. But in these latter days there have been brought into western dairies "cutting breakers," easier to use, quicker in action, &c., with side blades of metal and flat or diamond-shaped wires; and these are the curse of those dairies, not only interfering with the integrity of the system, but also bringing about the cause for the complaint that modern Cheddars (such have no right to the name) do not keep as those did which made the system famous. The pastures of Somersetshire cannot save cheese which are so made. We are not concerned to dispute the claim to superiority according to the standards of this market or that show, where quick-ripening goods, the product of cutting tools, are encouraged. They may be more profitable to their makers, more pleasing to the modern merchant and grocer, they may be the cheeses of the future for all we know, but they simply are not Cheddars--any more than they are Cheshires or Stiltons.

This work cannot be satisfactorily done by mechanical power, all attempts up to date have fallen short of the needs of the case. It is dangerous to prophesy, but we cannot conceive of anything that could fulfil the demands of the system fully. If curds were uniform in their action, they might be so broken, though the necessity for a progressive speed, under a complete control, would make the apparatus somewhat complicated. But the variations in condition and rate of hardening due to those which occur in fermentation, must be met by corresponding variations in the manipulation; and we know of nothing equal to the human hand, educated to recognise such, and—with the mind and will to guide it—ready to adapt the action to the conditions. Any apparatus which could do the work as well as the trained hand can do it would be welcome, but there is at present no prospect of relief. It is not claimed here that the implements described are the only ones which can be used under the system; for any others which fulfil its demands in regard to form and action are in order, and we shall be glad to see any real improvement on the present appliances.

The breaking being now completed, further help to the separation of the whey is given by heat, which encourages contraction and hardening. Its effects, however, depend for their kind and extent upon the size of the curd particles. If these are larger than the size given, the outer part of each closes up under the influence of the heat and contact with the breaker, and encloses a part of the whey which should have been expelled, and which no amount of after-treatment can fully get rid of. The retention of whey will therefore be in proportion to the excess of size in the curd. By failing to break it small enough, part of the advantage of the breaking (as against cutting) is lost; and the rule as to the size of the curd at this point is therefore an essential of the system. When however the curd is of the right size, the heat reaches the centre of each particle so fully as to secure a uniform condition throughout it, leaving the extent of the hardening and whey expulsion to be regulated by the length of the exposure to the heat and breaker-action. Whatever may be the state of the curd (under these conditions) at the time that this part of the process ceases, it will be at least alike throughout each particle, which it could not possibly be if it was too large. It is also important that it should not be broken too small, for although in that case the hardening will take less time, the liability to waste is greater, and the exposure to the air, when the whey is withdrawn, does more mischief by unduly reducing the temperature.

The heat could not be applied at any better time. Its action is controllable by varying (*a*) the temperature, and (*b*) the length of time during which the curd remains in the whey. These two items in the process must be carefully balanced according to the needs of the case, and therefore both must be considered separately, and as combined.

(*a*.) The proper temperature depends on several considerations. The system demands as low limits as are consistent with its general aims; and although higher ones would do the work more quickly, it is found invariably that, all other points being uniform, the lower temperatures give the best cheese, and the longer attention of the dairyer is well paid for. With this in view, the system eschews high temperatures for coagulation, and the curd is only exposed to a higher temperature about half the time between the renneting and the removal of the whey. This means much less fermentation than would accompany higher temperatures administered throughout. The temperature must be such as, with proper care, will keep it warm enough until curd-ripeness is attained, to encourage fermentation, and the expulsion of the free whey which will be taken up with it at a later point. If the curd becomes too cold these are unduly checked, and a sodden and troublesome condition arise,—with a defective texture, flavour, and keeping quality, if compensation by greater curing heat is attempted; or otherwise, an uncertain rate of curing, with bad flavour of a different kind. The temperature for this purpose should not be lower than 90° F. at *curd-ripeness*, and it is found necessary to employ a scalding temperature ranging from 95° F. to 100° F., according to the air, and the quantity of milk in use. This carries the work into the "most favourable" range of the friendly ferments with the natural consequences; limited, however, by the whey expulsion to narrower possibilities than in other systems. A lower range of temperature, with more whey retained, would give an equal fermentation, but would not by any means give similar final effects, for fermentation is not the only influence at work; and even this continues to alter the cheese in flavour, digestibility, and keeping quality up to the time of consumption, which—occurring at varying ages—must make it difficult to fulfil the main aims of the system by any compensation. The system is more certain in its results with an average temperature of 97° F. and the drier curd, than with any other combination which we can think of. The air temperature will always be lower in our climate than that of the scalding, and in proportion to the difference will be its power to reduce the latter, for during much of the time the contents of the vat will be constantly stirred in contact with the air. The quantity of curd and whey will also affect our calculations, because the smaller it is the more rapidly will it lose heat. The table below will give general guidance in this matter :—

Air.	Milk. 200 galls. and upwards.	200 galls.	100 galls.
65° F.	96° F.	97° F.	98° F.
60° F.	97° F.	98° F.	99° F.
55° F.	98° F.	99° F.	100° F.

With quantities which 100° F. will not keep at proper temperature, the loss of heat may be made good by applying a gentle heat a short time before the present part of the process is finished, but long enough before that to allow the vat to cool to the temperature of its contents before the curd is allowed to settle in it. It is not desirable to exceed the limit given, for the hardening effect of the heat increases in proportion to the excess of temperature, and, with a temporary check on the fermentation, disturbing the balance of influence. The further we proceed beyond the limit the greater is the difficulty, and even for special cases where the soil influence produces weakness of curd, we do not think it ever necessary to exceed 102° F.

The hardness of the curd should be uniform in order to the uniformity of texture ; and as the expulsion of whey will be proportionate in a curd of the proper size, the fermentation will be uniform too in the final product, other points being properly managed.

The variations of temperature will, to some extent, affect the length of exposure to the hot whey, which is necessary to the uniformity of hardness, and no safe rule can be made as to time in the case. Many makers, finding that a certain time seems to work rightly adopt it for a standing rule ; but observation shows that scarcely anything tends more to differences in curd-condition within the limits of the system than does this practice. It is wise to cast time out of the reckoning ; and, having chosen a proper scalding temperature, to carry on the work until the desired hardness is obtained, however long it may take. Only in this way can a regular result be secured, for curds differ from day to day, and they can only be brought to a like state by meeting them with corresponding variations in management. In practice the "*scalding*" of the curd is carried out by turning on steam or hot water, or removing a proportion of the whey to heat and return as in the case of heating milk for coagulation. In the last-named method it is usual to do it at twice, raising the temperature to a half-way point at first ; and while the whey is heating for this, to remove that needed to complete the work. The whey is returned to the vat by bowlfuls, with a circular sweep of the hand, so as to distribute it evenly and ensure as uniform heating of the curd as may be. To reduce the quantity of whey to be heated in the boiler, most makers finally remove as much as they can from the vat, while the first heating is progressing, but this may be carried too far. The whey should always be sufficient to allow of the curd freely floating in it, and the removal of more than one-fourth besides what is needed for heating is unwise. With a reduction of small quantities it is necessary to increase the scalding temperature to secure against undue loss of heat, or to recover it by a late heating. In this respect the original proportion of whey to curd is a distinct advantage, as better maintaining the warmth.

In getting out the whey for heating, it is necessary to let the curd sink for a few minutes, and then to use a strainer to prevent its being carried into the warmer. A hair strainer is best held, as in Fig. 96, from the inside of which the whey is dipped,—a much quicker plan than that followed by many makers, who dip the whey with much care to have as little curd in the bowl as possible, and pour it through the strainer held over the warmer. Whatever curd eludes this care is exposed to the colder air, with loss of uniformity in proportion to the quantity so exposed. The whey while being heated should be gently but constantly stirred, and the curd in the vat as well. The common practice of letting the latter rest until the whey is nearly hot enough, and then stirring it vigorously to float it afresh, is bad, for either there will be waste by the violence which must be incurred, or there will be liability of its being heated in clots and with proportionate lack of uniformity.

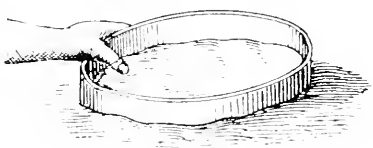


FIG. 96.—STRAINER PLACED FOR DIPPING WHEY.

The labour involved in this way of heating is not justified by the difference in cost between the old style of vat and that for water-heating. The comparison of these as already made applies in scalding, but it has been asserted that a special benefit is obtained by the curd being *suddenly* exposed to the action of the heated whey, a theory for which there is not the slightest foundation. The best makers among those who use it take all care to avoid this supposed benefit by distributing the whey as widely as possible, in the absence of which care an uneven scalding must result. Even if it were practicable to heat suddenly and evenly at the same time, no advantage could arise beyond the slight reduction of time in the after-treatment, which must be more than swallowed up by the waste of time in dipping and heating. Of late years supporters of this notion have brought out apparatus for reducing the labour, but their genius might have been better employed, for nothing has yet been given us which can equal, either in economy, or suitability to the system, the hot-water or steam vats as described. These, it has been said, tend to the clotting and over-heating of the curd, and—in careless hands—this may be true, as it is of the other method; but if the curd is stirred, as it ought to be in any case, no such trouble can possibly arise. It is best for all reasons to raise the temperature gradually, occupying fifteen to twenty minutes in the doing, and the breaker turned over as in Fig. 97, and kept scouring the bottom of the vat, and thrust into all its angles just rapidly enough to keep the curd well distributed.

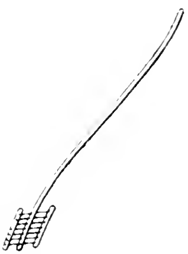


Fig. 97.
Breaker in Scalding.

In hot-water vats the allowance of time for removal of the heating water must be calculated by experience, so as to avoid too high temperature by its remaining too long around the contents. Some makers allow a part of the hot water to remain, but if this is done there should not be enough to reach the bottom of the inner case. In farm dairy quantities it may be useful in maintaining a slightly higher temperature than would otherwise be the case.

The stirring is afterwards maintained, but more slowly, until the curd has reached a certain hardness, which cannot easily be described. If before that some be squeezed in the hand, it clings together and mashes upon being pressed by the thumb; but when it is firm enough it will, under like treatment, rub abroad into its original particles. The actual point at which the stirring should cease occurs a little later, generally within a few minutes; and as it offers no evidence excepting a slightly greater firmness, it can only be learned by direct teaching or experience. It is often described as "shotty," but this conveys an impression of a greater hardness than is desirable, and is likely to mislead. The stopping point also depends somewhat on the size of the cheese, for a small one needs a fraction more moisture than a large one, because it loses proportionately more in curing. The difference is from one to five per cent., as shown by experience; but this cannot be calculated by any rule, and there is no test by which the amount present can be determined at the moment when it must be known. Observation alone can teach in this case.

The errors which may arise in this work may now be noticed. If the stirring be stopped too early, too much whey is left in the curd, with the consequences already noticed; while if it is stirred too long, the curd is too hard, and the cheese shows a dryness which seems to indicate poorness even when the fat proportion is ample. The dryness is opposed to the natural curing changes, at least those of fermentation. It has not been proved by direct experiment that the rennet is hindered by any such lack of moisture as might arise from this cause, nor does present knowledge of its action suggest its probability, but it is possible.

The curd is now allowed to sink and "pack," or "mat" together in a solid body. This would happen at any time from the commencement of breaking onwards, but it is avoided in the Cheddar system until the "stirring in scald" is finished, and then it is encouraged. The maker's aim is to get the curd into such a form that it shall lose as little heat as possible, and thus secure a steady progress of fermentation. If the whey was withdrawn at once while the curd was in a loose state, the air would mingle with it, and by cooling it check the fermentation to a serious extent; and since the fermentation induces the viscous state which helps the packing, it would be difficult to get it to pack after the check. So it is left under the warm whey long enough to become solid, though the surface particles are liable to be scattered by bad management. The packing is greatly hindered by too much hardness of the curd, and it is therefore only safe to judge of its state as ascertained by the hand; but a curd properly managed up to this point will be solid in thirty minutes, and variations in ordinary experience will not exceed a few minutes more or less than this. With a higher degree of fermentation it would take proportionately less time; with a lower degree, more time would be required. Here no time rule will serve.

Some makers keep the curd under the whey until it will "draw" with the hot-iron test; but this is inconsistent with the Cheddar system, which requires the removal of the whey as soon as possible after solidity is obtained, and only a sour or tainted curd will respond to that test at such a time. What are the reasons for the Cheddar rule? Our forefathers made it because they found that their cheese was much milder and finer flavoured when the whey was drawn early than when it was left longer; and we know now that the mischief wrought in the latter case was due to improper fermentation. In the whey, which not merely covers the curd but also fills the tiny spaces between its particles, the fermentation is making progress, although the evidences by any test show that there is but little more acid at the end of the stirring than at the renneting. The stirring has helped to this by exposing the contents of the vat to the action of the O of the air. But there is progress, and this becomes much more rapid after the stirring ceases, so much so that an hour or two will give the answer to the hot-iron test. But the flavour of the cheese will not be quite equal in any case, and often will be very inferior. This may be due to ferment relations unsuitable to the present needs of the curd, to the presence of bad ferments which are favoured by the progress of the L.A.F. and C.F., or to the other conditions under which the curd exists.

The L.A.F. have done much of their important work in forwarding the conditions of the curd, modifying the C.F. action, keeping in check other ferments, and giving firmness to the curd. They are still necessary, but their proportions in the whey of the curd—both that actually retained in it, and that which is free but mingled with it—are ample for all further needs, as experience proves, and their continued progress in the whey, where the C.F. have no equal chance with them, makes an ill balance. There is every reason to believe that the C.F. makes more rapid progress after the whey is withdrawn than before, for while the L.A.F. action may be necessary to the proper working of the C.F., there proves to be enough of it to carry forward the acid formation rapidly, and the C.F. has an increased proportionate influence. This is shown by the fact that, when the rennet is equal in two vats, the curd which is kept longest under the whey shows more acid, but a lower degree of the influence in which the rennet works with the C.F., to the mellowing of the curd. The rennet is also checked by the L.A.F. and its products ; but this does not satisfactorily account for all the result, even in the best cases of long covering by the whey. The whole ferment action is out of proper balance with that of the rennet. There is also the possibility of unfriendly ferments being retained with the whey, doing little or nothing until a certain state of preparedness is brought about by the friendly ferments, but then starting into mischievous activity. This would only occur in ordinary experience after the point at which the Cheddar maker draws the whey, and he therefore escapes it. Beyond all this there is also the moral certainty of the increase and retention of certain products of fermentation which are harmful by reason of their own flavours, and their tendency to form chemical combinations among themselves and with the materials of the curd and whey. These are largely got rid of by airing, which is impossible as long as the curd is covered with whey. This is the Cheddar practice referred to earlier as having been grafted on to the American system to the great advantage of its product.

From 100 gallons upwards, in vats of appropriate size, the curd may be allowed to sink evenly over the bottom; for with such quantities it will not harm if properly managed; but with lesser quantities the depth will be scarcely sufficient to save it from undue cooling, and it will give an advantage if the curd be drawn up to the vat-side in a deeper body, with care to have as nearly as possible an equal depth in the pile. It will be a work of patience, but worth the doing.

The removal of the whey is best effected with the use of a syphon (*a*) and cylindrical strainer (*b*, Fig. 98). The former is a bent tube, generally of tinned copper, $1\frac{1}{4}$ to $1\frac{1}{2}$ inch diameter, having one limb longer than the other by two or three inches; and the shorter of the two of such a length that, when resting on the vat-side as in Fig. 99, its end should reach within two inches of the bottom. The strainer may be from seven to ten inches diameter, and of such depth as to reach the top while resting on the curd. For the curd thickness $1\frac{1}{2}$ to 2 inches may be allowed, according to the depth of the vat. The best straining material for use with whey is perforated brass, the other parts being made of tinned steel. The strainer being sunk as low in the curd and as close to the side of the vat as may be, the syphon is filled by holding it under the whey, and its ends tightly closed as in Fig 100; then lifted to an upright position, and lowered to its place. The whey in the vat is subject to an air pressure of 16 lbs. to the square inch; and there being but little resistance at the end of the longer limb, the whey from this flows out and is followed by that in the shorter limb and in the vat, as long as there is sufficient to maintain the action.

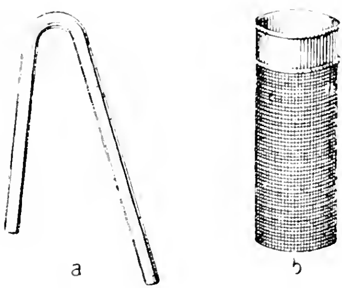


FIG. 98.—SYPHON AND STRAINER.

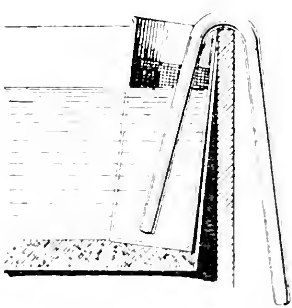


FIG. 99.—SYPHON AND STRAINER IN USE.

The whey might be drawn through the tap, but this would cause a powerful draught of the liquid over the surface of the curd, with the removal of any fine or loose particles. The use of a strainer before the tap-opening would prevent this, but it would be easily clogged with the curd and give much trouble, while the syphon with its cylindrical strainer causes but little disturbance by suction, and practically no loss. The syphon is sometimes made with a tap at the end of the longer limb ; this is useful where the whey is to be carried off in pails for want of any better provision. In such case the tap may be turned off, and the syphon kept full while the pails are changed. The advantages of the arrangement in our typical dairy will be seen as compared with such a method of removal. A conductor (18, Fig. 32) similar to that used for milk (Fig. 42), but without a strainer, is laid between the vat and the whey tank (19, Fig. 32), or the outlet, where no creaming is done, and the longer limb of the syphon so secured as to safely deliver its outflow into it. At the lower end of the conductor is a bag of strainer cloth (Fig. 101), which catches all curd which may escape after the opening of the tap. Before the whey is set running, all particles of curd which have been splashed against the vat sides above the whey surface should be washed down with a clean fibre brush.

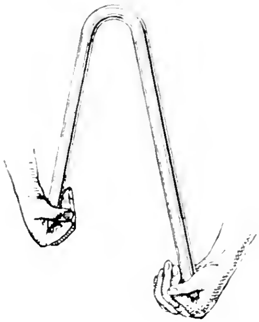


Fig. 100.—Lifting the Syphon.

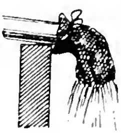


Fig. 101.
Curd Strainer.

When the whey has sunk to half the depth of the vat, this latter should be tipped (as in Fig. 102 ; or Fig. 37, if a round vat) so as to

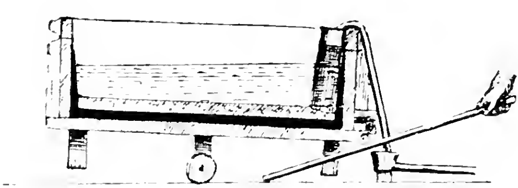


Fig. 102.—Tipping Vat.

deepen the body of liquid and enable the syphon to draw out much more than would be possible with the vat in a level position. This tipping must be done slowly to avoid disturbing the curd, which would otherwise rush with the whey to the lower end and be badly broken, much of the good sought in packing being undone. A pole, five to six feet long and strong in proportion to the size of the vat, is the best and simplest aid, this being set (as in Fig. 102) so as to take the descending weight, and, after the wedges are struck out from under the front legs, lowering the whole under perfect control. The wedges are then fixed securely under the hind legs (Fig. 103), so that they

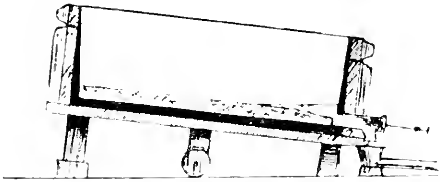


FIG. 103.—VAT TIPPED.

may not slip when the pressure is brought to that end of the vat. The conductor-head, which is at first raised as high as it can to meet the descending whey and prevent splashing, must be lowered to accompany the syphon limb.

In the factory (Fig. 62), the conductor may best be made to serve all the vats at once, having under the tap of each an opening, into which a funnel may be placed as in Fig. 104, so providing for the whey removal from either vat without delay. In this case a metal strainer is best, and a second will be useful to allow of replacement, so avoiding the necessity of keeping the loose curd away from the mass while the whey is being drawn from the several vats. At this time the whey supply for the next day's milk ripening should be taken, and all helps required during the next half-hour's work placed ready to hand. Further reference to the whey will arise in Chapter XVII.

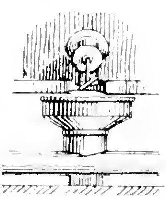


FIG. 104. — FUNNEL AND CONDUCTOR FOR WHEY.

When the sound of air-suction is heard at the end of the shorter limb of the syphon—warning that it can do no more —the tap should be opened and the syphon and its strainer removed, the latter being freed from curd by brushing. The curd should now be divided into two parts (as at *a*, Fig. 105) by a keen knife, which, to serve for later purposes as well, should have a blade of eight to ten inches long, according to the size of the vat. It is next drawn towards the sides of the vat, so making a gutter between the dotted lines *b b*. This is commenced at the lower end of the vat, so that as the whey is pressed out it may freely flow away. The lower part of the two bodies of curd so formed are next to be cut into squares of half their width

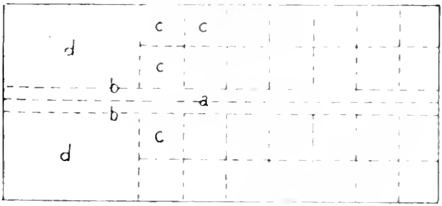


FIG. 105.—CURD DIVIDED FOR PILING.

(*c c*, Fig. 105) and piled. A scoop (Fig. 106), of a size to take one of these squares easily, is the best means of lifting them; and by deftly turning them over, as in Fig. 107, they may be laid closely and neatly in two piles on the parts *d d* (Fig. 105), with their upper surfaces, which have been exposed for a few moments to the air, turned under, so redistributing the temperature, and placing the looser surface particles where they will soon become solid with the rest. The square nearest to *d d* should first be taken, and the rest in order, so that the whey may be nearly or quite run off by the time

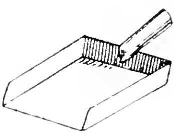


FIG. 106.
CURD SHOVEL.

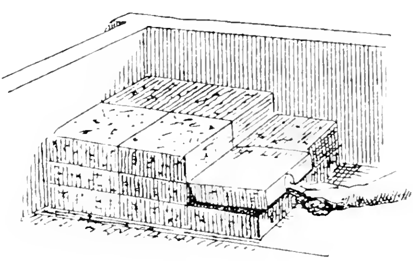


FIG. 107.—PILING THE CURD.

the lowest are reached. This, because the drier the curd is, the less is the danger of its being broken in lifting. The piles should occupy from one-fourth to one-third of the vat length, according to the quantity of curd. The smaller this is, the shorter should the pile be in proportion to its depth. It is well with less than 150 gallons to make one pile of the whole; while with larger quantities two piles are better, because they allow of a readier expulsion of the free whey than would one of double the size. The piles should now be cut as in Fig. 108 (*a*, plan; *b*, section), so as to trim off the rougher and lower portions at the sides and ends, these being placed with the cut side upward, on the top. Then the loose particles should be brushed out of the gutter with a whisk of yellow broom (*a*, Fig. 109), which is better than the brushes of hair commonly sold for the purpose, because more easily freed from curd and kept clean. Its worst fault is that it is springy, and scatters the curd in the act of collecting it; but this can be cured by tying the fibres with string at a lower point, as in *b*, and releasing them when they are shortened by wear.

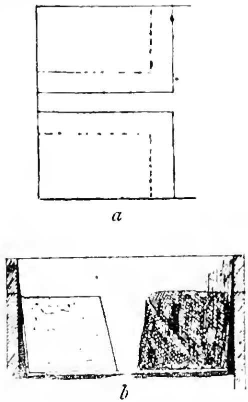


Fig. 108.—Trimming the Piles.

Immediately upon the clearing out of the sides and front of the piles they should be covered with strainer cloths, clean, sweet, and wrung out of the warm whey just before use, their ends being tucked under the lower edges of the piles, as in the right pile (*b*, Fig. 108). This will give them partial protection, while any remainders of loose curd are being swilled down with whey and brushed out of the vat, down the conductor, and into the strainer; from whence it must be taken up and put behind or below the piles, where it can be warmed by contact with the mass and become a part of it. The vat should then be covered and the curd left until it has become solid, with all the loose particles properly incorporated. This will take from fifteen to twenty-five minutes, according to the fermentation in the curd; and this again will depend in no small degree upon the management of the whey removal and piling. These must be done as quickly as is possible, consistently with neatness, and the avoidance of breakage, for delay ensures proportionate loss of temperature and check of fermentation, and it is not possible to restore these conditions to their proper measure without much trouble and damage. It is not, for instance, proper to turn on steam or hot water under the vat, or to put cloths dipped in boiling water upon the curd. These cannot give even a

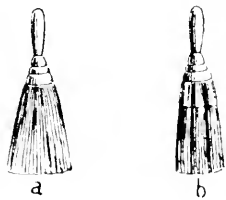


Fig. 109.—Curd Whisk.

nearly uniform temperature, and the excess of heat at the points nearest to its source must seriously check the ferments, or even destroy them, the curd being also unduly hardened. Neatness is scarcely less needful than quickness of movement, for it is easy so to smash up and scatter the curd in haste as to greatly prolong the gathering, and increase the difficulty of obtaining solidity. Experience with slow workers and careless ones makes it difficult to say which evil is the worse, but neither is excusable. We have known good curds ruined at this stage, taking hours to get to a semi-solid, semi-crumbly state, and then sodden and cold, and finally giving a slow-curing, soapy, and ill-flavoured cheese. We have also seen good makers get the curd from 400 gallons of milk, cut, piled, and covered, the vat swept clean, and the curd from the strainer safely in place, in from ten to fifteen minutes, with the happy result of a readiness for the next process in a similar time; and that even in cold weather, when the mischief which the air could do was at its greatest. Here method, and concentration of mind and energy, are all-important.

The management in a round vat differs only in the manner of cutting and piling the curd, which can best be done as in Fig. 110, the gutter being cut at *a*, and drawn to *b b*, leaving the portion *c* at the highest point, cutting the remainders as at *d d*, and using the portions *e e* to occupy the corners *f f* of the pile. The curd shovel must be a little larger in proportion than with an oblong vat, because of the irregular shapes with which it has to deal. This plan with a flat-bottomed vat is much better than the old one of piling the curd on the middle of a convex bottom, where it is much less perfectly protected and more difficult to reach for piling and turning.

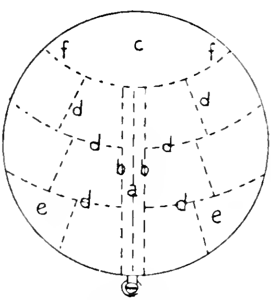
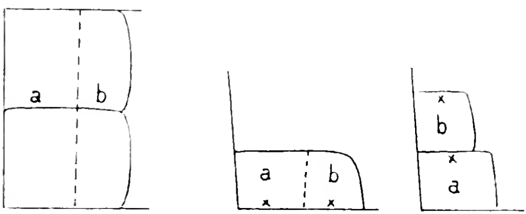


FIG. 110.—CURD CUT FOR PILING—ROUND VAT.

Curd Ripening.—The curd is still contracting and getting drier, but also still fermenting and changing from the slightly harsh and gritty touch to a softer one, and from the crumbly—by way of the solid—to a stringy or flaky condition; this being the work of the C.F. and rennet, the L.A.F. modifying their action. Less of this last than the system aims at securing would give a rapid-curing cheese, with a proportionate tendency to early spoiling; more of it than is required, would tend to hardness, and an early flavour, but to relative loss of digestibility. At the temperature which will now be from

90° F. to 95° F., the ripening will be so rapid as to effect as much in an hour as would take place in two or three days in the lower curing-room temperature, with the then greatly reduced proportion of whey. It is therefore necessary to watch the progress of the ripening carefully, and manage consistently all the remaining processes. The temperature can be taken by cutting the curd and closing between it the plate and tube of a thermometer removed from the case; and if it is in danger of falling below the safe limit, more protection should be given. This however will seldom happen if the scalding temperature was rightly fixed, and the management suitable to that of the air, for the fermentation assists in maintaining heat.

The tendency to sink soon reduces the depth of the piles, and fills up the gutter. The whey also sinks in the curd; and the uniformity being affected by variations in the proportion of moisture,



Plan. Section. Section piled.

FIG. 111.—CURD CUT, TURNED, AND PILED.

temperature, and fermentation, a redistribution is necessary. This is brought about by a turning of the curd, which, in all but small quantities, must be cut for the purpose into two or more sections. This is done as soon as the curd has attained the desired solidity, and even before, if by any means some part of it has failed to pack properly. This latter case however can only arise by error, and the turning is not a satisfactory compensation for neglect. The cutting, where necessary, should not be exactly in halves or quarters, because in the re-piling it will be difficult to keep them in good form, for the piles—being both elastic and top-heavy—are liable to fall. In Fig. 111 it will be seen that the part *a* is larger than part *b*, and therefore when *a* is turned *b* may also be turned and piled upon it, as in the third diagram. Here the curd will generally remain without further handling until its ripeness is reached.

It may now be tested by litmus to ascertain how near it is to that point, and the management determined accordingly. If for instance the pile has been covered by two thicknesses of cheese-cloth besides the protection of the vat cover, and the curd has only reached the stage of fermentation indicated by G in the Colour-plate, these cloths may be replaced; if the stage I has been reached, one of them may be discarded; if a further stage has been reached between I and J, the vat cover may be opened; while if actually ripe, the litmus showing the colour of J, all covering may be laid aside, and the curd left only a few minutes in pile to ensure redistribution of the conditions. No time-rule is of any real service, and to ensure safety the work must be governed entirely by test and judgment. A slit should be cut in the curd where it will be on the under side in re-piling, the litmus paper placed between it, and the curd closed upon it for a moment. In an ordinary curd, some time equal to or longer than that so far passed in pile, will be required to procure the ripeness; but the dairyer should train his judgment to estimate the probable time (erring on the safe side) at which his final test will prove the condition to be suitable to his next action. If the time is more than one-third longer than that first period, then the curd should be cut, turned, and piled again, in order to uniformity. Some makers, after the first cutting, re-pile the curd on a wooden rack (Fig. 112), supposing it to be better than keeping on

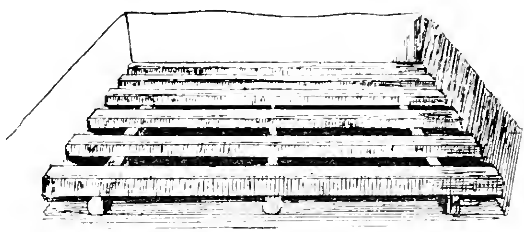


FIG. 112.—RACK.

the vat bottom. Experience does not lead us to endorse that view. It is not, however, an essential point. If the rack is used, it should be covered before the curd is put on it, so that the under side may be as well protected as the upper surface.

The *airing*, *drying*, and *cooling* of the curd should now follow without an undue check to the fermentation, and with maintained care to keep the conditions evenly distributed. This is done by exposing it to the air, at first in large sections, and later in smaller ones, dividing it at intervals. By this course the temperature is slowly reduced, and ripening makes a little more progress, in the meantime; the stage of curd ripeness being only a milestone on the road, and by no means a stopping-place. But the progress of fermentation becomes steadily slower as the ferments are affected by the changed conditions, all of which are calculated to check their activity and increase. If this exposure takes place before the curd is ripe, or if it is delayed after that point, the effects are as with originally under-ripe or over-ripe milk respectively, though with a greater proportionate C.F. influence.

The curd of 100 gallons of milk may be simply turned over without cutting, that of 150 gallons cut into two equal parts, that of 300 gallons into four parts, and so forth; being turned over in any case. This may be done in the vat, or in a separate vessel called a "cooler." This latter is a shallow wooden tub, as in Fig. 113, and the work is finished in it. The vat being set free, may be cleansed; but while this is done earlier than would otherwise be possible, the cooler must be cleansed as late as the vat would have been. The only real benefits are that the vat is by so much less exposed to the action of the acid whey; and that if the work should happen to be late, the vat can be ready for the night's milk. We have never found it necessary, though its convenience in some instances cannot be doubted. Its economy in

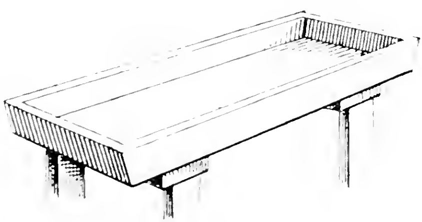


FIG. 113.—CURD COOLER.

saving the vat is set off by its own cost, and the labour of keeping it clean and sweet.

Where the cooler is not used, the curd—having been turned once in the vat after exposure—is cut in halves of the original sections, and removed to the cover (Fig. 82), where it is torn into halves again, and finally into pieces of about four inches square by two or three inches in thickness, and as uniformly as possible in all the divisions. At each cutting or tearing the curd should be turned over from its previous position, and yet again at a half-way point between this and the next division.

The time at which any division ought to take place may be known by the drying and slight yellowing of the surfaces in contact with the air. This coloration, which increases with time, is due to oxidation. Some of the benefits now gained by the curd are due to the O of the air; it loses some of the products of fermentation, and improves in flavour; but the oxidation of the casein and fats is a source of waste, and must not be suffered beyond what is necessary to the other advantages. The temperature must not be allowed to fall below 70° F., for instance, in cold weather, before the proper dryness be secured ; and the dairyer must calculate the relative probabilities of the drying, airing, and cooling, as he would those of ripeness, heat, and rennet in coagulation, &c. The effects, and the time required to produce them, will depend on the temperature and dryness of the air, and its rate of motion over and around the curd. We have seen that air can carry a certain amount of moisture; and if it has not already as much as it can carry, it will take up more from any body of water or damp surface. A dry air will therefore dry curd more quickly than a somewhat moister one, but the latter, if passing rapidly over it, may dry it as much or more than the former would if still.

Here the thermometer and hygrometer must be consulted; and the temperature and humidity being known, it is easy to determine on a suitable management. If, for instance, the air is cold and moist, the cooling will proceed faster than the drying ; and while a rapid passage of air would effect the drying, it would unduly reduce the heat and check the fermentation. This, however, may be allowed for in turning the curd, by leaving it in somewhat larger pieces, say an inch thicker and longer each way. Similarly, if the air is warm and dry, the cooling will be the more difficult work, though, as evaporation will be more rapid, it will be helped by that influence. In such case the curd should be torn into smaller pieces, so that it may be more quickly cooled. But in neither case would the provision be complete for success ; the passage of air must also be regulated, a rapid draught being sought in the former instance, a quieter air in the latter,—the one carrying off the moisture still exuding from the curd, more quickly in proportion to the cooling, and the other leaving more moisture in proportion to the reduction of temperature. The air-temperature will, of course, affect that of the curd more when in rapid motion than when still, but the size of the curd makes the balancing factor in the reckoning. Without pursuing the various probabilities of the case through all their windings (these the reader can reason out for himself on similar lines to the above), we may offer directions for certain combinations of conditions as a foundation for general guidance :—

Air.	Curd.	Air.
Warm, Dry.	Small.	Quick Motion.
,, Moist.	,,	Rapid ,,
Moderate, Dry.	Ordinary.	Moderate ,,
,, Moist.	,,	More rapid ,,
Cold, Dry.	Larger.	Quiet ,,
,, Moist.	,,	Rapid ,,

It must now be shown how these directions may be carried out. Up to this time the dairy has been kept at as uniform and suitable a temperature as possible, and the doors and windows closed. By opening these, so as to secure a draught, the necessary drying and cooling can generally be obtained; but the value of the draught will depend on the direction of the wind, the rapidity of its motion, and its temperature; and the dairyer must be prepared to judge of these as they occur, with constant variations. Regulation is easy with sash windows and louvre ventilators (Fig. 60) in the walls above them. A quiet draught may be secured by opening the latter; a more rapid one, with moderate cooling, by opening the window a little from above; a still more effective draught by opening this from below and causing the air to pass in its most concentrated form over the curd. The chief difficulty is with the regulation of its rate of passage. This is often sufficient even in warm days, and if it is so it can be controlled to meet our needs. But when the outer air is still, and the difference between its temperature and that of the inner air is not sufficient to induce a draught, as is often the case, then some aid is necessary. From experience we estimate the proportion of such occasions as averaging seven per cent. of the days of the cheese-making season, and at such times the want of an effective draught makes it necessary to choose between putting up the curd in too damp a state or allowing it to get too cool or too ripe before it reaches the proper dryness. This difficulty may be overcome by employing an exhaust fan (Fig. 114). The internal air is caught by the blades *a a*, and driven outwards at a rate which depends on their size and speed. A fan having a delivery surface of one square foot, and driven at 1000 revolutions per minute, would remove the air contents of the making-room (C, Fig. 32), about 2000 cubic feet, in two minutes. A pulley (*b*) of $2\frac{1}{4}$ inches in diameter, connected by a belt with a second pulley of 30 inches diameter, and this latter driven at 50 revolutions per minute, would meet the utmost demands. Lesser results could be obtained by lower speeds of a hand pulley, suitable to a farm dairy, while in a factory a differential pulley with several diameters would allow of the fan being driven from either, with corresponding variations of speed. A few minutes of driving after each turning of the curd would effect all that could be desired; in the factory, with its motor running throughout the time, the turning would be well-nigh continuous, and much time would be

FIG. 114.—EXHAUST FAN.

saved. It might well be a part of every factory outfit, if only for economy's sake.

This is a time when wholesome surroundings are more than usually important, for unfriendly ferments and bad air will affect curd injuriously. The chances of doing immediate mischief are less than with milk, partly because of the solid state of the curd, and partly because of the start which the friendly ferments have obtained; but as these are preparing the conditions favourable to others, it is only a case of time for the possible effects of their presence to follow. The danger is not past at coagulation; and with the free passage of air from without, it is greater than under the protection of closed doors and windows and a nearly still atmosphere.

So far the drying has had most consideration, but the temperature must not be forgotten. It must not fall below a safe point, and this will depend on that of the air. There will be still later exposure to that influence, and under conditions which will make cooling more rapid if the air is colder than the curd. It is easy to reduce the heat of the latter, if necessary. It is practically impossible to replace it if too low, as will be presently seen; therefore care must be taken to err, if at all, on the safe side. The curd temperature must not be allowed to fall so low at this point as to endanger its being too cold at the end of the making. The colder the air, the warmer should be the curd to bear the remaining exposure.

The safe limits are given below:—

Air.	Curd.
65° F.	70° F.
60° F.	74° F.
55° F.	78° F.

The temperature can be taken by wrapping a thermometer closely between the two parts of a split lump of curd for a couple of minutes. Daily observation will soon teach how to determine the size of the curd to meet the needs of temperature and drying at the same time. If it be too rapidly cooled, the difference between the outer and inner parts will interfere with the uniformity of fermentation.

By the time dryness is reached with a proper temperature, the fermentation will have wrought further changes. The curd will be flaky, and capable of being stripped into thin sheets of a few inches in length. There are, however, stages of this flakiness beyond the safe point; the sheets may be too thin, draw out too long, and be slimy and porous, in proportion to the excess of ferment action. The litmus test should not ordinarily give a higher indication than L in the Colour-plate, but if with that evidence of L.A.F. action the curd is not flaky, it should be kept until it is. Variations in the relative influence of the L.A.F. and C.F. may at any time make this necessary. The rennet is, of course, in regular proportion, and will not affect the question.

Some makers gather the curd at the first cutting into a strainer cloth, and tie it up tightly within a thick outer cloth (bagging), placing upon it a board or shallow milk pan reversed, with weights from 28 lbs. at the beginning to 56 lbs., or in some cases even 112 lbs., by the end of the ripening, which should be carried to the point at which the curd is finally torn abroad by the other method. In such cases it is once cut or torn into small pieces during that time, and replaced under weight, and again torn abroad and dried and aired immediately on ripeness being reached, which is a little earlier than in the other case because of the temperature being maintained at a higher point. This, however, makes a longer cooling necessary afterwards, and gives no real advantage either in economy, or in a better cheese. If, however, the temperature is reduced gradually, there is nothing in the practice inconsistent with Cheddar aims.

Preservative Treatment.—The proper state in these respects having been secured, the curd must be subjected to this treatment. For this purpose it must be reduced to small fragments, and the salt mixed with it. The curd is too dry for salting from the outside, and the Cheddar system demands a uniformity which is not possible with such a practice. With small quantities "crimming" may be followed, but it is rarely a true economy. A curd mill will save its cost in time in a single season in most dairies. The kind is determined by the system.

The Cheddar curd is comparatively dry, and, in order to a perfect texture and solidity, should be torn into ragged pieces which will readily join together. A wetter curd would lose minute particles in the whey pressed out by grinding. It is a complaint that the mills of the past cause this loss with modern curds; but such cannot possibly arise with a proper Cheddar curd, and if any white whey is seen with the grinding by any mill at present known to the trade, it must be due to departure from the system, or careless management. The best form of mill is that which neither cuts nor grinds (in the strict sense), but tears the curd asunder; and such an one is shown in section in Fig. 115, the two cylinders *a a* being

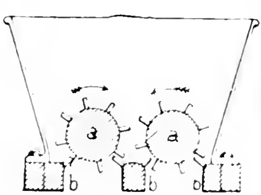


FIG. 115.—CURD MILL—SECTION.

of wood or metal, and carrying teeth which, turning towards each other (*see* arrows), catch the lumps of curd, tear it apart, and draw it through racks (*b b*) of similar teeth before discharging it. Mills are often sold on iron stands, with tubs to receive the ground curd, but it is difficult to prevent waste with this plan. A much better one is that

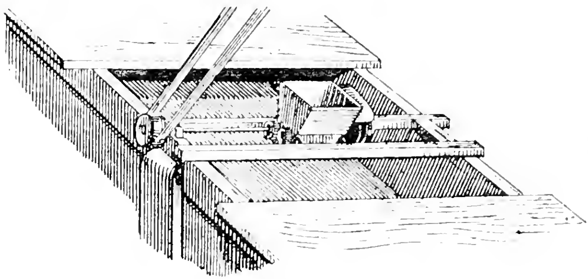


FIG. 116.—CURD MILL OVER OBLONG VAT.

shown in Fig. 116, where the mill is fixed to a wooden frame laid across the vat or cooler, and secured by a pin as in Fig. 117. The application of power is suitable to factory use, and pulleys (22, Fig. 62) are provided for grinding the curd of each vat over itself, shifting the mill and belt, and leaving each lot free for salting. The vat should be raised to its level and securely wedged, and the belt should be provided with a buckle to allow of tightening when needful. To ensure the quickest and most uniform grinding, the hopper should not be filled, but the single pieces fed to the cylinders as fast as they can carry them through ; for in a congested state of the mill the curd is so crushed as to set free some of its fat to be lost in pressing, and no time is saved, as some makers seem to imagine. Nor should it be allowed to accumulate under the mill, for in the middle of the pile the fermentation proceeds more rapidly than at its outsides, as can be judged by the higher temperature. When the curd is really ready for grinding it needs no further ripening under the early conditions, but rather a continuation of the checking ; and, under any circumstances, the fermentation in progress should be made as uniform as possible, by distributing the curd evenly over the vat or cooler, and breaking up any lumps which may form. The fragments should now be about a quarter

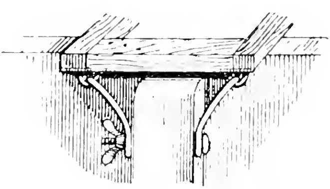


FIG. 117.—CURD MILL FASTENING.

of an inch through, and if any larger ones are seen they should be passed through the mill a second time. The best of mills will sometimes pass such, and the trouble of fresh grinding is well taken, for only by an equal size can there be uniform salting. If the curd has any ill odour, it should be well aired before salting by shaking it abroad with a scoop from a foot or two above the bottom of the vat or cooler. Generally there will be evidence enough of this at earlier stages to save from too long an exposure at this point. No other treatment is so beneficial in such cases ; but all pains must be taken to avoid loss of temperature. by grinding and airing earlier when the odour is discovered. This refers only to the non-putrefactive taints and the earliest degrees of the putrefactive forms.

The correct proportion of salt is 1 lb. to 56 gallons or 575 lbs. of milk used. The old method of weighing or guessing at the curd has already been discussed, and the reasons for the present course need not be repeated. Convenient as round figures would be, we cannot improve on the proportion nor express it in better form for calculation. All experience with such curds as we have here in mind confirms the wisdom of the fathers of the system. If the curd holds more whey than usual a proportionate increase of salt will be needed, or it must be kept after salting until it attains the proper dryness. If this latter course involves more than a few minutes' exposure to the air, and especially if that air is cold, it will be preferable to choose the former, making the loss according to the judgment, for it is impossible to describe degrees of wetness in a form suitable to our need.

The salt should be clean, dry, crushed free from lumps, and weighed correctly. Measuring is not safe ; the quantity which a vessel will hold depends on the pressure exercised in filling it. If bought in solid form, great care will be needed to avoid pan-scale ; and this can be best done by rubbing two lumps gently together, and frequently examining the surfaces, when any harder portion which produces scratches upon them should be removed by a knife. Uniform distribution is important, carried as far as it may be in the scattering of the salt on the surface, and afterwards by mixing it thoroughly. There is no better way than by drawing the hands, backs downward and finger-tips touching, under as much curd as can pass between them, and turning it over, so making a series of ridges, and turning these a second time before piling the whole at one end of the vat or cooler for the next process.

Moulding and Pressing. — The cheeses are formed out of the ground curd by being pressed in moulds or hoops. This not only brings the curd together in a solid body, but also gives it such protection that there is very little loss of heat as long as the pressing continues. It is therefore important that it should not go to press until it has reached a temperature at which fat will not be lost nor fermentation unduly encouraged. We have seen cheeses which originally showed no signs of taint actually swell under the action of fermentative gases formed while in press, and invariably with more or less of ill flavour, the result of neglect of this point. The proper temperature depends entirely on that of the air. When the latter is 60° F., the curd can be reduced by the end of salting to within two or three degrees of that same by proper management; if the air is lower than that, the curd must be sent to press a little warmer, as see following table:—

Air.	Curd.
60° F.	62° F.
55° F.	64° F.
50° F.	66° F.

In summer the air will be often too warm to allow the curd to be cooled sufficiently—as exposed in a thin body to the air—without too much drying, and consequent difficulty in getting it to cohere and form a solid cheese of good texture. Carried not very far beyond the correct stage, the result would be a crumbly article, very wasteful in the hands of tradesman and consumer. In such cases it is best to put it into the moulds immediately after salting, and place it, with no other covering beyond the cheese-cloth, on the presses or bandaging-table, until the cooler night air reduces its temperature to the limit of safety. This plan also sets the making-room free for cleansing.

Size and Shape.—The moulding of the curd brings up the questions of size and shape. From the early days of the system a large size of cheese has been so much associated with it as to have created a general impression that it was a necessity. The trade, as usual, encouraged a mere notion; and all the makers, up to quite recent times, have made, and many are even yet making, large cheeses to meet the demand, these ranging from 80 to 120 lbs. each in weight. It is fair, however, to admit that as an ordinary cured Cheddar is comparatively dry, it will retain its remainder of moisture better in large goods than in smaller ones; and it is quite likely that such attempts to make the latter without allowing for the greater loss of moisture natural to them, has had something to do with the prejudice against them. But it must be said, on the other hand, that Cheddar makers have time out of mind produced what are called "loaf" or "truckle" cheeses of 10 lbs. to 14 lbs. each, and of fine quality, and this should have sufficed to prove that there is nothing to hinder success in that direction. It may therefore be said that any cheese made according to the system is rightly called by its name whatever the size or form may be. This does not argue that these items are unimportant ; they must be taken into account in determining the management, for the condition of the curd when

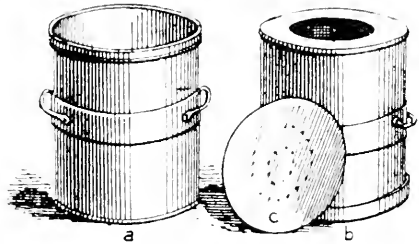


FIG. 118.—CHEESE HOOPS.

dropped from the scalding must depend—in hardness and consequent dryness—upon them.

The general Cheddar shape, whether of full-sized goods or loaves, is cylindrical, with the diameter and depth about equal. There are sound objections to cheeses over 80 lbs. in weight, in the unnecessary labour in handling them, and the risk of breakage and loss incurred by it, all these increasing with increase of bulk. As long as the trade will give more for the largest goods than for lesser ones, makers will be willing to face the consequences ; but there is a noticeable tendency to reduction, which has not reached its limit as yet.

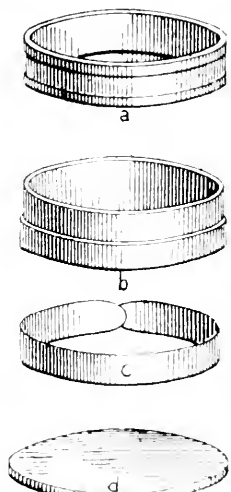


FIG. 119.
DOUBLE HOOP, FILLER, GIRTH, AND FOLLOWER.

The moulds are commonly called "vats" (a misnomer, for a vat is properly a vessel for liquids), and sometimes "*hoops*," which term we shall use to avoid confusion with the fungoid moulds of the curing-room. These were formerly made by coopers, of heavy wood, and many such are still in use, and likely to bend the backs of a few more generations. To facilitate the removal of the cheeses, a screw opening arrangement was introduced in the fifties, and this made them more tolerable. Better in every way are those made of tinned steel (Fig. 118), with a diameter of one-eighth to one-fourth inch greater at the open end than at the other, to allow the cheeses to slip out easily. They should be strengthened with bands, especially at the open end, where a flat galvanised iron band is much better than the usual round hoop. The bottom should consist of two parts, one fixed as shown at *b* (hoop reversed), with an open circle, the other (*c*) a perforated disc, exactly fitting above it when in use. This allows of a more perfect edge to the cheese, and an easier discharge for any whey pressed out; and is a convenience in emptying, the hand being pressed upon the bottom to start the cheese when needed. It should be deep enough to take the quantity of curd required, with no more than an inch of piling above the edge, so avoiding waste and crooked pressing.

Another form is shown in Fig. 119, the "double" hoop so called because it gives the cheese the form of the Double Gloucester, hereafter described. The products of the present system when moulded in it, are known to the trade as "Cheddar Doubles." The hoop *a*, of wood, is usually cooper made, and provided with a filler *b*, which fits on the open end with a metal rim to keep it in place. This enables the curd to be piled so high as to require a girth *c* to surround it, while this in turn allows each hoop to serve as a follower for the one next below it, so that several may be piled within one vertical press, the follower *d* for the uppermost cheese being a plain disc of wood of an inch or two larger diameter than the girth in place. The cloth is drawn tightly over the curd before the filler is removed, and the girth then quickly passed around it, being held as in Fig. 120.

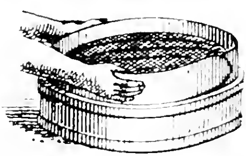


FIG. 120.
GIRTHING DOUBLE CHEESE.

A scale, Fig. 121, with a large scoop capable of weighing at least half the curd for a cheese at one time (and serving also for weighing salt), will enable the dairyer to secure uniformity in the depth of his cheeses, a point of some importance in the eyes of the trade. With any increase of moisture, a proportionate allowance in weight must be made to allow for after-loss. The knowledge of the total make of curd for comparison with the quantity and quality of milk, and the cheese as pressed, and as cured, is desirable, and furnished by the same means. Care must

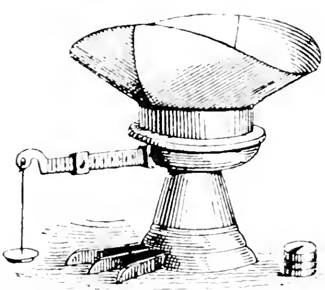


FIG. 121.—SALT AND CURD SCALE.

be taken to avoid scattering curd or salt on any part of the scale save the *inside* of the scoop, or it will soon be spoiled.

With the hoop shown (Fig. 118) a strainer-cloth is used large enough to hang inside it and fold conveniently, with margin enough to cover the curd. This put in place, the curd should be well and evenly pressed in with the hand, and the free ends drawn over and tucked in. Over all comes a "follower," or disc of tinned steel, another of wood (Fig. 122) called a "cross-follower," and the cheese is ready for pressing. This method is simple, and the best with ordinary presses, its only objectionable point being that it makes a second clothing necessary, and gives much washing work, the first day's cloths speedily becoming clogged with the curd. If allowed to get foul, they affect the flavour of the cheese similarly to some extent.

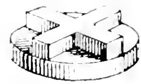


FIG. 122.—WOODEN CROSS-FOLLOWER.

Pressure is more necessary to the Cheddar system than to some others, because of the dryness of the curd; indeed it may be taken as a general rule that the wetter the product the easier will it "go together," as the old makers say. This rule must be taken with sundry limitations, but it is correct as to fact, and will be understood when we remember that the larger the remainder of whey, the greater will be the rapidity and extent of fermentation, and its results of curd ripeness and viscosity. Hence some systems do not need pressure at all. The amount of it suitable to the Cheddar system is regulated by the size and age of the cheese, for the variations in condition with well-made goods are insufficient to justify any difference in management. The larger the cheese the more pressure it needs, because it offers a greater resistance of elasticity to the action. In this respect it is like india-rubber, though possessing a much lower degree of the quality; capable of compression, but resisting as most substances do not until brought to their final possibilities of solidity. The contraction observed all through is due to the same cause,—the physical character of the coagulated casein. As to age, for the first hour it needs only a pressure sufficient to cause a dripping of the remaining free whey, which it is the business of this process to expel, and as this will be also in proportion to the size of the cheese it is a safe guide; but after that point it will need a greater weight—that which is effectual on the first day being too little to cause any appreciable further compression on the second day, for the resistance naturally increases with the solidity. However well made a curd may be, only by judicious and sufficient pressure can it gain a perfect texture and preserve its shape. Excess does mischief, especially at the outset, when it brings together the outer part too quickly, enclosing the air and free whey of the inner part, and making the latter of a loose texture, or full of "eyes" (irregular rounded cavities), as the case may be. This is more frequently found in *loaves* than in large cheeses, because the difference in proportion of pressure suitable to the two cases is not rightly calculated, the makers being most familiar with large goods, and making the small ones occasionally out of remainders of curd. Probably four-fifths of Cheddar loaves are so made, and being regarded as odd products do not receive the consideration they deserve in these minor points. Experience proves that the desired result can be obtained in less time than is generally supposed. When efficient presses are properly used, the cheese may be put into press on one day, the weight increased the next morning, and again the evening of the same day, and the cheeses should be ready for the curing-room on the following morning. As it is, they remain three or four days in press. With low power presses this is well, but in any other case it is wasteful of press and floor-space and hoops, with original cost, and that of their cleansing. We may therefore divide the pressing into three stages, and the weights suitable to these are given in the table below :—

Cheeses.	Stage 1.	Stage 2.	Stage 3.
14 lbs. or less.	2 cwt.	5 cwt.	10 cwt.
28 ,,	3 ,,	7 ,,	15 ,,
40 ,,	5 ,,	10 ,,	20 ,,
60 ,,	7 ,,	14 ,,	25 ,,
80 ,,	10 ,,	18 ,,	30 ,,

The best sources of pressure are combinations either of levers or springs with screws, attached to a frame so constructed as to hold the cheeses conveniently in an upright or a horizontal position as may be desired. A single press of the lever type is shown in Fig. 123, consisting of a bed *a*, on heavy feet *b b*, with uprights *c c*, bearing a head *d* bolted to them, and carrying the levers. This head is hollowed at a point midway between the uprights to allow of the screw *e* passing freely through it, and has projections to which the levers *f* and *g* are attached. The lever *f* is provided with a series of holes, with a pin *h* which can be placed in either of them, and upon which the lever *g* rests, while the latter carries at its free end a grooved pulley *i*, over which a chain *k* runs, carrying a set of weights *l*, so made as to allow of being easily put on and off. By shifting the pin *h* to right or left, the leverage is reduced or increased respectively; and this, with the alteration of the weights, enables the pressure to be regulated from the lowest to the highest limits of the table above. The screw is actuated by a wheel *m* with handles, a plate *n* resting on the followers. The screw being turned until it is tight raises the lever *f*, and this in turn the lever *g* and the weights, all of which sink again with the compression of the curd until the wheel *i* rests upon the press head, when a fresh raising is needed. At first the levers fall quickly, and need frequent attention; but every interval is longer than the last, and if the press is screwed up at nine o'clock in the evening, it will not run down by the morning. This style of press has its difficulties. The plate *n* being necessarily made to move easily between the pillars, and connected with the screw by a free joint, is liable to tip to one side or the other, and this in proportion to the looseness of the fitting. This last is excessive in some presses, a point to be watched in purchasing. If such tipping occurs in use, the result will be ill-shaped goods, and this especially when two or more cheeses are piled on each other. The buyer and consumer will both object to this, and the best of curds will lose from 1d. to 2d. per pound if out of shape. The cheese must be placed so that the screw may be immediately above its true centre in any case, and this may be done by setting the hoop by the circular whey gutters in the bed *a*, for when the press is properly constructed these are true to the screw centre. But it is not safe even then to trust the cheese without examination. A glance when screwing up afresh will show whether the pressing is level. There is a limit to the upward lever movements, the chain *k* preventing any further progress when the weights have risen to the head; if the screwing is carried further, the pressure on the cheese is excessive, and there is danger of either the cast-iron head or the chain breaking. Forewarned, however, is forearmed, and with these

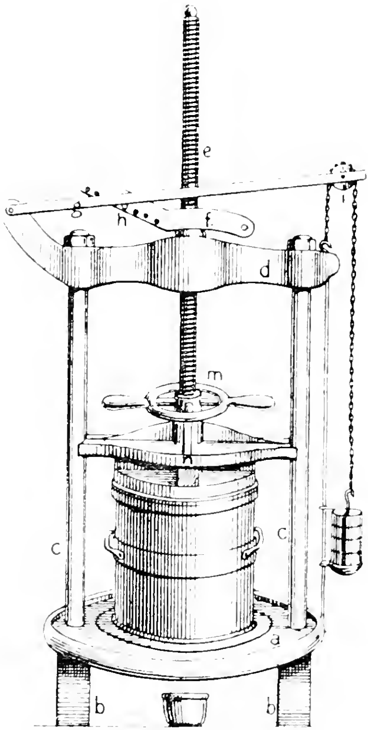


FIG. 123.—LEVER PRESS.

cautions observed, there is no single vertical press in the market which more nearly meets the needs of the case.

It is often desirable on economical grounds to have two or more screws in one frame, in which case the cost and space are both much less than with single presses. Such a combination is shown in Fig. 124, where the differences in the construction and attachment of the levers and weights will be observed; especially with the inner sets, the second levers of which are placed beneath the bed, and connected with the first by long rods, and the weights are lifted within the limited scope shown. Here the pressure is greater by one-third than with the outer sets, which should therefore be used for the earlier pressing. There is loss, however, as against the previous example, because the projecting arm cannot be provided, and the levers are shorter; there must therefore be an increase of weights. The bed here is of wood, with dishes of lead to catch and direct the whey into vessels below. If this part is of cast-iron it should be much stronger than is necessary in a single press. Commonly there is but one weight, and that insufficient for full requirements, and the dairyer should insist on a series of separate weights of known effectiveness, for otherwise he has no means of regulating his pressure. The press-makers' notion of the case is generally very elementary, to judge by the machines on the market.

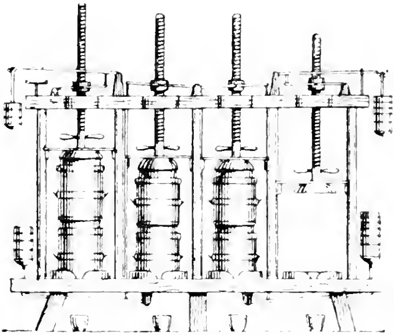


FIG. 124.—LEVER PRESS.

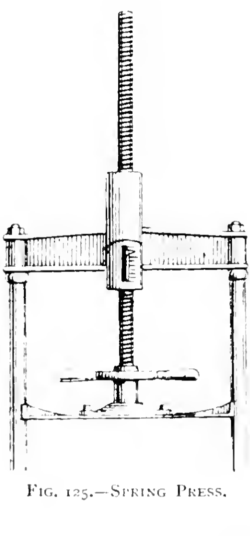


FIG. 125.—SPRING PRESS.

In Fig. 125 the source of pressure is a powerful spring, which is enclosed with the nut (below it) in a box, the screw passing through the whole. When the plate reaches the hoop, the screw is compressed by the further turning; and the pressure exerted by it is in proportion to the extent of its compression. This result is shown by an indicator, which rises with the spring, and points to the weight applied as marked on a brass scale. This plan does away with all shifting of levers and weights, and admits of any number of screws being set in one frame as near together as will allow only of the pillars coming between the cheeses, and therefore with saving of space, and proportionate increase of strength in the head. So far as simplicity and convenience go, this is the best type of vertical press for a factory. The one question remaining is the effectiveness of the spring, of which the reader may be doubtful, as we were until we found one which had been twenty years in use and was still doing satisfactory work. But everything depends on the particular spring in use; and with the possible variations in strength and staying power, it is well to require a guarantee of efficiency or replacement, extending over a reasonable period.

On the following morning, as early as may be, the cheese, if pressed in ordinary hoops, is removed from press and bandaged. There are several methods of doing this latter, either of which may be followed. The system has no rule on the point, but that described is the simplest and best of them all. A bandage of grey calico, the thickness of which must depend on the size of the cheese, made to fit it closely, is drawn upon it from the lesser diameter downwards, and should leave from $1\frac{1}{2}$ to 2 inches of ends to overlap. A little skill is needed to put it on without breaking the edges, and in order to this it should be laid about $\frac{1}{2}$ inch over the edge of the cheese nearest to the operator (Fig. 126), a hand then moving steadily on each side until the two meet, drawing it about an inch over on that side. Then the hands should return to their starting-place, drawing as they go, and repeat this rapidly until the work is done. If one hand only is used, or the two follow in rotation, the bandage will almost inevitably be twisted, and the seam will make a corresponding irregular mark on the cheese. The free edges being turned neatly back so as to lie as smoothly as possible, a circular piece of the cloth should be laid on the top of the cheese, the overlapping turned down upon it, and the metal follower of a second hoop laid above the whole, the hoop itself following. The latter is now turned over, the uppermost end of the cheese covered as the other, a plain wooden follower put in place, and all is ready for further consolidation. Doubles are bandaged in similar fashion; but instead of "tops and bottoms," a loose cloth is placed

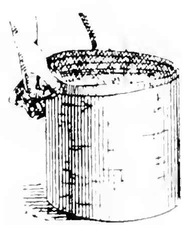


Fig. 126.
Bandaging Cheese.

over the end, the girth pressed around it, and as close to the table as possible (see Fig. 127), the hoop placed over, and the whole turned. The corners of the cloth are allowed to fall over the sides. The upper edge of the girth should now be level with the cheese surface; or if not so, then drawn up to it. A cloth laid smoothly over the cheese completes its preparation for the press.

When the cheese is taken from press, the bandage and end pieces are found to be adhering to it, and care must be taken not to detach them; for this done they cannot easily be made to take a fresh hold, and the surface under is very liable to crack. The overlapping is sewn with double thread, so as to leave two free ends, which—being drawn tightly—are tied, and the folds evenly and neatly adjusted, so as to leave as little impression as possible on the cheese. If the bandage is well fitted and strong enough (medium grey calico will meet the outside demand for strength), no other support will be needed.

One caution must be given here concerning the hoops. Their proper working will depend upon their being kept in good shape. Made as described, they will be easily emptied as long as they are not bulged; this once done a difficulty arises, and they are banged on the table to stir the cheese, more damage being done meanwhile. The hoops are easily spoiled, and the cheeses injured in shape by such foolish treatment.

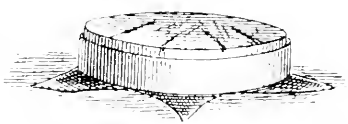


FIG. 127.
RE-COVERING DOUBLE CHEESE.

The cheese should now be marked with its date, and removed to the curing-room without delay. There it will be in a proper temperature, which will often be missing in the less protected press-room. Many a cheese becomes cracked by shrinkage in cold dry draughts through neglect at this point.

Curing.—The general character of the changes wrought in curing have already been described, and it is only necessary here to apply those earlier teachings to the needs of the system.

The best temperature for the Cheddar curing-room is 65° F., and the range from 68° F. upwards to 60° F. downwards. Above the upward limit the cheese dries too rapidly, considering its naturally dry character. For a time the fermentation makes progress in proportion to the temperature, but the loss of moisture checks it ere long, and the result is not the same as would follow with a wetter curd. Moreover, there is a greater danger of losing fat with a dry cheese of good quality than with a moister one. On the other hand, from the lower limit downwards the tendency to retain moisture in the outer parts, with discoloration, uneven curing, and ill flavour, increases steadily. It will, however, be readily understood that a Cheddar curd will not suffer so much in this way as one containing more moisture. The formation of mould will be scarcely noticeable within the range of temperature given, and this is an advantage because of the saving in bandages, which are more quickly spoiled, or if used afresh are more troublesome to cleanse than if free from moulds, and because of the greater cleanliness in handling the cheeses.

The regulation of the temperature by either of the methods already given should not be difficult. When the temperature has reached the lower limit of its range, if there is a probability of increasing cold, sufficient heat should be provided to raise it 5° F.; and if this rule is followed with any increase of cold the results will prove the economy thereof. There is great reason to believe that many dairyers, when they find the thermometer reading down even to 55° F., wait on the hope of better conditions returning, or, finding the temperature not far below the safe line in the day-time, give little thought to the possibilities of the night. The curing-room, as designed, is calculated to protect from sudden or considerable variations; but while the range of temperature within it will be narrow compared with that of the open air, it must not be supposed that the internal air will not get colder or warmer with outside changes; and it must also be remembered that whatever changes do occur within it will not be so easily corrected by returning ones without, as in a less protected room. The best curing-room in the world will not do much for its owner in the absence of intelligent management; and we are convinced that, within the lines of the strict system, there are no sources of loss so great to-day as bad curing conditions. So far as this item of heat is concerned, we also believe that there is no method of supplying and regulating it so economical and easily applied as the hot-water circulation earlier described. With rooms of the construction and proportions given in the farm dairy and factory plans, four doubles of pipes will suffice to raise the temperature an average of four or five degrees for each bend employed, and—with a proper control of the air inlets and outlets—maintain the needful warmth through our coldest nights.

The cheese needs more air moisture than the products of most other systems. It gives off in its first days 2 lbs. per ton and upwards in twenty-four hours, this decreasing slowly but steadily under correct conditions, the average being probably from 1.2 lbs. for heavy to 1.5 lbs. for smaller and thinner goods. It will be remembered that the latter are allowed to retain whey enough to bring them out cured with a mellowness and moisture equal to those of the larger cheeses.

The moisture so cast off is usually ample for the needs of the case, but it is easy to err in heating and regulating the air so as to give too free a passage of warm air, which will take up more moisture than a colder air would do, and so exceed the occasion; or, on the other hand, to confine the damp air until it is saturated, and cannot relieve the cheese of further discharges. The hygrometer must be frequently consulted, and the moisture kept within a range of 78° to 88° of humidity, or 2° to 4° F. difference between its two thermometers. The instrument should be so placed as to register the condition of matters near to the cheese, and not at a distance from it. When more moisture is needed than can be retained by proper control of the air, troughs (Fig. 128), containing water, may be set on the circulating pipes; or, when these are not in use, the floor may be sprinkled from a watering-can. This occasion is not so liable to arise as the opposite, which can be managed by simply allowing more air to pass through, with warmth to encourage its speed if necessary. The maintenance of sufficient moisture saves the cheese from excessive loss in weight, and so indirectly encourages the fermentative changes so essential to perfect curing; and this latter without the need for so much original whey in the cheese as would furnish the organisms and materials for excessive fermentation, especially of the L.A. kind.

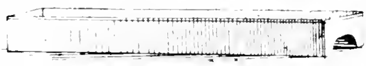


FIG. 128.—WATER TROUGH.

The cheese shelves may be of the simplest character. Strong standards of wood, as in Fig. 129, where the uprights (*a*, *a*) as shown are secured to the ceiling and floor, with cross pieces (*b*) bearing planed boards (*c*) of $1\frac{1}{2}$ in. thickness, and from 12 to 18 inches wide, according to the cheeses to be made. In calculating the length of the shelves, the diameter of the cheese, and an allowance of two inches for spaces between them, should be added together, and the result allowed for every cheese. The shelves also should have a similar air-space between them, being separated by a block of wood (*d*) as shown. Cheeses lying too near each other become sodden and discoloured at the nearest points. Each shelf should be of one board if practicable, or, failing that, have its joints kept well closed with putty, which should be allowed to dry

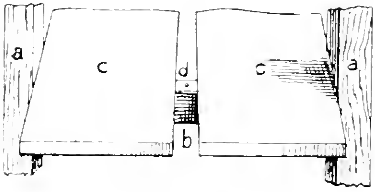


FIG. 129.—CHEESE SHELVES.

well before cheese is put upon it. The vertical distance between any two shelves must be sufficient to allow cheeses to be placed on or removed from them without damage or difficulty. Generally three inches more than the depth of the cheese will suffice. If goods of varying depth are made, it will be well to store the heaviest on the lowest shelves, and the smallest on the uppermost ones, both to save labour and risk in turning. The lowest shelf should not be less than 18 inches from the floor, which may then be used for storage in emergencies. The shelf edges should be slightly bevelled and quite smooth.

The cheeses will have need to be turned daily (excepting on Sundays) for the first month, on alternate days during the second month, and afterwards twice weekly will be sufficient, to secure the even distribution of the moisture and its accompanying advantages. They should be examined at the same time for evidences of damage, such as cracking, mites, &c.; and a keen eye will detect anything amiss in a cheese while it is being turned, so that no extra time may be consumed upon it. All goods up to 80 lbs. weight are best turned by hand, the lighter ones upon the hands only, the heavier with the aid of the knee. The cheese being seized as at *a*, Fig. 130, is drawn from the shelf, the lower hand supporting it so that it does not scrape against the edge in passing, and then dropped into position *b*, and turned over quickly *towards the operator*, so that if there should be any slip of the hand the cheese will fall against him. If such should happen when it was being turned in the other direction, it would be difficult to save it from a fall to the floor, or against the shelf edge, with almost inevitable damage. In replacing it on the shelf, it should be lifted as at *c*, carefully clearing the edge. With care the dairyer will soon find himself able to gauge distances in turning with safety, but beginners in their anxiety to avoid collision with the shelf are liable to strike the one above. The heavier goods are turned in the same way excepting that the hands are not trusted entirely, the bent knee taking part of the weight. The cheeses stored on the higher shelves make it necessary either to stand on a small

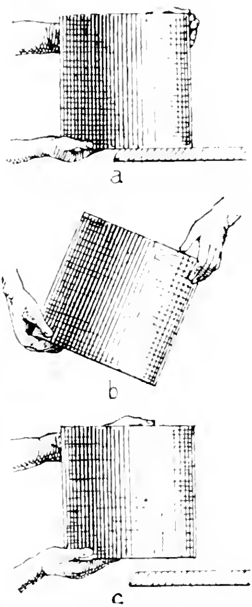


FIG. 130.—CHEESE TURNING.

bench, or on the lower shelves; in the latter case, one on each side of the gangway should be used, and care taken to avoid touching the cheeses on them with the feet. In carrying young cheeses care must be taken to avoid breaking them. Thin goods are most liable to breakage, and should be borne on their edges. In factories a little table on wheels, like to but lighter than the bandaging table (Fig. 72), may be used.

Some makers grease their cheeses with whey butter, or a special preparation, to keep them from becoming too dry and cracking, but this is unnecessary where the humidity is correctly maintained. Others press sheets of light straw paper on the surface of thin goods with a hot flat or "sad" iron, and for the same purpose, but this also is a waste of time and trouble. We followed this practice till we found that the cheeses which were not so treated kept in perfect condition in a proper air, and that these others would crack in spite of the paper when the air was too warm and dry. Years of subsequent experience have confirmed the teaching on this point.

For several weeks Cheddar cheese is practically tasteless; at two months it is beginning to develop its nutty flavour, and a month later this is distinct enough to meet the tastes of many consumers. The rennet, however, having had a better chance than would be possible with higher proportions of retained whey, the cheese is proportionately more digestible; and, so far as the consumer's advantage is concerned, he may use it then without either the effects of indigestibility on the one hand, or of pungency of flavour on the other. For those who desire a stronger flavour, it will have to be kept two months more or upwards; and if made on the lines laid down, and as perfectly as it may be from sound milk, will be at its best from eighteen months to two years old. If such long keeping is sought, it should be stored, after four months' age, in a temperature never exceeding 62° F. nor falling below 55° F., with the humidity of the air maintained. The loss in weight under such conditions will not be great, but taken with the interest on capital lying idle, and rent of storage space, and the cost of labour in turning and of fuel, will justify such an advance in the selling price as the trade will not meet. In this case the gourmand must either pay the dairyer direct for bringing his article to perfection, or do the greater part of the curing in his own cellar. In respect of firmness and safety in transit Cheddars are ready in three months, and apart from special trade developments it is well to market them at that time.

The proportion of cured cheese to the original milk depends upon the time of sale, with slight variations arising out of making conditions. An imperial gallon ($10\frac{1}{4}$ lbs.) of average milk will give a pound of cheese at four months old if made and cured as advised, but if waste is incurred at any point of the work it may require an excess up to twelve lbs., or even more, of such milk to give that result. As the milk quality is less, or the curing extended, the cheese ratio will be less, while with better milks it will increase.

At the time of sale the weight should be ascertained, and the loss by shrinkage since the making, and these facts, with the time in storage, recorded for comparison and reference. It is worth while weighing the makes of separate days or vats separately, so as to complete the records. They should also be examined, and, in case of special reason, cut with a cheese-taster. Useful as it is to know the quality of the cheese, it is not well to cut too many, the buyers naturally objecting to the practice beyond certain narrow limits. When the goods are sold the dairyer can easily take note of the qualities of each one ironed, and draw the buyer's attention to any of special interest, so reducing the number which it may be necessary to cut for information's sake. In this matter the factory, with its larger number of cheeses made together, enjoys an advantage—for one is a sample of the entire product of each lot of milk.

Influence of Essentials.—Having described the management appropriate to sound and natural milk of average quality, we may glance back to note the leading points in the system by which the special characteristics of the product are secured. They may be summarised as follows, viz. :—

(*a.*) A comparatively low standard of ripeness for milk and curd.

(*b.*) A correspondingly low level of initiatory temperature and a short exposure to its highest temperature.

(*c.*) The expulsion of the whey by pressure, during the process of dividing the curd, by the use of special implements, thus producing —with the after-help of heat—an unusually dry curd.

(*d.*) The extraction of the free whey by draining, airing, and pressing the curd.

(*e.*) The exposure of the cheese in the curing-room to a moist atmosphere, which but slowly carries off the water expelled in the process of curing.

These points are shared with all other systems excepting *c*, which is peculiar to the Cheddar system. But *c* is consistent with and helped by *a* and *b*, which tend to a slower fermentation than would accompany higher temperatures and ripeness ; and as *c* leaves behind a specially low proportion of whey in the curd, *d*—extracting that which is set free—leaves proportionately less in the made cheese than with other systems which do not follow the principles of *c*, while *e* provides for the retention of the remaining water to an extent suitable to the case and thus encourages the curing changes. The rennet is allowed a greater share of influence than usual, but the fermentation is well balanced with it, and the L.A. form furnishes, with the heat, sufficient firmness for all purposes. The fermentable materials of the whey being in such low proportion in the cheese, the flavouring changes are also slow, and never reach the pungency which belongs to old goods of other makes. Hence the Cheddars are,—

(*a.*) Digestible at an early age, because the rennet is not opposed by the L.A.F. to the usual extent.

(*b.*) Long-keeping and mild, because the fermentable materials of the whey are more limited, and the fermentation slower than would be the case with wetter curds, and to these leading characteristics may be added the following, which are needful for completeness, viz. :—

(*c.*) The quality is fully secured by the rennet and C.F. action in the casein, rendering it mellow and plastic, while other ferments help by converting casein into volatile fats.

(*d.*) The texture and solidity are helped by the avoidance of any sealing of the curd surfaces in breaking and scalding, by the ripening of the curd, by the grinding appropriate to the system, and finally by the pressure.

(*e.*) The narrow limits of fermentation secure them from the formation of poisonous ptomaines; and care of the cattle and their feeding will give freedom from objectionable qualities introduced by bad management before the dairyer comes into control.

The consistency of the Cheddar system with its aims is therefore established ; and the reader will by this time be able to justify the directions and cautions given with a view to the realisation of those aims, and to keep within the essential limits of the system such variations in practice as are at any time necessary.

The practical impossibility of obtaining uniform milk and attendant conditions will give him daily experience in manœuvring to obtain uniform excellence in the products, but this is possible, and the system elastic enough for any occasion.

Excess or Deficiency of Lime Salts.—These create difficulties which have already been noticed,—the former producing persistent alkalinity, and the latter giving deficient co-operation with the rennet, and are both troublesome to the cheese-maker. The product in either case is a *weak* curd, which, with ordinary treatment, is slow in coagulation and contraction, therefore also in whey expulsion and hardening, in curd ripening and drying, and finally makes a soft and soapy cheese, wanting in firmness, and more or less defective in flavour. The reader is recommended to read up the whole subject back to the foundation in soil composition.

Excess.—In this case the practice of ripening milk by whey is necessary, so that the acid already formed in the ripener may neutralise the alkalinity of the milk, and more whey than usual will be required. As the dairyer will in very few instances have the means of determining the excess, which will vary somewhat with movements from one part of a farm to another, or with the feeding of foods from different parts, it will be best for each to make his own experiments, with notes thereon for constant guidance. Taking his clue from earlier references, he can judge whether his soil is likely to be the cause of any irregularity observed, and carry the investigation as far as analysis if he finds reason to do so. If the grounds are sufficient, he can increase his use of whey until he finds his milk and curd working as described under ordinary conditions, and fix his practice accordingly whenever his milk comes from the troublesome locality. We have had experience with a milk the owners of which asserted that no good cheese had ever been made from it in the home dairy, and which proved to be hampered with this condition. The test applied showed it to be unusually alkaline, and when treated with this it resisted coagulation under air conditions for a day or two longer than other milks beside it. But mixed with other milks in large vats, or treated as advised, it gave no trouble, and showed no characteristic in. the cured cheese which might be attributed to the original difficulty.

Deficiency.—The proper cure for this is to furnish the soil with lime in some soluble form, and no treatment of the milk in the dairy is so satisfactory. Indeed there is not at present any other method of supplying the requisite CaO which we are able to recommend to the dairyer as properly meeting the case. With a slight deficiency it is possible to procure a firm curd by an increase of whey, the acid being able to coagulate casein in the absence of lime salts, but only in such cases can this be used without seriously disturbing the balance of initial influences. Nor are the effects —even within narrow limits—exactly the same, nor the cheese on the strict Cheddar model. An instance of the necessity for the soil-correction on a large scale will be referred to in a later chapter, showing the entire practicability and advantages of that course.

CHAPTER XII.

THE CHEDDAR SYSTEM WITH OVER-RIPE AND TAINTED MILKS.

Classification.—In this chapter we deal with the management of four kinds of milk, which may be classified as follows, viz. :—

(*a.*) Sour milk, in which the friendly ferments are in excess, but which gives no evidence of putrefactive taint.

(*b.*) Milk in which the C.F. is in excess of the L.A.F. without evidence of taint.

(*c.*) Milk tainted by unfriendly ferments.

(*d.*) Milk which has absorbed odours from other sources than those referred to in preceding divisions.

The third class does not here include milks affected by the microbes of infectious *animal* diseases, such being dismissed as unsuitable for food production.

(*a.*) **Sour Milk.**—There may be here either an equal L.A.F. and C.F. action, carried beyond the standard of milk ripeness, or of the two the L.A.F. may be in excess of the other. In either case the result is a "pure sour," with a flavour and odour not disagreeable, and capable of being made into a comparatively valuable cheese. In the former case, however, the C.F. helps the rennet to the ordinary curing, though the L.A.F. influence is opposed to it ; whereas in the latter the L.A.F. action is proportionately greater by reason of the relatively weaker C.F. action, and the rennet has still less chance of effecting its digestive work,—the product of the former is therefore better both for the dairyer and the consumer. They cannot be distinguished at the outset, but the rate at which the curd becomes flaky or stringy will point to a safe conclusion,—for when this is rapid, we may be sure that the C.F. is equal, or nearly equal, in influence to the L.A.F. ; whereas when the curd is hard and crumbly, the greater influence of the L.A.F. is shown.

Between the extremes of equality and difference in power there are many degrees of relation, which may be recognised by the means described, and the management varied accordingly. It is of no material consequence to know anything beyond what the acid and speed in coagulation can show until the whey is removed, the management up to that point being the same in all cases. The state of the milk being ascertained by the litmus test, the early probabilities may be estimated. The colour may range from F to N (Colour-plate), but beyond the latter coagulation is liable to take place before the rennet can be stirred in, and the curd will be practically useless.

What should be the relation of rennet to a sour milk? The excess of acid would suggest an increase of rennet to balance with it; but this would also unduly hasten coagulation, and make an increase in the rate of breaking necessary, with a corresponding loss. On the other hand, while less than the ordinary amount of rennet would lengthen the time of coagulation in proportion to the deficiency, it would equally increase the influence of the acid as against the rennet. It is therefore well to leave the rennet quantity unchanged; and here experience confirms theory. Fermentation and rennet action will give more than the usual curd contraction, and in proportion to the former the temperature may be lowered with advantage, within limits fixed according to that of the air.

In warm weather, when sour milks are naturally most frequent, the subtractions of degrees (F.) in Column I. of the table at the end of this section may be made from the standard temperatures; while in colder weather, below 58° F., those given in Column II. will be suitable, taken according to the litmus indications. In any case, the heating must be as rapid as possible, and if the old method is followed some new milk should be used for the boiler. Despatch must be made of all work, for every minute lost increases the difficulty and risk, so that it is wise to have help to carry through the preparations for coagulation. The stirring in of the rennet must be vigorous, and cease as soon as is consistent with proper distribution. The time taken to produce coagulation will vary, the numbers in Column III. giving the minutes under average conditions. The breaking must be done at a speed proportionate to the coagulation. There will always be some loss, but it should be made as little as possible consistently with the main aim, which must be to get the curd as small as usual before scalding. Of the two evils the waste of curd by breaking is the least. The temperature for scalding may be reduced by the degrees given in Column IV. for warm weather, and in Column V. for colder weather. The hardening in scald will occur earlier, and must be watched for from the end of heating with great care. The stage of curd hardness should be the same as in half-creamed milk; for the whey must be as fully expelled by the end as in an ordinary curd, and the greater contraction will not carry it to the desired result if the stirring be stopped earlier.

From this point for the most advanced curd with the lowest scalding temperature, the variations may rise with less advanced curds to the ordinary hardness with such as are but little over-ripe, as F. The whey will naturally be removed earlier, but the time must be determined by the packing ; and here is the first point at which the management is varied to meet the case of equal L.A. and C. fermentation, or an excess of the former. The packing will proceed more rapidly in the former case than in the latter, and by the time occupied in this we may judge which experience is before us. Taking the case of *equal fermentation*, Column VI. gives the average time in minutes required for the proper consolidation of the curd ; and as it varies from this in the direction of increase, being tested by the hand, it may be known that the L.A.F. is in proportionate excess.

The curd should be treated, after the whey is drawn, consistently with its state as shown in Column VII. In the lower stages of fermentation it is best to pile it as usual, simply cutting and turning at proportionately shorter intervals until it reaches the ordinary curd ripeness, or—if not then solid enough—for a little longer ; but with higher stages less depth in pile is desirable, until

FIG. 131.—CURD TIPPED FOR AIRING.

at J and onwards the squares of curds can be tipped against each other as in Fig. 131, when the air will cool it and check the fermentation. The turning, airing, grinding and salting, must follow as quickly as is consistent with the state of the curd. The proportion of salt will depend on the dryness of the curd, which should not be far from equal to an ordinary curd. The stringy and soft state of a sour curd, especially in advanced stages, gives an impression of more moisture than is present, though often there actually is more than usual, and this must be judged as nearly as may be. Wherever a drying oven (Fig. 209) is available, the dairyer can test the amount of moisture in an ordinary curd for a standard, and in varying sour curds for comparison, and make note of the results with suitable proportions of salt. Such a test could not be made in time to be of service with the same curd, but it would be valuable as training the judgment, though only as applied to curds which the dairyer had handled would it be of use, because the condition cannot be accurately described. Hence we do not attempt a standard here. The salt must be calculated for an excess of free whey as in other cases, but no advantage can be gained by increasing it for any other reason. The pressing temperature should be a degree or two lower if the final stage of fermentation in the curd is beyond the ordinary standard, and according to the excess. If the curd is unusually wet, it will give out some white whey in grinding, and the pressing must be less than ordinary at the outset when such is observed. No change need be made in the curing temperature.

The cheese will cure slowly so far as concerns digestibility, but will early develop a flavour, sour, and more or less distinct, according to its history. If a wet cheese, it will be liable to crack, wet the shelves, and attract the flies. If too dry, it will be crumbly. Both evils may be avoided if the possibility and causes of them be kept in view. In the earlier stages of excess the cracking will be very slight, and give a marbled appearance to the goods by reason of the blue moulds which soon occupy the cracks. The flavour, with its pure acidity, and a possible smack of the mould, is much relished by the gourmand and sought by the trade ; and we have known the prizes at a leading English show to go to such goods, though these, however much they may be enjoyed by the consumer, are not according to the standard of the system in the important point of digestibility.

	Subtract from temperature renneting.		Average time of curding.	Subtract from temperature scalding.		Equal Fermentation.	
						Aver. time packing.	Piling.
	I.	II.	III.	IV.	V.	VI.	VII.
F	1		18			27	Ordinary.
G	2	1	16	1		24	,,
H	3	2	13	1	1	20	Half depth.
I	3	2	10	2	1	16	,,
J	4	3	7	2	2	12	One layer.
K	4	3	5	3	2	9	,,
L	5	3	4	3	3	7	,,
M	5	3	3	4	3	5	,,

When the L.A.F. is in excess, it is necessary to pile the curd as quickly as possible in the ordinary way, for it is better to have too much fermentation than coldness and the increased tendency to be crumbly. The litmus test will be of little service here, the fitness of the curd for airing must be judged of by its flakiness and solidity. Nothing can be gained by increasing the proportion of salt, excepting for increase of moisture; for though it would check the L.A.F., it would even more check the weaker C.F., and less than usual would unduly encourage the L.A. fermentation. The results are, still slower curing, greater indigestibility, and lower food value than with the fermentations equal, and there is no escape from them. Commercially the product may be made more valuable by encouraging the blue moulds. The foregoing directions cover all that can be safely advised at present for making the best of bad cases. The chief points of the matter are, that the dairyer must keep up with the progress of his curd, and by reducing temperatures discourage fermentation as far as s safe. Concerning the latter, it should be noticed that the various stages of the work occupying less time, and in proportion to the advance of fermentation, there is less risk of the curd becoming too cold than would ordinarily be the case.

(*b.*) **Milk with C.F. in Excess.**—In our occasional experiences with such milk we found the earliest practical evidence of the existence and operations of a casein ferment. The effects observed, and attributed to this cause, are given as they arise, and we know of no other consistent explanation. With little or no excess of L.A. fermentation, there has been very quick coagulation ; but in the absence of the rennet test this was not suspected, the first sign being followed so closely by the curding of the milk as to give no room for saving the curd from being broken into minute fragments. The rennet test would have shown the danger, and therefore should be used, at least after any such occurrence, and until the regular ferment relations are established afresh. We have found in most cases more L.A. than usual, and this, though far from enough to account for the time of curding, has given warning of special conditions. In such case great care in stirring, and the use of the curding test, saves from the waste which must needs follow too long an agitation. Whether the frequency of occurrence without any excess of L.A. fermentation is sufficient to justify the daily use of the rennet test it is difficult to say, for the known observations which have been complete, and have led to our conclusions, have been few. Only in the presence of acid and coagulation tests, with conditions favourable for observation, can the facts be properly noted ; but we may now hope that such occurrences will be reported to the dairy press.

It is, however, certain that the rennet test would give an advantage from the first, admitting of variations in the preparations for coagulation in consistency with the facts. Since the action of the C.F. is found to be rennet-like, in that it tends to the softening and breaking down of the casein, less rennet may be used, reduced in proportion to the difference between the natural expectation based on the L.A. indications and the actual time of curding in the test. Supposing, for example, that with ordinary acidity (E) and the usual proportion of proved rennet, the milk would coagulate in ten minutes, as shown by test and calculation; then, since the C.F. can *with these* procure that effect in half the time proper to ordinary conditions, the rennet may be reduced to half its general quantity. If, however, the acidity would justify the expectation of a sixteen minutes' coagulation (G), the reduction in rennet would be a little less than one-fourth its usual proportion. This so far as balancing the two influences can go; but it would be better to reduce the temperature (as advised on page 221), and so make a less reduction of rennet necessary; and in the second example, the excess of L.A. would suggest that the greater excess of C. fermentation would probably act as an equal set-off against its opposition to rennet action, and the ordinary proportion of the latter—with a quicker manipulation—would give the best results. With differences between the two fermentations greater than this last, the rennet should certainly be decreased. In such cases the after-management would be closely like to that of ordinary or slightly sour curds.

When the state of the milk is only discovered at its coagulation, the curd must be managed so as to counterbalance, as far as possible, the mischievous conditions. The rate of breaking must be regulated by the acidity, for if this be no more or less than usual the curd contraction will be weak and slow, so that the rapidity proper to sour curds would be both unnecessary, and more than commonly wasteful. If, however, the softening tendency of the C.F. is more nearly balanced by the L.A.F., the speed should be greater up to the equality of the fermentations and the hardening suitable to such case. A quantity of sour whey may be added to the contents of the vat just after the skimmer is withdrawn, and this tendency to increase of the L.A.F. will greatly help to restore the balance of affairs. The proportion may range from one gallon to five gallons per 100 gallons of milk, according to the proportion of L.A.F. to C.F. influence originally present. A greater hardness of the curd must be secured in the scalding, not by a higher temperature but by longer stirring, or the cheeses will be too weak to retain their form, and the proportion of whey proper to be left in an ordinary curd is too great in view of the higher fermentation. A few minutes' stirring beyond the usual point will suffice in any case, but the use of sour whey in proportion to its state and quantity will reduce the necessity for this. The packing will be rapid; the whey should be removed as soon as the curd is solid enough, and the latter laid as Fig. 131, unless it nearly approaches to the ordinary or slightly sour condition. The C.F. excess will naturally tend to an early flakiness, and not unlikely carry it too far. The salt proportion need not be altered, unless no whey has been used, in which case it may be increased by a quarter oz. to one oz. for every pound (as calculated by common rule), and according to difference between the fermentations. According to the final relations of the two fermentations will be the rate of curing, but it is not possible to foreshadow the effects on flavour, solidity, and keeping quality beyond the general tendencies of the varying combinations. With the C.F. finally ahead the cheese will be ready earlier than usual; with the L.A.F. brought up to level, the result will be mainly like a good sour cheese.

(*c*.) **Milk affected by Putrefactive Taints.**—The ferments which cause diseases of milk have been already discussed. We may therefore proceed to describe the relations which they bear to the friendly ferments, and find in these the clue to the best management possible in the case. These relations may be classified as (*a*) association with, and (*b*) conquest of, the friendly ferments. The first relation is by far the most common—the two classes existing side by side, and varying in their relative influence; the latter is less frequent, and we have not met with any case of complete absence of L.A.F. with the presence of the taints. It is easy to account for this, for the friendly ferments being universally present it is simply a case of numerical proportions, or favourable conditions, determining the chances which the unfriendly microbes shall have of increasing in number and damaging the milk. It would seem from all observed facts that the two classes are, in a certain sense, in competition; and it is distinctly providential that the friendly ones are generally the most powerful. But there are cases in which the bad take the lead, and defy the dairyer to put them down by any practicable means of encouraging the good ones. When such cases arise no really useful cheese can be made, at least with present knowledge.

When, however, there is sufficient lactic acid present to prove the activity of its producing ferment, there is hope for the result; and if the acid is equal to the taint, and not more than should accompany ripeness, the outlook will be fairly satisfactory, and still better as the taint fermentation is weaker. The cheese cannot be strictly fine in any case, but the taints may be well brought under. But when the taint ferments are beyond the limits named, it is best to have the L.A.F. well up with them, when a good sour cheese may be made, with probably a peculiarity of taste which cannot be always absolutely got rid of, but better than anything otherwise possible. The dairyer's policy throughout is to help the friendly ferments to conquer the others, and this was followed long before any explanation of its effectiveness was known. "Fight taints with acid," said the factory managers making under the American system; and though carried out in the dark, the rule proved very valuable with their frequent bad curds. There are of course limits to its application, but the principle is sound. With this in view, we may describe the management.

The presence of a taint being discovered before coagulation, variations may in some cases be made in preparing for the renneting. If the acidity is below the ripeness stage, then—even though the ferments may be liable to cause quick coagulation—sour whey in the ordinary proportions may be used to advantage. The effects of increased speed of progress in the earlier processes will be more than counterbalanced by the quality of the cheese. It must be ascertained, of course, that the whey used is not already affected by the taints, which may in some cases reach it and the milk from the same source. No change in the rennet quantity is necessary, unless there is good reason for believing that the taint ferments are akin to the C.F. in action, as shown by similar experience. In such case the directions earlier given may be followed. Temperature may be regulated as with sour milks, when the litmus test justifies it. The heating should be rapid, and the curding test kept at work from the moment of renneting, with cautious stirring, which will leave the coagulum at rest at a moment's notice.

It is not always known at the time of receiving milk that anything is amiss. The heating brings forward the evidence in hasty coagulation, or later in the scalding, with a smell. In the former case,—the ripeness, temperature, and rennet, being as with good milk,—the after-management must supply such compensations as are possible. The introduction of sour whey in the course of breaking, when there is reason to believe that the taint is ahead, may be properly resorted to.

The tendency to the production of foul gases must be met by breaking more finely than usual, so that they may not be sealed down by the heat and cause a floating curd. This makes necessary a more rapid breaking speed than with a sour curd, but the loss of curd and fat is better than the mischief which the taints can do. The "floating" does not always accompany even the most advanced taints, but there will almost invariably be some gas, of which much less will be retained in fine curd than in that of ordinary size.

Unless with a special fermentation of the C.F. kind, the hardness in scalding should be as with ordinary curd. The vat should not be covered after scalding, and the whey should be drawn as soon as the curd is packed. If acid is in excess of ripeness, treat the curd as if sour; otherwise, pile and help it forward as quickly as possible. The standard of acidity should be advanced a stage or two, according to the power of the taints; and when reached, the curd should be divided and aired as quickly, and in as small size, as is consistent with he maintenance of a safe temperature.

The main point now is to expose the curd to the action of the air, and as soon as it is dry enough it should be ground *twice*, and shaken from the shovel held at a good height over the vat or cooler, with a good draught passing. By this means the volatile products of fermentation are burned up, so to speak, by the O of the air, and the ferments checked. With the air-temperature lower than 60° F. the curd temperature may be maintained by warm water under the vat, kept at from 80° F. to 70° F., according to need. This airing should be done before salting, the latter having a tendency to harden and seal the curd surface so that gases do not escape as before. If the drying is too quick, it may be checked by sprinkling with water warmer by ten degrees than the curd should be. The proportion of salt must depend on the state of the curd, an increase of from $\frac{1}{4}$ oz. to 2 ozs. to the pound as calculated, being made as need arises with the wetness which often accompanies a taint, and with the extent of the final fermentation. The pressing and after-management may be as with sour curds. If any gas forms within the cheese, it should be set free by a skewer. The time required for curing will vary much with the fermentative combinations, and it is useless at present to attempt any settlement of the matter. The character of the curd, as seen in the light of the general teachings on fermentation, will enable an estimate to be made in each case consistent with the facts.

(*d.*) **Milk affected by Non-putrefactive Taints.**—These necessitate but few alterations in the general working of the system. When the air-temperature is lower than that for pressing, the scalding temperature should be advanced a degree or two as may be needful, and the curd ground twice, and a little earlier than usual. These changes prepare us for a thorough oxygenation, as with a putrefactive taint, the curd being exposed to the air (see last section) for the removal of the odour, and this before salting. With the precautions noted, there will not be undue drying or cooling.

The principles, and in the main the practices, recommended in this chapter for the purposes enumerated are suitable to other cheese-making systems, with such modifications as may be consistent with their general principles.

CHAPTER XIII.

THE CHESHIRE SYSTEM.

THE cheese of Cheshire has long been famous, but we are unable to account, even with probability, for its origin.

The county of its birth is an undulating plain, almost wholly occupied by the rocks and soils of the New Red Sandstone system, the latter being either sandy or clayey. These soils having no limestone materials mixed with them by transportation (as in Somersetshire), would not be the best for cheese-making, but for the local practice of applying lime in one form or another, that now most in vogue being bone. The late Mr George Willis, one of the greatest makers and teachers of the system, speaking in 1884, said, "Draining and boning at a cost of from £8 to £14 per acre are the foundations on which our present system of dairying has been raised. Rich pastures make rich milk; and rich milk, if rightly handled, makes good cheese." The proviso in the last sentence shows plainly that the speaker did not believe that the soil solely governs the cheese, but that correct management of the milk was also essential. The practice referred to by him is, however, a valuable example of the proper treatment of land naturally deficient in lime, and liable to trouble the dairyer with weak curds; and the results prove its propriety.

The manufacture has not as yet been so fully systematised as that of Cheddar cheese, and there is a corresponding looseness and length of range in the practices. On the borders of the home district there is also a mixing with other systems, especially with the Staffordshire making, rendering a correct classification of the goods difficult. Here too the results are not equal to those which follow the consistent central lines of management. It is therefore our business to point out the leading characteristics of the cheese, and their causes in their individual and combined relations; and, later, to describe the practices most consistent with these and most successful, with the hope of reducing them to a common basis.

The variations in making Cheshire cheese make it also difficult to give its correct average composition, for while they make more numerous analyses necessary to such a result, there is a greater lack of reliable figures than with the Cheddar product. The following is the average of sundry analyses which seem worthy of notice :—

Water	35.15
Fat	29.38
Casein	25.38
Sugar and extractives	5.77
Salt	1.75
Ash	2.57
	100.00

In the light of this table the character of the cheese will be understood. The water is in higher proportion than in Cheddar, which arises directly out of the larger quantity of whey retained in making, and this gives a larger yield of cured cheese than is possible to the other system when carried out in its integrity. This commercial advantage is, however, only secured by the sacrifice, to some extent, of certain others which affect the food value. The fat and casein are consequently in lower proportion, and the ratio of the former to the latter is 1 to .863. While it is not possible to give the composition of the original milks; judging from the cattle commonly kept in the county and their feeding, there is every reason to believe that the milk quality is much the same as in the best Somersetshire pastures, and the comparison is therefore fair. Moreover, the result is just what might be expected from such milk by the system.

The quantity of whey in the newly-pressed curd was very much larger than that in the cured cheese would at first suggest. The water ratio between young and old cheese is not equal in the various systems. The higher the proportion of water, the greater is the proportionate loss within a given time by expulsion and drying ; so that if two cheeses started with a difference of six per cent., they would in three or four months after be not more than two per cent. apart in this constituent. This is not only confirmed by the actual practice on this point, but also by the remarkable proportion of sugar and extractives, including lactic acid and other products of fermentation, which is about double the Cheddar average, and even further exceeds the best results of that system. The whey being held in the cheese, all of its solids remain when the water is lost in curing, and are mostly included in this group in analytical tables. Part of the sugar is fermented, but by no means all ; and the more is retained in whey with corresponding after-loss of water, the larger will be the unfermented proportion, because when the limit is reached by the ferments they cease their work of conversion, and leave the balance of sugar to the action of the B.A.F. and other microbes, and these after all leave a quantity of unchanged sugar. The whey, however, is throughout sufficient to encourage a much higher fermentation of all kinds than in the Cheddar, the ferments being naturally in proportion to the quantity retained. We have therefore both more of sugar and of the products of fermentation than in a system which makes a point of expelling more whey from the curd. The proportion of salt left finally is larger than in the average Cheddar; but here, again, there has been more used than the figures suggest, for some of the original quantity has passed off in the free whey lost in draining and pressing, of which loss the system knows more than the Cheddar. The points of a true Cheshire may therefore be summarised as follows, viz. :—

The quality is a little lower than the Cheddar standard, and the digestibility likewise on account of the higher fermentation. There is a greater liability to the presence of mischievous ptomaïnes, and the flavour and odour are distinctly more pungent than in a Cheddar of equal age. One peculiarity of flavour deserves special notice, a sugary sweetness, very pleasing to the average palate, and due to the proportion of sugar. This is not to be confounded with the nutty flavour of the Cheddar, being very distinct from it, and impossible to the Cheddar made as herein. The keeping quality is in proportion to the fermentation.

The texture is the most noticeable characteristic, being loose and flaky, strikingly unlike the Cheddar's smooth solidity. This gives a softness and appearance of quality which is considered a special Cheshire excellence by the merchants of the great north-western towns, who object to the Cheddar as too hard. The size and shape are commonly similar to those of the Cheddar, though the upward limit is not so high; this is natural, in view of the lower level of solidity.

The colour is usually made a brick-red by the use of annatto, to the point of positive disfigurement. On this matter in a general way we have already delivered ourselves; but the grievous experiences of the Cheshire makers justify special reference to it here. Long ago the trade adopted the delusion that this cheese ought to be highly coloured. Whether the makers or the buyers were originally responsible it matters not; the latter seized on the notion, and the former justified thereby their continuance of the foolish practice. It was said the London market demanded it, and in those days the great city fixed such fashions without doubt. The makers have had to pay dearly for this. A discoloration, locally called the "*fading*" or "*flying*" of the colour, has been always more or less prevalent, and at times has taken the character of an epidemic. The loss caused has been very great, for whatever gain (!) in appearance might be made by the practice, it is certain that a mottled colour is worse than a regular paleness. Much trouble has been taken to conquer the evil without giving up the practice, but has so far failed, and we believe it to be impossible.

There are several causes of *fading*, most of them arising out of errors in detail in the manufacture; but there is at least one which is at all times liable to arise, viz.—the presence of special ferments feeding on the vegetable colouring matter, and not only reducing this, but either creating mischief in the substance of the cheese, or making the way for others to do so. Observation has led us to the conclusion that though these ferments may be present in uncoloured cheese, they are inoperative; and a comparison of the experiences of the makers in colouring and non-colouring districts and periods strongly confirms it. Nothing is more reasonable than that, among the many forms of microbes, there should be some which feed on vegetable substances alone; and a few such, it is believed, are known already. If our belief is right, the fading is caused by such kinds, in which case the only real cure is to banish the annatto. We have known the goods of famous makers to be practically spoiled by this cause, and with wetness, ill-flavour, and other evidences of special fermentation of the cheese substance *in proportion to the fading*. So strong and so justifiable are our objections to the use of colour, that we deliberately withhold any directions for reducing the risks of discoloration, saving the only effectual and sensible advice to empty any remaining colour on the rubbish heap, and never to buy any more.

An average milk is suitable for this system.

The dairy and its general furnishings may be like that for the Cheddar system, with the single addition of an oven (Fig. 140), and such alterations as arise out of the provision for heating it. This is generally so set as to derive its heat from the kitchen fire, or from a circulating boiler at its back; but as it ought to be in steady operation by night as well as by day, it is better to provide for its being independently heated. It will be best described along with its use.

The standard of milk ripeness is D (Colour-plate), a little lower than that of the Cheddar system; and as a consequence the management of the night's milk should be confined within proportionately lower limits of temperature. The practice with various leading makers ranges between 60° and 70° F., according to surrounding conditions. The aim seems to be to secure ripeness without special treatment in the mixed milk, and by good judgment this is often done; but there is just as much need to guard against over-ripening, and on the other hand to obtain full ripeness at renneting, as with any other system.

The means already described may be used to bring up any deficiency. In this and all other matters which have been earlier discussed repetition is unnecessary, and we shall confine our attention to main principles and special practices.

The temperature for renneting ranges from 75° F. to 90° F. We have reason to believe that when a lower temperature is followed a higher standard of ripeness accompanies it, or is proper. It would be difficult to make successfully in the absence of such a balance. The general custom makes the temperature from 85° F. to 90° F. with the lower ripeness, and this is most consistent with the after-practices. By the end of two hours from coagulation, the fermentation has reached the level of the corresponding time in the Cheddar system.

The rennet is estimated to produce a curd of the Cheddar firmness in an hour; and the calculation based on the time to curding is the same in both systems. The combined effects of the three initial items differ from those of the Cheddar method, according to the upward tendency of the heating, and that of the ripeness downwards; but as the curds are differently treated from the outset of whey separation, it is unnecessary to follow out the comparison further.

This system recognises *cutting* only as the means of dividing the curd, and the implement mostly used consists of a frame (*a*, Fig. 132) 12 to 15 inches square, within which are a number of blades crossing each other at squares of 1 to 1¼ inch. From the angles of the frame, iron rods *b* rise, meeting in the handle *c*, the height of the whole being 3 feet to 3 feet 6 inches, according to the size of the vat. When a round vat is used, one side of the frame *a* should be rounded so as to fit against the vat's side. It is of course desirable to cut the curd as evenly as may be at all points of the process; but it is not so important a matter as in the preceding system, because uniformity can be much more easily attained with cutting than with splitting. The cutter being set against the side of the vat, and sunk through the curd to the bottom, is drawn up again so as to cut the cubes

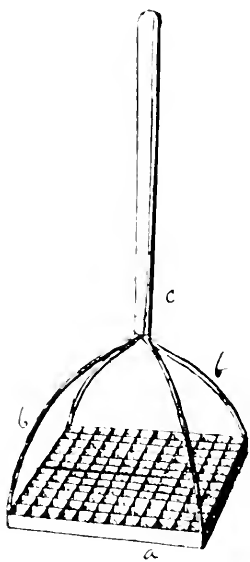


FIG. 132.
CHESHIRE CURD CUTTER.

afresh, as in Fig. 133, this saving time and involving less waste than by causing the tool to return in its old track. The cutter should cover the width of the vat in either two or three times its own width. Its first use must be slow and gentle, with a later increase of speed as the curd grows harder. After a few rounds of the vat in this manner, the tool is drawn in various directions, as in Fig. 134, alternating with a vertical movement which brings the curd up to the surface, and gives the maker an opportunity of seeing that it is being uniformly treated. In order to the least waste possible the edges should be keen; and in this respect the cutters as commonly made are defective, for their square edges of tinned steel cannot fail to rasp the curd. The Cheddar round edge would do much less mischief. Some makers have adopted the knives of the American system (Fig. 135), which are all that could be desired in that respect, and convenient as well. The vertical knife *a* is first used after the fashion of the Cheddar tool; the horizontal knife *b* cutting the vertical strips into cubes—somewhat irregular—for the curd does not present a rigid body; after which the knives are alternately used in oblique directions.

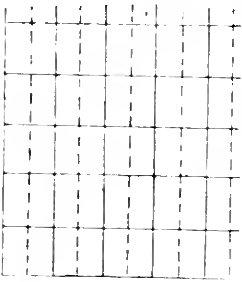


FIG. 133.—CURD-CUTTING.

Formerly small wires were used in the frame-cutter instead of blades, and these exercised a similar influence to the larger wires of

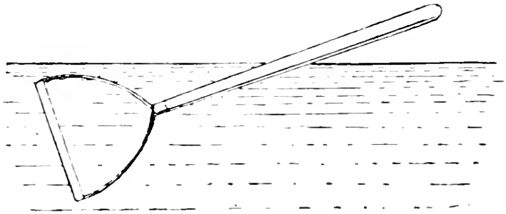
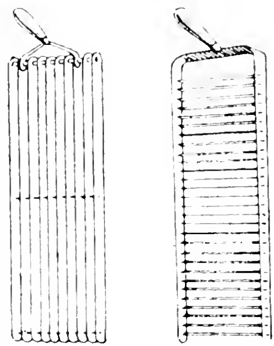


FIG. 134.—CURD-CUTTER—SECOND POSITION.

the Cheddar breaker, though in a much lower degree, not only because of the difference in size of the wires, but also because the curd was left in larger lumps. With equal care and judgment a good cutting tool would do better work, in view of the aims of the system to retain a larger proportion of whey. The final size of the curd should be a little larger than the "peas" standard of the Cheddar method, and yet a little larger when a wire breaker is used.

When the curd is small enough it is allowed to sink, and when packed—which takes about half-an-hour, but should be tested—it is gathered under the whey. This may be done by the hands, the curd being doubled over from the lower end of the vat upon that at the upper end. It is better done with a "gatherer," Fig. 136—a perforated tinned sheet *a* stretched on a light iron frame, having projections *b b* which rest over the vat sides, with thumb-screws *c c* which hold it in place at any point. With the help of a second person the work may be very soon done; each having one hand to propel the gatherer, and the other to keep it at the right angle, as in Fig. 137, with an occasional touch to the curd to prevent its rolling or breaking. When the curd is doubled, the gatherer should be fixed in place by the screws; and the hands, or a wooden rack, pressed on the curd surface to settle it in place. Here it remains until it has reached a stage of fermentation, which varies with different makers, but which, to be consistent with other points as here given, should be at least equal to I of the Colour-plate. Then the whey should be drawn, and the curd piled deeper if the air is below 60° F., and covered, the vat also being covered with its boards. In some dairies a separate cooler (Fig. 138) is used, a large cloth being spread within the racks, and the curd piled closely within it. This should have also a wooden cover, and room enough beyond the racks for the curd to be ground. Since in the old method no heating is done after coagulation, the propriety of the higher renneting temperature and the advanced stage of fermentation will be seen. The curd is cut, and, where no sink is used, piled afresh on a rack (Fig. 112), and covered again; and this



a *b*

Fig. 135.—Curd Knives.

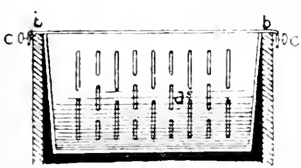


Fig. 136.—Curd Gatherer.

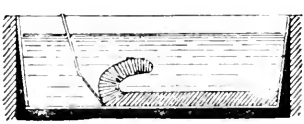


Fig. 137.—Curd Gatherer in Use.

may be repeated if the curd ripeness is not reached at the end of an hour and a half from the removal of the whey.

The next stage of fermentation is shown by the litmus K (Colour-plate), and at this point the curd may be ground. If the ripening be carried beyond it there will be a corresponding tendency to hardness and solidity, and the texture special to the system will be

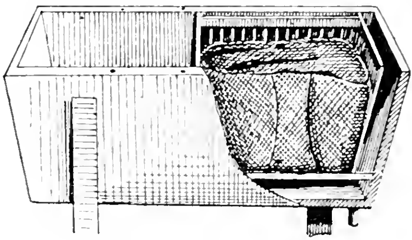


FIG. 138.—CURD SINK.

lost. It is still wet and comparatively soft; and in the ordinary cylinder mill is liable to lose a good deal of fine curd and fat in the whey expressed by the teeth. Tearing is still better than cutting for the sake of the texture, but if it is adopted the teeth should be larger, and the cylinders correspondingly farther apart than in that suitable to the dry Cheddar curds. Attempts have been made to introduce cutting mills, but we do not know of one which properly meets the case. Apart from the improved tearing, the best practice is gentle crimming, the curd having first been cut into 3-inch cubes. It will be difficult, if not impossible, to avoid some loss by white whey. That is one of the disadvantages of the system, but it need not be so great as it commonly is.

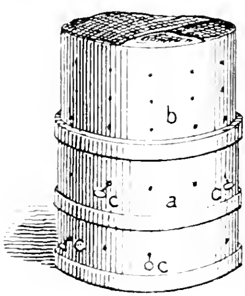


FIG. 139.—OVEN HOOP.

The proportion of salt is one of the mysteries of the Cheshire dairy, and has many variations according to the practice of the individual makers. Such a curd as we have in mind should receive one pound to every forty gallons of milk, the great excess—as compared with the Cheddar reckoning—meeting the higher fermentation and the loss of salt in the whey. As the latter item varies very much in different dairies, there is a like variation with the salt proportion also; and as it is not possible to describe the degrees of wetness, we must leave the dairyer to follow his judgment, with the light given here and elsewhere to guide him. It is to be hoped that the public teachers will succeed in reducing the wetness to a fixed rule, as the hardness of the Cheddar curd has been, and so secure as nearly a uniform practice as may be. The coarse-grained salt is largely used with Cheshire curds, and mixed with them at this point.

The curd is next put into a hoop *a* (Fig. 139), having a deep girth *b*, and numerous perforations which admit of skewers, *c c*, being thrust into the cheese to assist in removing the free whey contained in its crevices. In this hoop the cheese is put into the *oven* (Fig. 140), which is a cupboard large enough to contain one or two cheeses, the door *a* providing for ventilation (*see* arrows), the gutter *b* for the collection and discharge of the whey drainings through the spout *c*, and the hot-water pipes *d* for the heating. The temperature should be sufficient to secure a steady contraction of the curd with little or no pressure. The late Mr George Willis used to say that a well-made cheese should go together without pressing; but doubtless this will depend on the temperature used, and the corresponding rate of fermentation and contraction. The average of sundry practices makes 80° F., with a range between 70° F. and 90° F.; but we think that with the cheese made as above, from 80° F. to 85° F. will best meet the case. A self-registering thermometer (Fig. 24, p. 108) should be employed. Some makers use the water boiler in place of an oven, after its ordinary use is over for the day; but while this may serve as a makeshift, it cannot be as manageable in temperature, and therefore not as reliable, as a regular oven.

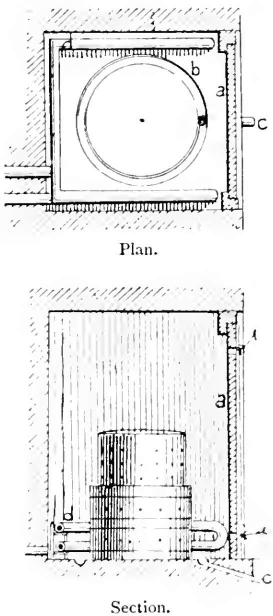


FIG. 140.—CHEESE OVEN.

In the evening the cloth is changed, and the cheese replaced in the oven; in the morning it is removed, reclothed, and put under low pressure. In the oven a half-cwt. is ample with a curd most needing pressure, and one cwt. is sufficient to commence with in the press. The weight is increased steadily during the four or five days it is in press, finally reaching a ton with all cheeses of 60 lbs. and upwards, and not less than 15 cwts. with lesser goods. In respect of pressure, the system goes beyond the Cheddar practice in point of time, but falls behind it in weight applied, and this is proper in view of the character of the curd and the texture desired. A greater pressure, and more rapid increase of it, would tend to retain an excess of *free* whey, and this could not fail to do mischief, encouraging irregular and excessive fermentation. However the systems may differ in their aims as to the proportion of whey to be held *in* the curd, they all agree to expel the *free* whey which may be found *among* it. The Cheshire system seeks to effect this expulsion slowly, but none the less thoroughly in time; and here may be noticed the old rule, that a cheese which becomes concave at its ends is a good one, while one which rises or becomes convex is judged to be inferior. The concave surface says plainly that the free whey has well escaped; and the convex, that it is retained in sufficient quantity to cause undue fermentation, or that there is a taint at work. In either case gases are formed, which cause the bulging, though the taint is undoubtedly the worst of the two causes.

A steady dripping of whey during the pressing, barely ceasing by the end of it, is also a sign of a good curd. The whole matter is dependent on the avoidance of haste, and excess, in the application of weight, and no shortening of the time of pressing can therefore be made without constant risk of damage.

The steady draining of whey makes it necessary to change the cloths daily, otherwise the outside of the cheese would be sodden, and the separation of the remaining whey hindered. The bandaging must therefore be left until the cheese is ready for the curing-room.

The Cheshire makers lay on their bandages with flour paste, a custom for which we have so far failed to get any satisfactory explanation. The bandage as commonly made may need such help to adhesion, because it is not sewn to fit tightly; but the paste does not help the cheese, and the arrangement is clumsy and messy in spite of the fact that neat dairyers make a presentable cheese. The use of a closely-fitting bandage drawn on a few hours before the cheese finally leaves the press, would be cleaner, more easily applied, and afford a much better support to it.

In the curing-room the goods are generally laid on plain shelves, or on the floors, and turned daily for the first month, on alternate days for the next month, and twice weekly afterwards. They are laid on straw when fairly dry, but by the time a true Cheshire comes to the straw the advantage of its use is doubtful. Whatever purposes it is intended to serve are equally procurable on dry clean boards, in an atmosphere fulfilling the needs as to temperature and humidity.

The curing temperature most suitable to the system is similar to that of the Cheddar, ranging from 60° F. to 65° F.; but the moisture should be a little lower, ranging in the difference between the hygrometer readings from 4° to 6°. There is reason to fear that, as with makers by other systems, the curing conditions are neglected; but it must be plain that with so large a proportion of moisture in the cheese, the regulation of those conditions is a matter of the highest importance. The liability in this case is to an excess of atmospheric moisture, both because the cheeses need less than Cheddars, and because they give off at least 50 per cent. more, which cannot fail to increase the proportion in the air. This will often enough be in the wrong direction. On the other hand, the air must not be too warm or dry, or the goods will crack. The tendency to this is met by greasing them, in which case the material used should be simple wholesome fat, and a little—well rubbed on—will be better than a much larger quantity lightly applied. The time of curing will be from three to four months, and such a cheese will improve for as many more. Such, however, is the loss in weight that modern makers clear stocks as early as they can be carried safely.

We may now describe new practices arising out of the change from the round wooden vat to the oblong one of metal, with its convenience for heating. One of these consists in heating the curd in the whey, somewhat after the manner of the Cheddar system of scalding, but with much less stirring, and no attempt at procuring any special degree of firmness. This takes the place of the oven, the temperature being raised as in the following table, viz.:—

Air.	Curd.
65° F.	94° F.
60° F.	95° F.
55° F.	96° F.

The effects of such temperatures on the fermentation is similar to that of the oven heat at 80° F. applied *after salting* and lasting fifteen or sixteen hours; and the contraction of the curd is much greater also, tending to a dryness by the time it is ready for salting, equal to that of oven-dried curd when ready for pressing. A trained judgment will doubtless make equally good work by either course, but the old method is the safest in most hands. There is some difficulty in manipulating curd of such large size, and so tender, so as to avoid waste on the one hand and over-heating on the other. Some makers stir with their hands, laying their finger-tips together and drawing them towards themselves and upwards nearly to the surface, and then plunging them forwards and downwards again, so keeping the curd in a gentle rising motion. Others use an old-style wire breaker, or even a wooden hay rake.

The hand-stirring needs two persons for the time; either of the tools make one sufficient; but the latter are liable to cause more loss of fine curd and fat.

Another practice is to heat the curd to about 90° F., and use the oven with a temperature of 70° F. to 74° F. to complete the work. Either method will serve, though we fail to see any practical advantage in the latter. The full scalding shortens the time of manufacture by a day, and is entirely consistent with the principles of the system; the partial scalding effects no economy whatever.

The system as described is calculated to produce a typical Cheshire cheese, but there are still other practices which deserve notice. One is old, and still followed by a considerable number of makers in the early autumn, though it is not believed to work well in the later part of that season, when a return is made to the practice given. It is known as the *slow-ripening* process, and by it some of the finest goods possible to the system have been made in past years. But the desire for an earlier turnover of capital is directing attention more and more to the most recent or "quick-ripening" process. Besides these there is the Cheshire-Stilton method. These shall be dealt with in the order given.

Slow-ripening Method.—This proceeds with the night's milk as the medium or standard method does, but uses a rather higher renneting temperature, averaging 90° F., and, with a corresponding decrease of rennet, produces curd of ordinary firmness in an hour. The curd is cut to the size of small peas, some makers scattering a little salt (apparently no definite quantity is used) over the whey during the division, with a view to check acidity. This last is a questionable practice, and might advantageously be replaced by a better management of the initial ripening. The heating, whether in vat or in oven, is applied as earlier described, and the whey removal and piling likewise; but the salting is done earlier than usual, the curd being crimmed for the purpose, and the salt proportion averaging 1 lb. to 40 gallons of milk. It is then put in a cloth or a hoop, and under a pressure of 28 lbs., for an hour, when it is crimmed again or ground, and sent to the oven under a pressure of 56 lbs. The after-management is like the other process.

Quick-ripening Method.—This commences like the others, but uses whey to forward fermentation, the standard of milk ripeness being equal to that of the Cheddar system, and the ripening may be safely carried out as there advised. The renneting temperature is low, 78° F. to 80° F., but the rennet is in great excess, some makers using as much as 50 per cent. more than for the medium process. The curd is ready for cutting in treble the time of curding, and is reduced to the size of horse beans, when it is allowed to sink, and is gathered as usual, without scalding. The standard of curd ripeness is equal to L (Colour-plate). To allow for the great excess of whey, the salt proportion averages 2 lbs. to 50 lbs. of curd. For the same reason the pressing is lower than in the other processes, and the draining continues somewhat after the cheeses have reached the curing-room. In other respects than those mentioned the management is as in the other cases. The cheese is ready for sale in three or four weeks.

It will now be well to briefly compare these methods. The most noticeable feature is the size to which the curd is cut in each case, providing for the retention of the appropriate quantity of whey; the after-processes for whey extraction being alike, though differing in extent. The pains taken to expel whey and discourage fermentation in the slow-ripening process also belongs to this connection. Next, the slight reduction in the rennet proportion of the slow-ripening, and the great increase of it in the quick-ripening method, and with these the variations in heating are consistent. The slow-ripening process approaches the most nearly of the three to the Cheddar, the quick-ripening method is its extreme opposite. The consistency of all three with general Cheshire principles must be manifest.

The manufacture of quick-ripening Cheshires is attended by sundry risks and forms of commercial damage, which cannot be elsewhere so fitly considered as here. It may be freely admitted that a greater yield of produce is made, and a better price, along with an economy of time and labour in curing. The bare statement would seem to establish the desirability of making such goods, especially from the farmer's point of view, but it does not. Against these items must be set the following, viz. :—

(*a.*) The goods are subject to early deterioration; and if not sold and used on the improving side of their best point, they are a source of serious loss to the maker, the trade, or the consumer, or to all of them.

(*b.*) The increase of yield beyond the reasonable limit is entirely in water, and there is no advantage in that excess to any but the producer. Cut cheese in the hands of the consumer is subject to more waste by drying than would be possible with a standard cheese, and the shrinkage in the hands of the trade is unnecessarily high.

(*c.*) The better price is due to the state of the market when the early spring-made goods of this kind come into it, rather than to any inherent value.

(*d.*) The excess of fermentation, although accompanied by an excess of rennet, affects the food value prejudicially; and the moral certainty is that the consumer, finding the tendency of the cheese to interfere with digestion and produce nausea, &c., will gradually cease to use it. It is evidently to the real and lasting interest of the Cheshire maker to encourage the use of cheese, and the making of quick ripeners is but a means of "killing the goose which lays the golden egg." It will probably be answered by those who profit temporarily by the practice that the cheese was never more popular than now. That, however, has been true with many other things just before their collapse. Trading upon the ignorance of the people is growing more and more dangerous every day. They are learning to judge better of the value of foods; and although the day of enlightenment may seem far off, it is really very near. The people will not much longer buy whey at food rates, when its presence is known to be injurious to the cheese and to themselves. In the interests, as we conceive, of the makers of Cheshire we offer the foregoing facts for consideration, and with the hope that they will take the higher and safer ground of making the best food within the possibilities of their system, and so maintain their ancient reputation and their share of the public favour.

The Cheshire-Stilton Method.—This is followed, to a small extent, with a view to the production of a cheese with certain characteristics of the two systems shared in common. The Cheshire texture, shape, and outward appearance are preserved, and the main lines of procedure; but the fungoid moulds of the Stilton with their special flavour are secured also. We have already shown that the penicillium moulds can be cultivated in any cheese; but this being the common practice of the Stilton makers, and of but few others in the country, the compound name chosen is appropriate. The management is like that for a slow ripening cheese until the curd is salted. Then a quantity of the previous day's making, which has been kept partly covered in a stoneware vessel to prevent its becoming too dry, is mixed with the new product, and this carrying with it the spores of the mould starts the "*fade*," as it is locally called. The proportion of the daily curd kept over is as follows, viz.:—

Air Temperature.	Proportion of Curd.
65° F.	$\frac{1}{7}$
60° F.	$\frac{1}{6}$
55° F.	$\frac{1}{5}$

Certain Continental systems pursue a similar course. It is important that the curd should be certain of being reached by the spores; and if at intervals of a few days a little curd be kept in a separate vessel until it is mouldy, the means of inoculation are always at hand. It is not safe to expect mere exposure to the air to secure the result, for a varying proportion of these goods fail to mould, and have to be sold at a low price. The oven is not used, the heat being destructive of the mould spores. The pressure is low, commencing with $\frac{1}{2}$ cwt., in order to ensure the openness so necessary to the mould spreading, and which is so liable to be lost with the drier curd ; and, as a result, and as a guide to practice, the dripping should have barely ceased when the cheese comes from the press. The best curing is done in a humid atmosphere, fully equal to that recommended for Cheddar cheese, and with a temperature ranging between 57° F. and 63° F.

Finally, a comparison of the Cheshire and Cheddar systems will enable us to estimate their relative values, and teach us that neither can claim in full all the cheese virtues and economical advantages. In quality, digestibility, and keeping character, the Cheddar holds the first place ; but in cheese yield, and softness of body, the Cheshire surpasses. In labour, the Cheshire dairyer gets through his making earlier in the day ; but the long pressing, and many removals, and the changing and washing of cloths, fairly balance the account. It is out of our power to secure all the good points of both methods in their highest developments by any compromise; and the makers of both systems are recommended to stick to them, and do their best within their lines.

CHAPTER XIV.

THE DERBYSHIRE AND KINDRED SYSTEMS.

MOST of the remaining English hard-curd systems may be properly grouped together. They hold their principles in common, and their practices do not vary more than those of Cheshire makers in different dairies. Their products also are made either into small cylindrical cheeses, or flat and thin ones; the latter being probably twenty times as numerous as the former, and in even greater proportion by weight, because the flat cheeses are from two to four times as heavy as the others. This matter of size is determined by the character of the curds, which could not be safely made into large forms. Nothing seems to be known of the origin of any of them; but they have been followed time out of mind, and their simplicity confirms the probability that they are as old as either of those already described.

The Derbyshire method is the most completely typical of the group, and shall be first dealt with, as fully as is requisite for practical purposes,—the others being afterwards compared with it, especially in the points of difference. As they are all alike in need of being reduced to a proper basis, the same course will be pursued as with the Cheshire system.

The product of the Derbyshire method comes about midway between those of the Cheddar and Cheshire methods in proportion of water and in texture, being drier and more solid than the Cheshire, and more flaky than the Cheddar. In food value it holds an equal place with the Cheshire if equally well-made, and at its best is a fine article. Commonly, however, it is inferior to either; and while we have known dairies which could command prices equal to the best made by other systems, we have generally found it tough and soapy, or hard and crumbly, ill-flavoured, and unevenly coloured. There is no explanation but the want of system and skill in the dairy. The pastures of Derbyshire are much of the same character of the best lands of Somersetshire, consisting of New Red Sandstone soils, skirting and uniting with the Carboniferous Limestone of the Peak district; and we believe that there are no better or more easily managed grass lands in any part of the country. Experience in making Cheddars from the milk of the southern part of the county has taught us that the soil influence is the same as on the Mendips,—the casein acting admirably under the rennet, and with standard milk-ripeness expelling its whey and hardening in the scald in about the same time as in the best Somersetshire dairies, and in less than half that required on ordinary sandstone or clay soils. There is therefore no "refuge for the destitute" in the mysteries of land and herbage; and the high possibilities of the method having been demonstrated, we see no reason for allowing it to fall into discredit and disuse. The milk is of much the same quality as that used in other hard-curd dairies, and is in good repute with the town trade for its keeping qualities. Large quantities are despatched daily to London, Birmingham, and other populous places. Here also are found the largest proportion of British cheese factories, the goods in which are made on the American, and not, as commonly stated, by the Cheddar system.

The following description has nothing to do with the factory management of the Midlands, but refers simply to the making of the true Derbyshire cheese.

From such materials as are at hand the accompanying table has been constructed as approximately representing the average composition of the cheese. The eminent chemists who have analysed the products of other systems have largely passed by this article, but the figures given correctly present its special characteristics of composition.

Water	35.00
Fat	28.00
Casein	29.00
Sugar and extractives	4.00
Salt	1.15
Ash	2.85
	100.00

The high casein ratio, 1.036, is partly due to the practice of skimming the night's milk, followed to some extent (though the average reduction of the fat would be much greater if it were commonly done), and partly to the smaller extent to which the casein is changed by its fermentation into fats. The sugar and extractives are in much higher proportion than in Cheddar, but much lower than in Cheshire cheese.

The Derbyshire has been called a "*sweet-curd*" system; but the term is liable to mislead, by conveying the impression that no acidity is developed. True, in comparison with the Cheddar, the production of acid in the early processes is lower; but before the making of the cheese is completed the curd-ripeness standard of that system has been passed, to reach its own, which is K (Colour-plate) by litmus test. One of the special causes of failure has been the insufficient encouragement of fermentation, as we shall presently show.

The dairy in its general construction may be as for the Cheddar system ; the furnishings special to the case will be described in order.

The management should secure a state of the night's milk which, mixed with the morning's, will bring the whole to the D standard (Colour-plate) ; and the greatest care should be taken not to exceed that point, the possibility of compensation being very limited by the principles of the system. But if the state of the mixed milks falls short of this standard of ripeness, it should be brought to it before renneting, otherwise the whole process will be scarcely less hampered by the effects of an ill balance than in the preceding systems. It is safest to err on the lower side of the standard, if at all ; but the best results cannot be uniformly obtained away from it.

The renneting temperatures are as in the accompanying table, with proper variations for small quantities :—

Air.	Milk.
65° F.	79° F.
60° F.	80° F.
55° F.	81° F.

The curd firmness, which is equal to that of the systems already dealt with, should be reached in an hour ; and this, with the low standard of ripeness and temperature, makes a higher proportion of rennet necessary. The relative and combined influence of the three items gives the rennet the leading position and a start which would tend to softness and defective texture and flavour but for the later acidity. The careful covering of the vat is of the utmost importance, and the double-cased vat may hold water kept at the renneting temperature with advantage. The division of the curd is as is in the Cheshire system, the fine wire breaker being much used, but this is inferior—for the system—to the cutter or knives, for the curd is slow in hardening, and more liable to waste than a more acid curd would be. It should be reduced to the size of horse beans, and then allowed to sink. The packing will be rather slow, but as the baling-out of the whey will take some time, this may be commenced in fifteen or twenty minutes, a hair strainer being used to prevent the disturbance of the curd (Fig. 96). The latter part of this work is but slowly done by hand, and the curd is much exposed to the air in any case ; it must therefore be as quickly performed as possible, without waste. The curd should be pressed by the hand, or by a wooden rack (Fig. 112), to consolidate it before the last whey is removed, and afterwards placed in a hoop (Fig.

119), and put under a gentle but increasing pressure, beginning with 14 lbs. and ranging upwards to 1 cwt., or even more, before the end is reached. The ancient plan was to press with the hands on the follower, and when the strength had reached its limit in that way the dairymaid knelt on the follower. It was observed that small women were unable to carry the work so far as was desirable before the cheese was put into press; for the presses used were of the old stone sort, which could not be regulated, and tended to seal up the whey in the curd, as undue pressure at first does in a Cheddar. More weight was needed to bridge over the gap, and as a heavy woman could furnish this, the old maxim "The bigger the dairymaid the better the cheese,"

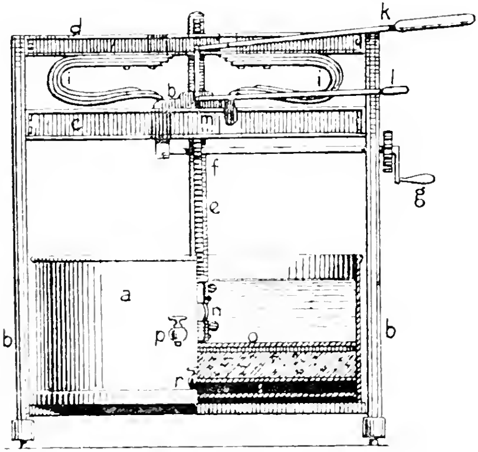


Fig. 141.—Derbyshire Cheese-making Apparatus.

came into use. The practice gave the dairymaid sore limbs, however, and sundry attempts were made to put an end to it. The best of the devices for that is the apparatus designed by the late Mr Joseph Harrison of Brailsford (Fig. 141), which places the vat (*a*) upon a frame, from which two uprights (*b b*) rise to a height of five or more feet, according to the diameter of the vat, and support two transverse bars (*c d*), which are largest at their midway points where a toothed bar (*e*) passes through them. This bar is raised or lowered by a wheel (*f*), worked in turn by a crank (*g*), an arrangement which gives a much quicker motion than a screw could do. Upon a boss (*h*), the ends of two powerful springs (*i i*) press, and the boss is controlled by a lever (*k*), while a second lever (*l*) controls a pin (*m*), which catches between the teeth of the bar (*e*) at any point desired. At the lower end of the toothed bar another short bar (*n*) connects it with a large tinned steel plate (*o*), which is fastened to a light but strong frame of malleable iron. The joints are so made as to allow this plate to be tipped, so as to put it out of the way, while giving all rigidity to it when in use. The plate has many perforations, of one-tenth of an inch diameter, which allow the whey to pass through it when it descends, and it should fit the interior of the vat as closely as possible without actual contact. The vat must therefore be a true cylinder, and if a hot-water case is provided it must be under it only. A tap (*p*) just above the level of the compressed curd, and another (*r*) at the lowest point, should be provided for the removal of the whey. The bottom should be flat, and well supported by a ring (*s*) under it or in the hot-water space. The use of the apparatus is very simple. The plate, with a heavy covering of baize, serves as a cover for the new curd. When it is ready to cut, the lever (*l*) is pressed down, releasing the catch-pin (*m*), and with the handle (*g*) the bar is raised as high as it will go and the plate tipped.

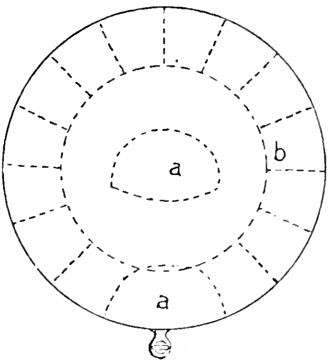


FIG. 142.—CURD CUT.

The curd having been cut, the plate is let down into its place, and slowly lowered until the curd will support it with only the least perceptible lowering of surface. Then it can be left to itself for ten to fifteen minutes to the pressure of the plate and bar, the catch pin being fastened back to allow free motion. Then the lever *k* being pressed down, the boss *h* is raised an inch or two, and the pin *m* being released it catches in the teeth of the bar *e*, and the springs pressing on the boss force the bar and plate downwards. A repetition of this at intervals of five minutes will by and by depress the curd surface below the level of the tap *p*, when the whey should be drawn off, and the pressure continued until the curd is packed firmly enough to stand without support. This will be readily learned by observation. The plate should then be raised and tipped, and a piece of the curd a foot or more wide be cut from around the tap, as in Fig. 142, and placed at the centre. If the curd around the free space breaks down easily under its own weight, it needs more pressure before removing the remaining whey; if it stands well, the whey may be drawn off, and the curd cut as in the illustration, the pieces *b b* being piled quickly and neatly in the middle. Then the pressure may be gently applied afresh, with increase until the curd is spread abroad nearly to the sides,—the vat frame being tipped an inch by wedges, so that the expelled whey may easily drain away. This cutting and pressing is repeated until the curd will bear crimming without loss of *white* whey, when it should be so treated, and put into a hoop, and under a pressure of 1 cwt., this gradually increasing to 3 cwts. in five hours after. In a system which works the expulsion of the whey entirely by cutting and pressure, it is plain that the weight must be very light at first, and gradually increased as needed, but without any sudden leap of even a few pounds from one stage to another, until the curd is able to bear 1 cwt. without loss of white whey. This delicate control is given by such an apparatus as we have described, and is essential to the usefulness of any invention for the working of this system. The shortening of the curd exposure also helps to the very superior result which follows this plan, as compared with the older methods.

Up to this point the advance in fermentation has been slow, and the curd has scarcely got beyond the Cheddar milk ripeness (E, Colour-plate); but being sent to press without salting it will ripen at such a rate that by the next morning it will show L (Colour-plate) by litmus. A small surface of the cheese being exposed by shifting the cloth, and a slit cut in it, the litmus paper should be pressed between its sides. If the stage given is not reached it should be returned to press. The time necessary to attain ripeness may easily be learned by observation, and the probabilities of temperature influence during the making and following night should be watched as well. If the fermentation has exceeded the proper stage, a slight increase of salt will check it; but as it will also tend to dry the cheese unduly, it cannot be a proper compensation.

The consequences of under or over ripening are as in other systems. The former is the more common experience; the result of starting with too low a fermentation, of the loss of temperature in the course of the work, of being in too great haste to salt, of salting by rule of time or insufficiently or unevenly, &c., and, in no small number of cases, due to the fear of over-ripening, and—for want of means of testing progress and of regulation—falling short of the proper condition for safety's sake. Hence the soapy, discoloured cheese so often found under this system. In support of this, great benefit has been obtained by the practice, occasionally met with, of keeping over a quantity of unsalted curd from one day to the next to mix with the new curd before sending it to press. What is this but the introduction of a considerably fermented curd—for the curd so kept is distinctly acid—into one which has but the beginnings of fermentation, and this instead of putting whey into the milk? The difficulty of estimating a day beforehand the quantity of curd required, with all the uncertainties of changing conditions affecting the rate of fermentation in the old and the new curds, will occur to the reader. Nevertheless, some of the best cheeses made by the system have been treated in this way; and Professor Sheldon quotes, in "Dairy Farming" (Cassells), an increase of price in one dairy of 15s. to 20s. per cwt., directly following on the adoption of this plan. The proper ripening of the milk, and the after-management on the lines already laid down, must needs, however, give much more uniform results than this practice, and in this way the Derbyshire maker may move towards certain and permanent improvement.

Another item in the past and present practice must be noted. Most of the cheese-making is done in the farm kitchens. For several reasons earlier discussed this is not desirable, but in this particular case it has an important influence on the work, and one we believe seldom if ever suspected. The kitchen is generally the warmest room in the house during the hours of cheese-making, and being used much in the evenings also by the family or servants, it keeps at a comfortable temperature during the colder nights of the making season. This is specially good for the cheese with its low temperature and ripeness; and the removal to a separate dairy would necessitate either a warming of the apartment at the colder times, or a raising of the initial conditions favourable to fermentation, in order to balance matters afresh.

After the curd ripeness comes the salting. The method practised from time immemorial has been that of rubbing salt on the outside of the cheese, or immersing it in brine, or both. Hence in part the shape of the cheese, which is calculated to allow the salt to reach its middle. It is, however, quite certain that many cheeses are never so penetrated, and that all the rest are unevenly salted. Experience proves what common-sense would dictate, that it is impossible to properly season the inside of a cheese without over-doing its outer portion; and some makers finding this, scatter a little salt on the curd, from 1 to 5 ozs. to every 10 lbs. of curd. Even from this an improvement arises, but it by no means properly meets the case. It is believed by some that differences in soils make it needful to vary the methods of salting in different districts, and even on adjoining farms. This, however, we are convinced is a delusion; and in cases where one method answers and the other fails, a search will prove that the secret lies in the management. It is, for instance, easy to understand why many curds made from unripe milk, or salted too early, and so damaged in curing by a proportion of salt which would have been suitable to a perfect curd, may be helped by the outside salting; but the cure is not to be found in this, with its unevenness of result, but in the proper management of the fermentation *from the beginning*. In the calculation of the salt, too, no invariable proportion can be used unless there is also an invariable condition of the curd as to fermentation and dryness; and yet there is too much reason to believe that when the salt is mixed with the curd, the state of the latter is not generally considered. There is, moreover, an impression among the makers that the adoption of this practice would spoil the goods, or at least involve such a revision of the management as they do not care to undertake. In this they are mistaken. The only necessary addition to the furniture is a mill (Fig. 115), with which the curd should be ground when ripe, being torn into pieces of two or three inches across for the purpose. With only the trouble of doing this, and calculating the salt by a table and according to the dryness of the curd, and without the sacrifice of a single essential principle, the change can be made; and, as we know from experience, with entire and permanent benefit. We will not, therefore, waste space by describing the old methods, but recommend the employment of 1 lb. of salt to 50 gallons of milk, with slightly increased proportions according to need. The size of the cheese may then be increased without danger, even to Cheshire proportions if desired; and this also with benefit, because with less waste by shrinkage, and more perfect curing.

By the use of lever presses the last pressing may be more perfectly done than with those of stone; but, as with Cheshire cheese, the increase must be slow, taking from four to five days, and the figures given for that system is appropriate with this. The temperature is never likely to be too high for pressing under the main conditions of the system and in this climate, but the upward limits should not exceed those of the Cheddar; and of the curing temperature the same may be said. The danger is in the other direction; and it must be clear that too low a temperature in either case would do more mischief than with a cheese made from the first with higher temperatures. The necessity for avoiding this error is therefore urged, and any reasonable means for bringing the curd out at the time of going to press at the temperatures in the accompanying table should be used:—

Air.	Curd.
65° F.	60° F.
60° F.	63° F.
55° F.	65° F.

The curing-room should not fall below 60° F., nor the hygrometer vary more than 4° F. between the dry and wet readings. The Derbyshire cheese needs more air moisture than the Cheshire. The curing will take from three to four months, and improvement will follow for as many more; but the thin shape allows of too much drying to admit of profitable keeping, and on the same account the cheese is not so palatable after the limit given. In the face of long usage the adoption of the Cheshire size and form, with internal salting, is desirable.

The yield of cheese by the Derbyshire system is between the Cheshire and Cheddar, but comes nearer to the latter because of the greater drying. In labour it gives less than the Cheshire in the earlier stages, being out of hand an hour or two earlier when a proper apparatus is used. There is no oven-heating, no skewering, and only the same changing of cloths as with the Cheshire; and with the salting *in* the curd, the time and toil of the outside treatment is done away.

The *Lancashire* cheese-makers follow the Derbyshire system in every essential point, and, so far as we can learn, even in the details of practice. In East Staffordshire it is also commonly used, but in the north-western part of that county the tendency is to the Cheshire system. In North Warwickshire and in Nottinghamshire it is the general method, gradually mixing with or melting into the Gloucester in the former case, and into the Leicester in the latter. To the cheese-making within this wide field the foregoing applies as a whole. No small part of that district lies on the New Red Sandstone soils, concerning which the remarks on Cheshire soils will be useful.

The Leicester System.—This prevails in the county of that name, especially in its western part, occupied almost entirely by the Sandstone formation. The eastern part is, to a like extent, occupied by the Lias, and is the district of the Stilton manufacture, though the Leicester is made more or less in different parts of it. The product is more flaky than the Derby, but less so than the Cheshire, and in all practical respects holds an intermediate position between them. The average of sundry analyses is given in the accompanying table:—

Water	34.05
Fat	28.28
Casein	28.50
Sugar and Extractives	4.98
Salt	1.12
Ash	3.07
	100.00

The proportion of sugar and extractives confirms the position assigned to it. The system is entirely consistent with these facts. The dairy, as for the Cheshire system, is suitable to it. A higher fermentation is secured by the renneting temperature in the adjoining table, though some makers use lower ones, and draw nearer to the Derbyshire standard :—

Air temp.	Milk.
65° F.	82° F.
60° F.	83° F.
55° F.	84° F.

The half-way point is, however, very desirable, as giving a definite and distinguishable result, and this is only attainable by the higher range given. The standard of milk-ripeness should be D (Colour-plate), and the rennet calculated with the other items to cause curding in twenty minutes, the standard of curd firmness being reached in an hour, as in the previous systems. The curd should be cut rather than broken, and reduced to the size of horse beans. No scalding is allowed, but a second heating to bring the contents of the vat back to the renneting temperature is proper whenever more than a couple of degrees Fahr. have been lost. The curd should then be allowed to settle for twenty minutes, and gathered by hand or plate (Fig. 136) under the whey, after the removal of which it is cut and piled, and covered until it is ready for the next stage. The curd is now put under a gentle pressure, and this increased until the curd ripeness (K, Colour-plate) is attained, when it is ready for salting. By keeping the curd up to its first temperature as nearly as possible—water kept at equal temperature being under the vat, and this latter well covered—it should be ready for salting in the evening of the same day, just as the Derby with its lower temperature and whey proportion is ready on the following morning. The Leicester makers have long followed the Derby practice of outside salting, the remarks concerning which are quite as appropriate in this as in that case. The proper quantity for such a Leicester as we have before us will be 1 lb. of salt to 45 gallons of milk. All the after-management should be as with Derbies.

The Gloucester System.—This is mainly confined to the county of its name, and to the adjoining north-western part of Wiltshire. The product is an advance Cheddar-wards from the Derby standard, being more solid and less flaky. There are two makes—the "*single*" and "*double*" Gloucesters,—about which very erroneous notions prevail among the consumers. The most common is that the former is made from whole milk, and the latter with a double proportion of cream. The real difference is in size only,—the single being made of 14 lbs., and the double of 24 to 28 lbs. weight.

The accompanying tables give the average composition of the two makes :—

	Single.	Double.
Water - - -	27.66	33.78
Fat - - -	27.12	27.19
Casein - - -	38.00	31.50
Sugar and Extractives -	3.05	3.21
Salt - - -	1.26	1.55
Ash - - -	2.91	2.77
	100.00	100.00

The first of these represents well the modern typical "*single*," made from the night's milk, creamed, with the new milk of the morning, the casein ratio being 1.438, and the water much less than usual, partly due to the creaming, and partly to the shape of the cheese, which is seldom more than $2\frac{1}{2}$ inches thick. In earlier days the practice of skimming was little resorted to, but in these it is the rule rather than the exception, and the cheese has largely lost its old reputation, and goes to the colliery districts of South Wales for a market. The "*doubles*" are but little made now—an exception this to the law of the "survival of the fittest." Their composition shows a moister cheese, with a casein ratio of 1.154, showing some skimming. The capabilities of the system are equal to those of the Derbyshire, if correctly pursued, and with whole milk of average quality. It is therefore a cause of regret that it should have been allowed to fall to its present level. The only difference between the two in management is that the Gloucestershire makers use a wire-breaker, or the hand, the result being a loss of the moisture and flakiness peculiar to the cutting systems. With this exception, the principles and practices are given under the Derbyshire system. One peculiarity of this make, however, must be mentioned with condemnation,—the practice of colouring the outsides of the cheeses with Indian red or Spanish brown, or a mixture of both rendered with beer, and so giving them a distinctive appearance by which the public are, or used to be, guided to the real (?) article. It is to be hoped that an earnest effort will be made to restore the ancient reputation of the cheese; and that such a decoration, not being needed to secure its credit, will be discarded.

The Wiltshire System.—This was probably at one time identical with the Gloucester, for even yet some of its goods, though of different shape, are made in that way. No fairly reliable representative analyses are at hand, but the cheese as now made may be divided into two kinds,—(*a*) the flat (or "*double*-" shaped), or deeper cylindrical goods of Cheddar diameter; and (*b*) the small cylindrical cheeses known as "Wiltshire loaves." The former are made as the Gloucesters, with one exception, and that a very important one. From the Cheddar system, whose stronghold is the neighbouring county of Somerset, it has borrowed the principle of a second heating—the average temperature used being 90° F.; and this, while not equalling in its effects the higher scalding of the Cheddar, makes such a difference in the fermentation and the resulting firmness, texture, and flavour, as to justify a distinction from all others. The only item which needs to be mentioned is the standard proportion of salt, which is best fixed at one pound to fifty gallons of milk, with such variations as may be needed. In all other respects the principles and practices are those of the Derby and Gloucester systems, the wire-breaker being used.

The second make is exactly similar to the Gloucester, no second heating being used. Salting on the outside is somewhat practised, but should give place to the better method earlier discussed. The unsuitability with cheeses of nine inches diameter and equal depth must be evident.

The Dorsetshire System.—This—if it deserves to be called a system—has reference to the treatment of milk that has been more or less creamed, the county producing large quantities of butter, and the cheese being regarded as of secondary importance. The stock is that common to the other systems described in this chapter, but there has been more or less grafting on to it of Cheddar practices, so that it is difficult to bring them into any order. Two main aims are kept in view—(*a*) the retention of sufficient moisture to ensure a mellowness of the cheese; and (*b*) the cultivation of the blue mould. The former (*a*) has been dealt with at large under the Cheddar system; and the Cheshire, Derbyshire, and kindred systems have illustrated the principle with variations in temperature and fermentation, productive of corresponding variations in cheese character. It is, therefore, unnecessary to go into details. The general result of the Dorset practice is a cheese with a little more water than the Gloucester, but inclined to a Cheddar texture rather than to flakiness. The latter (*b*) is supposed to be a magnificent mystery, known only to the Dorset makers, and worth a fortune to its possessors. Unfortunately, however, for this notion, it can be practised with any British system, and the result happens occasionally in all dairies without any attempt at cultivation. The grafting of curds kept over for a day, as in the Cheshire-Stilton practice, is all that is needed, with an appropriate management of the curing temperature. The love of the mould flavour in the case of the Dorset gives it undeserved favour with consumers who do not know of its origin.

The Wensleydale System.—This, which is confined to a district of small farms in Yorkshire, is specially adapted to small quantities of milk, and is really the Derbyshire system with wider ranges of temperature to allow for the rapid loss of heat. The largest cheeses seldom exceed 20 lbs. weight, the smallest weigh so little as 7 lbs. each ; and are of variable shape, though generally inclining to that of the Derbies. The best practice may be reduced to a brief statement of the points in which it differs from the Derbyshire system. Standard of milk ripeness, C (Colour-plate) ; renneting temperature, 97° F. Rennet to cause curding in fifteen minutes, the curd being cut in forty-five minutes, and broken by hand, or by a small-wire breaker. The temperature is restored at the end of breaking by hot whey—old Cheddar fashion. Curd put under pressure of 7 lbs., increasing to 56 lbs. Temperature, 82° F. at hooping. Removed, crimmed, salted, and replaced. Salt, 1 oz. to 3 gallons of milk. Final pressing temperature, 60° F.

CHAPTER XV.

THE STILTON SYSTEM.

We have now to describe a system which differs so markedly from those which have gone before, and is of such importance, as to need special consideration. The Stilton is a modern method, dating, so far as its history is known, only from the middle of the last century. Its procedure is so unlike all others of its own age in England, and possesses so many points in common with certain Continental systems, that we consider it likely to have been imported. So persistent have been the efforts to keep it as a monopoly of the original district in Northern Leicestershire and West Rutlandshire, that it has always been difficult to obtain information concerning it. It has often been asserted that the real product cannot be made out of that district,—that the soil and herbage are different from all others, and that the secrets of the manufacture are locked up in the bosoms of its dairy-maids and will never be divulged. But in spite of all this we have tasted Stiltons made far away from Leicestershire, of as fine quality as any we have ever seen of the make of that county.

The Lias soils are found in other cheese-making districts, and with similar herbage. The special points in the construction of the dairies, and in the system itself, are within the reach of human intelligence; and the application of scientific principles to the aims and practices now known, will give higher and more uniform results than have been obtained in any past period. But for commercial considerations the Stilton might easily become as well known as the Cheddar or American cheese in the markets of the world. The dairy suitable for this system costs much more, the labour is much greater during the making, the time of curing is longer, and the cost of production proportionately higher, than with the systems already described. The prices of years ago paid well in spite of all these things, the maker realising 10d. per lb.; but we are assured that this is only rarely obtainable now, and that at times the price has fallen as low as 6d. per lb. Calculating upon a reasonable basis, it cannot pay the maker when it falls below 8d. per lb., for at 7d. it would scarcely pay for its milk at cost production and making expenses. There should be no difficulty in securing a paying price, for the article is a luxury of the highest order, and people who desire it should not hesitate to pay from 10d. per lb. and upwards for it. It will probably never be a cheese for the masses, for its food value is no higher than the average hard-curd cheese, and this points to a narrow limit of increased production. The manufacture should only be undertaken with the certainty of a sufficient demand, and under conditions which will make possible the finest quality.

The Stilton is known by its drab-coloured wrinkled skin; its texture, which tends to be crackly rather than solid or flaky; its mould, distributed throughout; and its flavour, in which the mould and the products of fermentation mingle to produce a combination only possible to such conditions. The material is either whole milk only, or this with extra cream in varying proportions. The cheese made its fame with the latter, the highest proportion of fat allowed to it being given by mixing the cream of the night's milk with the whole milk of the morning,—an increase of from 30 to 45 per cent., according to the average size of the globules and the conditions of creaming. Hence the common notion that the product is a "cream cheese." It is, however, not usual now to give it so much fat, and the extra cream more likely ranges from 10 to 15 per cent. increase on the average milk proportion. The original milk is of no higher quality than in other leading dairy districts; and as the average cream yield under ordinary conditions is from 10 to 12 per cent., it may be taken that the proportion in the united material will range from 11 to 14 per cent., about equal to 3.50 to 4.50 per cent. fat. This is a much lower range than the old standard, but increases considerably the fatness of the cheese, because of the increase of the solids in proportion to the loss of water.

The following analyses by the late Dr A. Voelcker (R.A.S.E. Journal, vol. 22, part 1) give a good representation of the facts of composition. The first was a comparatively young cheese, selling at a shilling, and the second an old cheese selling at fourteenpence, per pound.

	I.	II.
Water	32.18	20.27
Fat	37.36	43.98
Casein	24.31	33.55
Sugar and Extractives ...	2.22	
Salt	.89	.29
Ash	3.04	1.91
	100.00	100.00

Dr Voelcker noted that the latter, with its lower proportion of salt, tasted much more salty than the former with three times as much, and properly attributed this to the ammoniacal salts produced in the curing; and he stated that he has found in old Stiltons as much as 1.81 per cent. of ammonia (NH_3). More of this later; but it should be noticed that if the casein proportion of No. 2 be reckoned as equal to that of No. 1 (.65), though by reason of the increase of fat it would naturally be lower, it will have 7 per cent. of sugar and extractives, proving a high degree of fermentation with no original excess of whey, as shown by the final water proportion, and therefore the result of a low salt proportion. This typical example leads us to ask what the effect of such treatment is on the food value of the article. It is clear that the casein will be in a more advanced state of decomposition, and to some extent therefore more digestible than in No. 1, but the pungent NH_3 salts, volatile fats, and ptomaïnes of fermentation, would render such a cheese altogether unfit for the use of many consumers, and more or less mischievous to as many more. There must also be some waste of the casein, which would be a good food with a lower fermentation, but—with the higher—is converted into products of little or no value.

The increase of fat beyond the proportion of good milk does not increase the food value as much as is usually believed. That butter as a luxury is worth more money than casein, is true in these days; but pound for pound it is of far less value for the building up of the human body. Now it must be evident that when a certain quantity of partly creamed milk is sent to the pigs because its cream is wanted to enrich the morning's milk, the loss on the former increases the cost of the cheese in proportion to the cream added to its material. In view of the real difference in food value, is it worth the while? We believe it is not. A cheese of high quality can be made from good whole milk without such waste; and the maker who follows the old plan should calculate the loss arising from it, and claim for his cheese the extra price which will compensate him. If that is not obtainable, he will do well to fall back on the plain milk.

Another question arises out of the assertion, sometimes made, that the finest goods can only be obtained from the milk of one farm, or even of one milking. The influence of mixing has been already discussed, and it remains only to be said that there is nothing in the Stilton system to justify any fear of it. The alleged necessity for using milk straight from the cow is based on the supposition that the loss of "animal heat" is detrimental, if not fatal, to high quality. This also has been dealt with elsewhere, and we have failed to find any special reason for an exception in the case before us. If it be shown that some makers have succeeded better with fresh milk than with a mixture of night's and morning's; or with the milk of one farm than with the milks of two farms blended; then we may safely say that the explanation is to be found in the inability of those makers to adapt their management to varying conditions. With fresh drawn milk there must needs be a modification in practice; we shall not waste space in describing it, but leave those who choose to make cheese twice a day on the strength of a foundationless belief, to judge from the facts of Chapter VIII. what the management should be.

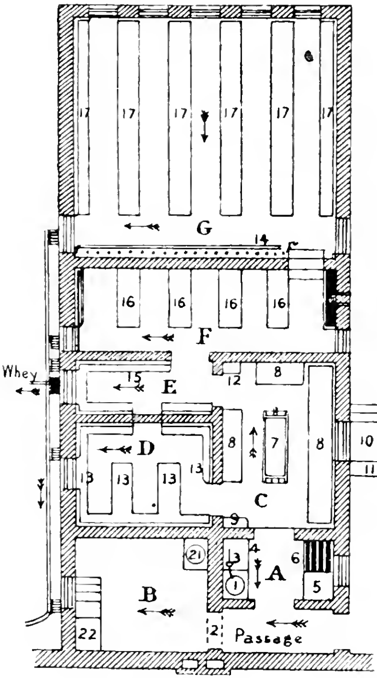


FIG. 143.—STILTON DAIRY—PLAN.

The Stilton dairy differs so much from those of the preceding systems as to justify a special description. The location and aspect may be as before, and in Fig. 143 is shown the best arrangement of the interior for an equal manufacture. Entering the boiler room A (10 × 5), we find the boiler (1) with its flue (2), its feed pump (3) above the return water-tank (4), and the washing-tub (5) and rack (6), as in the Cheddar dairy (Fig. 32). In the making-room C (14 × 10) are the vat (7), draining troughs (8), sundry shelves (9), of which there should be several tiers fifteen inches apart for the numerous stores and utensils; and if the night's milk is set in pans, these will rest on shelves over the draining troughs (8). The milk is delivered by a conductor through the window, below which is a platform (10) protected by a projecting roof (11) (as in Cheddar dairy). A desk (12) completes its furniture. To the left are two rooms; the first D (12 × 8½) being the *draining* room, fitted with racks (13). A set of heating pipes connect directly with the hot-water boiler, so that this room may be warmed separately. A flue leads to a revolving ventilator (Fig. 50) on the roof. We next reach the *coating* room E (12 × 5), also fitted with shelves, and ventilated like D (15), but of smaller size, because the cheeses do not remain in it so long. The drying room F (22 ft. × 7 ft. 9 in.) occupies the whole width of the building. The process carried on in it necessitates a passage of air, but this must be under complete control, and therefore a special provision must be made for it. No attempts to regulate the air, which may be admitted from without by windows, perforated zinc, wall ventilators, &c., can be altogether sufficient at all times, and in order to the best results we recommend the use of a fan (Fig. 114) with a simple device for the proper distribution of the air admitted. A wooden partition at each end of the room, 6 in. from the wall at the west, and 9 in. from that at the east end, makes an air space which communicates with the outer air on the west by louvre ventilators (*a*, Fig. 144), behind which are sliding shutters (*b*) to allow of the air being cut off if necessary. The ventilators can be reached by little doors (*c*) in the partition. There should be three sets, two feet apart, and about half as high above the ground as the shelves are within the room. A series of holes (*d*) of four inches diameter, and covered with perforated zinc, are so placed as to distribute the air evenly. The hot-water pipes *e* for the room are set within this partitioned space, with a door (*f*) to reach them. The partition at the west end is constructed on similar lines, but there is only one outlet, where the fan works. So to prevent the air from gathering to the points nearest to the fan, instead of covering the whole shelf-space in its motion, the draught holes (*a*, Fig. 145) are set vertically, and at half the distance between the fan (*b*) and the wall, and a cross partition *c* supports the main partition and divides the air in the space, so helping to spread the draught. The fan may be worked by a water-wheel driving the differential pulley. The use of this provision will be explained in its place. The shelves (16) in this room should be in double sets,

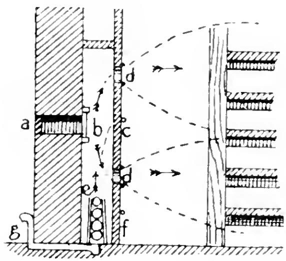


FIG. 144.—AIR DISTRIBUTION.

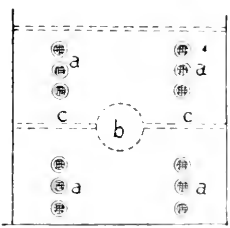


FIG. 145.—AIR OUTLETS.

and of five tiers 13 inches apart, placed across the line of the draught.

Beyond this room is the curing-room G (22 × 20), similarly fitted with shelves (17), but in tiers of six, a single set also being fixed against each end wall. Flues (18) to a revolving ventilator on the roof work with the heating pipes (19) and air ingress holes (20), as in the Cheddar dairy. In placing this room on the ground-floor we are respecting an old Stilton practice, which seeks the necessary humidity by sinking its floor a couple of feet below ground level. We do not believe there is any necessity for this, and the cost of the building is considerably increased by the greater amount of foundations and roof required. A very little trouble would meet the need of air moisture; or, by shortening the time in the drying room a little, the youngest cheeses entering would maintain the proper condition. If the dairy be divided into two floors, the rooms F and G may occupy the upper. The provision of perfectly jointed ceilings, with sawdust, and a lined and white-washed roof, is as necessary with this system as with any; and in order to perfect control of the temperature, which must have more limited range than even with the Cheddar, it is advised that rooms D, E, and G be lined (Fig. 28), and with C and F, be provided with double windows, and these again with thick blinds or shutters. The room B, used as before for boilers and coals, needs no description, beyond the fact that since the hot-water circulation must, in part at least, be nearly on ground level, the boiler (22) must be set lower. A difference of three feet will be ample. The arrows show the direction of the various floors, and the drains are laid as in the Cheddar dairy (Fig. 32).

The management of the night's milk is the same as in all other systems, and where creaming is done on the old lines any good setting system may be followed. The use of cold water will make the ordinary double vat as good for the purpose as any, and for enriched cheese the creamed milk may then be drawn from under the cream to any desired extent by slightly opening the tap. The vat may be made deeper and narrower with advantage. When the whole milk only is to be used, the agitator (Fig. 77) is strongly recommended. Every precaution against ill odours should be taken. Probably the neglect of such has sent some makers, after sundry disasters, to the twice-a-day making; a very costly and unnecessary remedy.

No standard of ripeness seems ever to have been recognised; but that one is as necessary as in any other case, there can be no doubt. We believe that, in view of the general tendency of the processes, the standard should be D (Colour-plate), and that this is better than a lower one would be, with more latitude given for after-fermentation by using less salt. The items to follow will be made consistent with this. The temperatures should range as in the accompanying table:—

Air.	Milk.
65° F.	84° F.
60° F.	85° F.
55° F.	86° F.

and the rennet should be sufficient, with these conditions, to produce a curd of the same firmness as in previous systems in an hour. Here we differ from some makers, who follow a more advanced standard of firmness ; but Continental experience with kindred systems, shows that the best goods are made with curds not exceeding, but falling behind, the Cheddar standard ; and some of the most successful Stilton makers

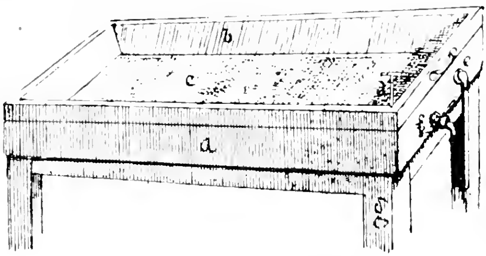


FIG. 146.—DRAINING TROUGH.

confirm this. The contents of the vat should be kept as closely as possible to the renneting temperature by covering, and even by using water of equal temperature around it if necessary. The proper condition being reached, it is well to cut the curd with keen knives, such as those used in the American system (Fig. 135), thus assisting a little

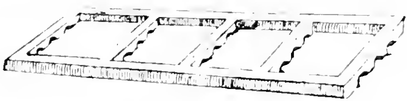


FIG. 147.—FRAME TO CARRY PERFORATED PLATE.

the expulsion of the whey, and enabling the next process to be done without waste.

The draining trough (Fig. 146) is now brought into use. This is best made in two parts, the outer one (*a*) of wood being 28 to 30 inches wide inside, and as many times that measure in length as may be necessary for the quantity of curd made at the height of the season. The inner case of tin (*b*) should rest on the outer one, sloping inwards an inch and half on every side, and being as much less in depth, so as to allow space for water around and beneath it. At an inch to two inches above the bottom of this case, a plate *c* (or plates if the vessel is more than 4 ft. long), with coarse perforations, should rest on a loose frame, constructed as in Fig. 147, with spaces cut on the under sides of its cross-bars to allow of the whey draining off towards the spout at *d* (Fig. 146). This rack is necessary to prevent the plate from sinking in the middle. The total depth of the inner case should not be less than 6 inches, but may be deeper with large quantities of curd up to 10 inches. The whey outlet should be made as in Fig. 148, and the joint with the outer case made water-tight with a rubber ring and white lead. An overflow pipe *e*, Fig. 146, should be provided for the water, and a tap *f* for removing it finally. The inner case needs a support also, as shown in Fig. 149, but this may be fixed. The whole should be made to slope a half inch in every 28 inches towards the outlets, and stand upon a substantial framework *g*, making—with the trough—a total height of three feet. Squares of strainer cloth are now required, of 45 to 48 inches, and these secured by pins or hooks to simple frames, which rest upon the trough as in Fig. 150. The frames must be as wide as the trough, and 2 inches longer than that width, to allow of their projecting an inch on either side. Into these cloths the curd is now to be ladled by a bowl as quickly as is

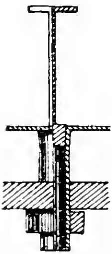


FIG. 148.
WHEY OUTLET.

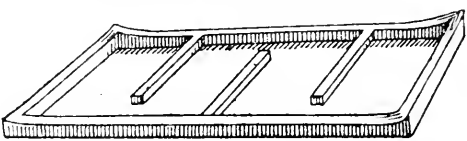


FIG. 149.—SUPPORTS OF INNER CASE.

possible without waste, distributing it equally among the cloths in use. After all that can be taken up by the bowl—with the vat tipped—has been got out, the remainder can be removed by the tap, fully open, the last being gently forwarded by the hand, and caught in a shallow pan placed close under the tap, so as to prevent the smashing which would take place with a longer fall. The vat is now done with for the day. The trough should now be covered, and if the air temperature is below 65° F. water kept at the renneting temperature should be supplied to maintain it. The more frequently this is done the less risk there will be of mischief,

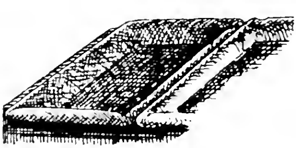


FIG. 150.—STRAINER CLOTH ON FRAME.

either by the curd getting too cold or being over-heated, or unevenly heated, in bringing up the temperature afresh. The quantity of water and frequency of removal will depend on the air temperature; but if it be kept within two degrees of that for renneting, as tested by drawing a little from the tap *f*, there will be no difficulty.

After fifteen minutes of draining, the frames should be removed, and the cloths tied loosely together as in Fig. 151. At thirty minutes from the first covering the whey can be drawn off, a conductor carrying it through the coating-room to a receiver outside the building. This draining must be repeated at increasing intervals (the whey being expelled less in proportion as time goes on), whenever it has nearly reached the plate, and the plug replaced until the curd can bear the air temperature (which should be from 55° F. to 60° F.) without harm. As the contraction of the curd proceeds, the cloth must be drawn as closely around it as may be without pressing out white whey. The ends being untied and drawn upwards with the right hand as at *a* (Fig. 152), it is grasped with the left hand as at *b*, as closely to the curd as will give the proper pressure. Then the right hand releases the ends, and—passing under the left—draws from its grasp the nearest corner, as at *c*, and—giving it a slight twist—carries it round the others, leaves it for a moment to be held in place by the nearest fingers of the left hand as at *d*, and returns to take it afresh and tuck it under its own noose as at *e*. This should be repeated at intervals of half-an-hour, one, and two hours respectively, according to the state of the curd, which can be judged of after a little experience by the looseness of the cloths showing the extent of curd contraction.

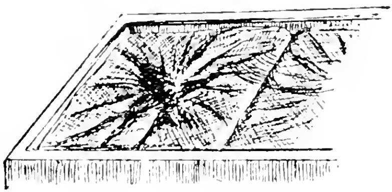


Fig. 151.—Curd in Cloth.

When it is found that a four-inch cube cut from the curd will keep its shape without support, the whole may be cut into blocks of that size and distributed about half-an-inch apart upon the plate, which should be taken into the coating-room E, so that the making-room may be cleaned and aired before the arrival of the night's milk. A light tin cooler of the same width as the trough, and long enough to contain one or two of the plates as may be needed, will be very useful. Here it should be kept lightly covered with a cloth until it is ripe and firm enough to be salted. This will usually be early the next morning; but the probabilities should be estimated, and if ripeness is likely to be reached during the night a light salting, at the rate of from a quarter of

FIG. 152.—TYING CURD.

an ounce to an ounce of salt to every ten gallons of material, according to expectations, may be applied, the balance of the full amount being added when ripeness is secured. Better still for the cheese, the dairyer may turn out in time to salt it in the ordinary way. The standard of curd-ripeness should be K (Colour-plate), and the salting at the rate of 1 lb. to 60 gallons of "double cream" material, or to 50 gallons of whole milk. This difference, with variations suitable to intervening degrees of enrichment, is made because of the increase of fat out of proportion to the casein, and beyond the limits considered in Chapter VIII. The curd is gently crimmed to fragments as large as the top of the thumb in preparation for salting. The dryness of the curd at this stage should be uniform from day to day, or a suitable difference made in the salt quantity if ripeness comes before it is dry enough. The curd is now placed in the hoop (Fig. 153), which may vary from 6 inches to $8\frac{1}{2}$ inches in diameter, and from 10 to 13 inches in height, the sizes of cheeses produced within this range being suitable to its character and the demands of the trade. The curd being pressed by the hand when filling, such hoops will hold enough to make cheeses of 10 to 15 lbs. in weight. For uniformity's sake the quantity of curd which the moulds used will hold should be ascertained, and weighing practised.

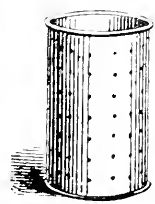


FIG. 153.
STILTON HOOP.

In the hoops the curd should now be taken to the draining-room, and kept at a temperature of 65° F., and with a humidity equal to a difference of two degrees in the hygrometer readings. It is customary to provide wooden shelves ten inches wide, and having grooves cut in them to carry the whey drainings to a common point of discharge. These are, in such case, covered with cloths, which must be frequently changed, and entail a great amount of wear and washing. A better plan is to provide frames only, with tin plates (Fig. 154) half-an-inch wider each way than the diameter of the hoop, and having three sides turned up and the remaining one turned down, so as to carry the whey into a shute of zinc screwed to the front of the frame. This shute discharges into a common pipe at the end, where a vessel or conductor receives the whey. With this arrangement no cloths are needed, there is no soaking of the shelves with sour whey, and the plates being movable can be brought to a common tub for cleansing and much more easily

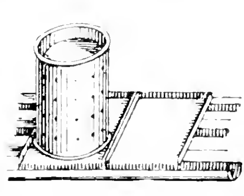


FIG. 154.—TURNING PLATES.

kept sweet. They also take the place of followers whenever pressure is not required; and where it is, a single tin follower for each hoop is not enough, but specially thick ones (*a*, Fig. 155) should be provided, one or more of which may be laid on the cheese according to need, and drawn out by the hook *b* at turning. A few dozen of such followers should always be at hand.

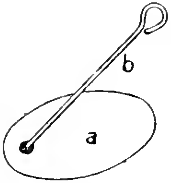


FIG. 155.—FOLLOWER AND HOOK.

The cheese must be turned in the hoops three or four times next day. At the early morning turning, the hoops should be washed on the outside with water at 80° F. to 90° F., and the plates also cleaned. For this a tub should be brought into the room. In this a stool, with a top nearly as large as a turning-plate and as high as the tub is deep, may conveniently be used. A cheese with its plate being lifted from the shelf and placed on this stool, the hoop may be washed down with a brush and wiped. Then a clean plate being laid upside down on the top of the hoop, and held in place by the left hand, the right hand being passed under the lower plate, and, with a firm pressure of the plates against the ends of the hoop, all may be turned, and the cheese and the plate now under it placed on the rack; the dirty plate being then washed in readiness for the next cheese.

In this way no cheese is more than two minutes away from its place, whereas all the cheeses on one of the ordinary shelves must be removed in order to its being cleaned. The second, third, and fourth turnings should be made at three, four, and five hours' intervals from the previous turnings respectively, and without washing. During this period skewering should be practised at every turning and once between each two turnings. Some makers, anxious to secure the blue-veined appearance caused by the moulds, when the latter fail, are said to use brass or copper skewers, which—left in the cheese and rusting under the action of the acid whey—give an imitation of the colour, but with danger to the consumer by reason of the poisonous nature of the rust. It is to be hoped that nobody will ever more be so foolish. The moulds can be propagated with almost infallible certainty; but even if this was not so, no advantage in price could excuse such a practice. The skewers should be of steel, and not exceed one-sixteenth of an inch diameter. In the absence of any practical pressure the importance of this skewering is great. The cheese soon shrinks away from the hoop, becomes firm though elastic, and gets a nearly smooth surface. This generally takes from four to six days, and should never take more than eight days. We have heard of cases in which twelve to eighteen days have been required, but there could not have been any necessity for this apart from bad conditions.

At this stage the hoop is removed; all the visible crevices sealed up, by drawing a knife-blade flatwise against the cheese; and a bandage of grey calico, a little wider than the depth of the cheese and long enough to allow $1\frac{1}{2}$ inch of overlapping, is stretched tightly and pinned securely upon it. The hoop is replaced, and it is sent to the coating-room by way of the cupboard. This is made in the wall between the two rooms, and has a door on each side, and shelf-room enough for one day's cheese. Its use prevents much running to and fro, and admission of cooler air. The bandaging is continued daily until a proper coat is formed; but by the second day after entering the room, the cheese should be able to stand well with only the support of the bandage, and the hoop may be removed when this is found to be the case.

The coating has generally been done either in the draining-room or in the making-room. There is a risk in the former case of "*slip-coat*," which arises out of the lodgment within the skin of moisture which ought to come out, and which, under the influence of the warmth, produces rapid softening of the casein with sliminess. The skin will then break away, and the moist matter must be removed by scraping. In any such case there must needs be waste; there will also generally be deterioration in the value of the remainder. The main cause of this is an atmosphere, by no means dry in itself, but too dry for our purpose, forming too close a skin; and this in the presence of defective contraction, or too little salt, closes in the whey which is working toward the outside. Skewering has now ceased, and the only preventive is a lower temperature with maintained humidity; and this the coating-room affords, being kept at 5° F. lower than the draining-room. The making-room has been mostly used in such cases, but there is a total impropriety in keeping cheeses at this age, and so affected, in a room where milk has to be held over-night. The special apartment meets the case well, and as the cheeses remain two days in their hoops there is no sudden lowering of their temperature. In both rooms the ventilation should have constant attention. The coat first shows itself by dry patches on the bandage, which increase steadily. When it covers all the cheese the bandage can be taken off, washed, and used on others.

The cheeses now go to the drying-room, which provides a controllable draught of fresh air, for the cheeses ought now to be dry enough to allow of their skins being hardened without risk of *slip-coat*, and the remaining moisture must be treated as in Cheddars. They should be removed in the evening, so that they may become accustomed to the gentler draught of the night, when the inlets are so set as to secure the goods against mischief from any unexpected fall of the temperature. In the morning the state of matters should be early examined, and the draught increased if the atmospheric conditions warrant it. The influence of the draught depends on its temperature and its dryness,—the former should not fall below 55° F., and the latter should not be such as, with that temperature, to produce any cracking. Beginning with a difference in the hygrometer readings of 4° F. in the morning, the drying may be carried on to 6° F. difference by the warmest part of the day. If this can be obtained by the passing air only, the matter is simple ; but if not, the fan should be brought into use. The drying-room (in Fig. 143) is arranged to admit air from the west, from which our prevailing winds blow. When the wind is in the other quarters, the fan will be more needed to induce a draught of western air, as usually warmer than that from the north or east winds, and cooler than the south wind. We believe that with such a provision the time of drying can be materially and beneficially shortened ; but there must be a limit to such an economy, and that on the safe side of any cracking, which would not only make the cheese too dry, but also open a way for the flies which, with the judgments of true gourmands, seem to specially enjoy a fine Stilton. Mites also share the same taste, and make more havoc with this article than with any hard-curd cheese. The variations within the correct range of humidity when properly graded are not injurious to the goods ; but sudden changes must always be avoided, especially in the direction of increased cold and dryness. The appearance on the outside of black mould is a sign of too much air-moisture. The original drab colour should always be maintained.

In from fifteen to twenty days the cheese will be dry enough to go to the final curing-room. If one cheese of each batch be bored with a trier, not cutting more than a quarter-inch diameter, it will be easy to establish a standard of dryness, and recognise variations from it on crushing a small fragment between the finger and thumb. From that time onward the cheese should be kept at a temperature of 55° F. to 60° F., and with a similar humidity to the coating-room. The ventilation must be carefully watched.

The internal mould is obtained in the coating and draining room, and when once it is established in these rooms the cheeses will seldom fail to contain it. In every new dairy it will be necessary to encourage it by keeping a little curd over until it is well moulded, and scatter the spores from it around the new cheese. Doubtless, too, under present arrangements, some inoculation is done in the young curd in the vat or draining-trough by floating spores, but these need not be depended on for the presence of the mould in the finished product.

We may now briefly review the main points of the system. Apart from the addition of cream, which is not an essential, its main business is to secure a special flavour;—and in order to that, in part, a free cultivation of mould ; and, in other part, a fermentation in character and degree approaching to that of the Cheshire; and in order to the spread of the mould, a crackly rather than a solid or flaky texture. Hence the avoidance of a second heating and pressure, and the consequent slow settlement of the curd, with all of which the remaining details are consistent. The length of the process as a whole cannot be reduced beyond the limits given without detriment to the product.

CHAPTER XVI.

CREAM CHEESE.

THIS delicacy is made by most town dairymen to meet the ordinary and very uncertain demand for it; but it is also produced in some country dairies, and in cheese and butter factories, on a larger scale; and deserves notice, if only because every dairyer is liable to be called upon to supply it, and, being a profitable article, he should be ready to do so.

First Form.—There are two kinds of cream cheese. In the first form it is simply cream reduced to a certain degree of solidity, with the effects of fermentation added, and the manufacture is of the simplest. The cream should be thick, and free from any but the friendly forms of fermentation. Cream mechanically separated (see Chapter XVII.) is best for the purpose, because it can be obtained in much thicker condition than that which is skimmed from set milk. This, put in a clean earthenware or glazed brownware vessel, should be left in a pure air at 60° F. until it has become thicker by fermentation, which will usually take three days. It should then be poured into a deep linen bag of fine texture, and closing with a draw-string; and in this hung out of contact with other objects, and with a vessel under it to catch the whey dripping from it. The bag should not be more than one-third full. Here it will in two days become a soft and comparatively dry curd. It will now need pressure; and this can best be applied by the simple device shown in Fig. 156. It consists of two boards (*a*) hinged together, and grooved on their insides; the grooves on the upper board furnishing a grip for the bag when in place, and those on the lower one a means of gathering and discharging the whey. A ledge and spout completes the provision for the latter purpose.

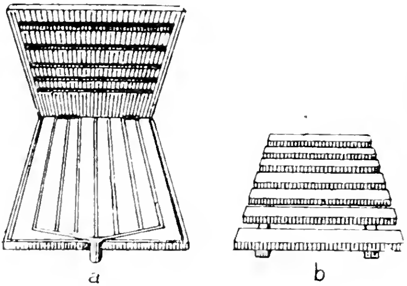

a b

FIG. 156.—CREAM CHEESE PRESS AND RACK.

A light rack (*b*) fits within the ledge when in use. The cream should now be compressed by hand in the lower part of the bag, the loose part tied (as in Fig. 157) as closely as possible and placed between the boards as in Fig. 158. In this illustration it will be seen that the lower board is raised by angle pieces (*b*), so as to give it a fall for draining the whey, while the upper board (*a*) has a ledge (*c*) to keep in place certain weights used to give the pressure. The latter may be ordinary scale weights, of which a 2-lb., 4-lb., 7-lb., 14-lb., and 28-lb. will suffice, or twenty lead plates weighing 2 lbs. each, the latter being the best to buy because the simplest to use, if the others are not already at hand. The weight should be gradually increased from 2 lbs. to 40 lbs. during the following twenty-four hours. The curd being emptied from the bag, requires to be kneaded with a wooden knife (Fig. 159) until it is reduced to a uniform consistency. It will then be ready for the mould, which is a small frame of tin of any convenient shape, fitting into a board, as at *a*, Fig. 160, and lined as at *b* with strips of chemically pure butter muslin or vegetable parchment. The curd being pressed into this, the ends of the lining are turned over, the mould lifted, and the cheese removed. It is now ready for use.

FIG. 157.
CREAM CHEESE IN BAG.

Second Form.—The other kind is made from a mixture of milk and cream, the latter forming one half, two-thirds, or three-quarters of the material as the case may be. The coagulation may be by fermentation, as in the previous case, or it may be helped by rennet; if the latter is used, it should be at half the proportion required for Cheddar, for the fermentation should have the chief influence. It should be mixed with the material when this has reached the L standard (Colour-plate). In either case the process and conditions will be as before, but with rennet the time of making will be much shortened.

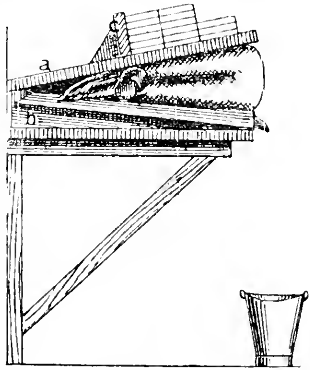


FIG. 158.—CREAM CHEESE IN PRESS.

The products may now be compared. That of the pure cream will differ from the other in its richness, and as a rule this is the favourite with British consumers. It tends, however, to early spoiling by B.A. fermentation and consequent rancidity. A little salt worked into it with the knife, or rubbed over its outside when finished (in which case wet muslin should be used for wrapping), will keep it longer, but the flavour is not generally liked. Those made from the mixture are more strictly cheese-like in texture and flavour; and those made with rennet will develop the characteristic casein digestion and mellowness. Salt should be used with these, being mixed with the curd at the rate of one-eighth to one-quarter ounce to the pound of curd, as the fat proportion ranges from the highest to lowest points given. They will be

FIG. 159.—KNEADING KNIFE.

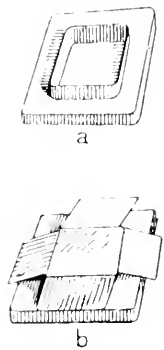


FIG. 160.—CREAM CHEESE MOULD.

ready to eat in two or three days, and in the meantime should be kept turned at a temperature of 55° to 60° F. Most people would suppose the whole cream article to be worth more than the others, but from the food point of view the reverse is the case; and the mixed material being the least costly its cheeses can be sold at a proportionately lower price.

CHAPTER XVII.

CREAM AND THE METHODS OF ITS SEPARATION FROM MILK.

CREAM, consisting of the fat globules of milk with a portion of the plasma, is of itself a food, and the source of butter. Its use at the table has greatly increased since better methods of creaming and after-treatment have sent it to the consumer in such a form that he can depend on its character and keeping quality. The cream of commerce is no longer the thin skimmings of milk set but a few hours, or the half-soured skin of a day old and upwards, formerly sold as a great favour to the dwellers in cities, to whom the name suggested a perfect delicacy, and who were happy with it in the absence of anything better; but a thick and sweet article, which is much cheaper than the old one as compared at their respective prices, because of its lower proportion of water, and better food value in other respects. During the fruit season a very large demand is made for it, and the prices obtainable are so much in advance of the possibilities of butter-making during the same part of the year, as to justify the cultivation of the trade, even at some expense for suitable appliances and packages. For this purpose, means of immediate separation from the fresh milk is a practical necessity, and the proper management of cream for sale will be described in due course.

Creaming, by whatever system, proceeds upon the same lines; recognising the laws which govern the relative densities of the fat globules and the plasma, and varying only in the method of applying those laws. These have been already discussed at length in Chapter III. and need not be re-stated. The business of the dairyer is to secure all the fat, in the least time, and in the most perfect condition possible, in consistency with a proper economy. Exception will probably be taken to the first of these points, for there are those who assert that the smallest of the globules which are removed by the most recent methods yield only an inferior butter, which does not pay for the cost of securing them. It may be granted that certain conditions arise in connection with the more complete separation, ignorance of which may give the inferior results referred to, but there is no necessity for them. So far as the experiences of those who recognise those conditions are in evidence, they show—what we might have expected—that whatever the size of the globule, the butter is always the ordinary association of the fats earlier described, and there are no differences between these globules and the larger ones save in their size and the relative proportion of the envelopes to their contents. Whatever difference there may be between the food values of the butters of different systems of creaming, the cause must be sought for, and will be found elsewhere, as we shall by and by show. The economy of the question has been settled beyond dispute.

The time occupied in creaming is of some consequence. It determines the space necessary for the appliances used, and therefore the original and working cost of the dairy as well, and, under ordinary conditions, the quality of the cream and butter. Nobody will quarrel with our remaining points of cream condition and economy; we will therefore leave them to be illustrated as occasions arise.

Cream and Butter Dairy.—The dairy in which creaming and butter-making are to be carried on must be first described. The farm cheese dairy as illustrated in Fig. 32 has a room for making the whey butter of the cheese-making season, and the milk butter of the winter. Here, however, creaming is done for the former in the tank 19, and for the butter in the vat 7, or by special creaming appliances placed in the cheese-making room, which will form a very good apartment for the purpose, and for some parts of the butter making as well. In the butter-room are found the cellar 25, shown in section in Fig. 47, with its cooling provision of an overhead water-tank, the shelf 27, which should be of slate, the churn 28, and butter-worker 29, these being the principal furnishings.

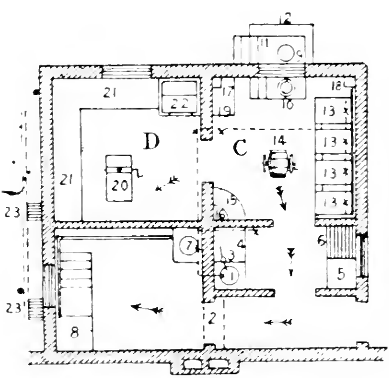


FIG. 161.—FARM BUTTER DAIRY—PLAN.

In a very large majority of cases, however, butter-making is carried on by itself; and the dairy for this purpose may be reduced to four rooms, and form a wing to the farm-house, as in Fig. 161. The boiler-room A and coal-store B properly occupy the same places as in the cheese dairies (Fig. 32, &c.), and are quite as desirable here as there. The boilers 1 and 7, with their common flue 2, the washing vessel 5 and rack 6, are necessary; and the tank 4, with its pump 3, may well be provided wherever a water-cooling system is used for creaming. Adjoining the boiler-room, the room C (12 ft. by 11½ ft.) should be devoted to creaming, cream ripening, and churning, the nearness of the hot-water supply and air warmth being an advantage; while the room D (12 ft. by 12 ft.) should be kept for the working, making-up, and storage, for which a low temperature is necessary to the finest results. The water-tank should therefore be within the last-named apartment. A delivery arrangement at the window in C should consist of a conductor 9, with a distributing vessel 10, a platform 11, with a projecting roof 12, as before. The creaming apparatus 13, of whatever kind, but here shown as setting pans; a churn 14; a shelf 15, for cream pans, with a water-heating coil 16 behind it, supplied from the boiler 8; air outlet flues 17, 18; a cupboard 19, for stores; and the water-pipes shown by dotted lines, complete its fittings. The flues 17, 18 proceed to a revolving ventilator (Fig. 50) on the roof, and can be used separately or both at the same time, as circumstances may demand. In the room D, the butter-worker 20, the slate shelf 21, and the cellar 22 are found; while the drain wells 23 are outside the building. If the creamed milk is to be used on the farmstead, it may be discharged into a vessel placed on the delivery platform through the conductor 9 reversed, a small platform, which may also form a stand for the distributing vessel 10, enabling the dairyer to reach the conductor easily. This where a setting system is followed, while from a mechanical separator a pipe may carry the milk direct to the conductor. The direction of the floor inclination is in each case shown by arrows. In all other respects the building construction should be as advised for cheese dairies, and the internal temperature should be carefully under control.

Factories concerned in this department of dairying may be properly divided into (*a*) creameries, where creaming only is practised, these being either branches of the butter factories, or engaged in the cream-selling trade; (*b*) butter factories, in which either the whole business is carried on, or in which butter is made from purchased cream; and (*c*) blending factories, in which purchased butters are blended together in various grades. This classification will probably be objected to by those who have been accustomed to the present loose methods of description, but it is at least consistent with facts, and therefore necessary to our purpose.

The Creamery.—The first kind supposes a milk supply insufficient to justify a complete provision, and such a building as is shown in Fig. 162 may be managed by a man with only the help of a youth, and that without difficulty. The general practice is to send the creamed milk back to the farm, and a convenient provision is here made for despatching it for this purpose, or for the more profitable household consumption, which should be cultivated everywhere. If it is to be used by the creamery owner in feeding calves or pigs, it may be carried to them by glazed ware pipes, first, however, being discharged into an open-air well, after the fashion of drainage waters (Fig. 29).

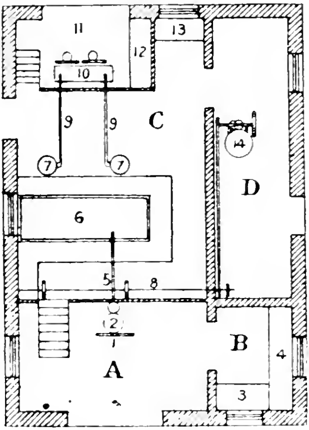


Fig. 162.—Creamery—Plan.

The building consists of a milk-receiving platform A (16 ft. by 9 ft.), with a combined office and testing-room B (9 ft. by 6 ft.); adjoining to it a creaming-room C (23 ft. by 16 ft.); and a combined boiler-room and coal-store D (23 ft. by 6 ft.). On the platform A are the tipping barrier 1, the receiving vessel 2 (which discharges by the conductor 5 into the milk vat 6), the desk 3, and shelf-table 4, serving for entry and testing purposes. From the vat—which is fixed on pillars and surrounded by a foot-board to allow of its being conveniently reached for cleaning—the milk is distributed to the mechanical creamer 7, which is driven by belts from the power-shaft 8, and which delivers its creamed milk by the pipe 9 to the capillary cooler 10, on the despatch platform 11, where a small desk 12 is provided for entries. A hot-water tank 13 is supplied by the boiler 14, which, for this case, may be a vertical, with the engine attached or separate, as may be most convenient. Other things being equal, we advise that it be separate. If the building can be placed on ground of sufficient slope the despatch platform may be done away with, the floor being higher than the ground outside. Any convenient location and aspect will answer for a creamery.

The Butter Factory.—The butter factory may consist of a similar building with churning and making rooms added (the latter having a north aspect), steam power used for churning, and more cool storage room provided. The plan, Fig. 163, shows such a factory. The receiving platform A, with the office B, and laboratory C, are arranged as in the "Cheddar" cheese factory (Fig. 62), and enclosed together. Where the creamed milk is sold or returned to the supplier, a second platform D

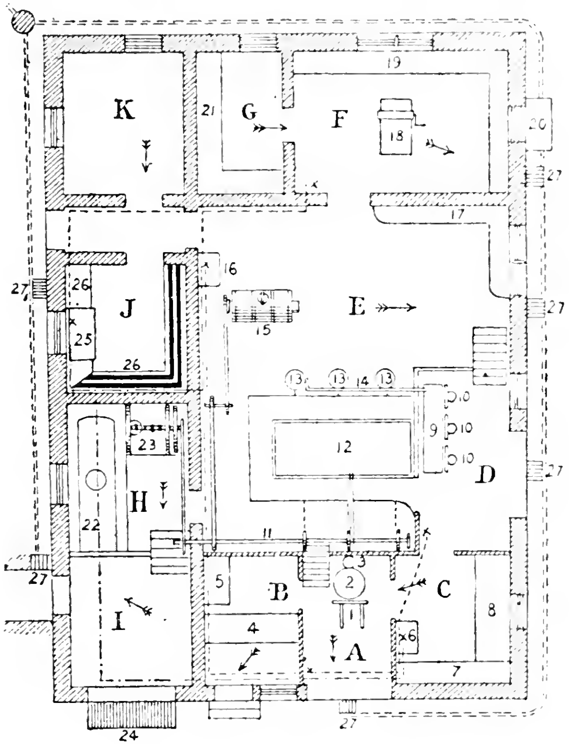


FIG. 163.—BUTTER FACTORY—PLAN.

1, Tipping barrier; 2, Receiver; 3, Conductor; 4, Counter; 5, Desk; 6, Water heater: 7, Shelf; 8, Testing table; 9, Separated milk receiver; 10, Coolers; 11, Shaft for separators; 12, Milk vat; 13, Separators; 14, Separated milk pipe; 15, Churn; 16, Water-heater; 17, Shelf; 18, Butter worker; 19, Shelf; 20, Shade over window; 21, Shelves; 22, Boiler; 23, Engine; 24, Coal gates; 25, Water-heater; 26, Shelves and racks; 27, Drain wells.

————————	Water Pipes.
— — —·—·—	Steam Pipes.
==========	Drains.

may be placed conveniently for the cooling and despatch; and in the latter case the supplier can proceed from one to the other, so clearing the way for others to deliver their whole milk. The room E should be devoted to creaming, cold weather ripening, and churning; F to warm weather ripening and making up; G to cool storage (the water tank is over this and part or all of the making room); H to the engine and boiler, the boiler front being within the coal store I, as in the Cheddar factory (Fig. 62); J to washing; and K to stores and packing-boxes. The structural work should be as in the other examples, the furnishings as in the list of references; the latter will be described as they come into use.

A blending factory will be simply a butter factory with the room and appliances for creaming and churning omitted, and needs no special description.

The Methods of Creaming may be separated into two main divisions,—(*a*) setting systems, and (*b*) separation by centrifugal force.

Setting Systems proceed by leaving the globules to rise through the plasma under the existing natural conditions, or cause them to rise more quickly by changing those conditions for others more helpful. These shall be taken in order, commencing with the simplest.

The *shallow-setting open-air pan*, Fig. 164, is the oldest form of creamer now used in this country. It is frequently made of large size and oblong shape, set on a frame, and provided with a plug (Fig. 148) for drawing off the creamed milk. This method gives a shallow body of cream of a varying density, the surface globules being closer together than those below.

Fig. 164.—Shallow Pan.

By reason of drying and oxidation a skin is formed in course of time, and with sufficient cohesion to resist breakage. But the under globules are free, and easily float away from this skin. It is usually removed by a shallow *skimmer*, made as in Fig. 165, or with a long handle for use with wide pans as in Fig. 88. The cream being detached from the side of the pan at a starting point, the skimmer blade is carried under it and lifted. The milk runs out through the perforations, which must neither be too large, too numerous, nor too near the edge, or loss of the lower globules will follow. It will be plain that with all possible skill and care there must be more or less of such loss, or else a considerable relative proportion of the plasma must be removed with the cream. When the main body has been removed there will remain a fringe of cream against the sides, which, when the milk has been poured away over the clean part, should be scraped off with a

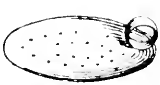


Fig. 165.—Skimmer.

piece of horn. Numerous devices have been brought out for collecting the cream or drawing the plasma from under it, but in view of the facts now to be presented we think it useless to describe them. The method stands condemned on several charges, and its days are numbered. In order to prove its comparative wastefulness and general inferiority, let us summarise its conditions and action, and compare it with others.

Milk as drawn from the cow loses temperature before it can be set, and from 102° F. will fall to 80° F. with the air at 50° F., or to 90° F. with the air at 65° F., unless the dairy is very near and unusual care be taken to protect it, in which case an advantage of two or three degrees may be gained. The fine streams of milk which pass from the teats into the pail, and from the strainer into the setting-pan, cannot fail to give off their heat to a serious extent. The milk being set at rest in the pans, the globules begin to rise at a rate dependent on the difference between its temperature and that of the air, this affecting the difference between the density of the globules and that of the plasma.

This influence of temperature is just what is possible to a falling of twenty-five to thirty degrees Fahr. and no more, for the air of the dairy cannot reduce the temperature of the milk below its own. The results are much better, of course, than as if the two were at the same temperature, but as set against better methods it is a failure. At thirty-six to forty-eight hours after setting, the best of skimming or drawing will leave fat in the plasma which other methods would remove, and that in such proportions as to make the latter economically profitable. But not only is the rising of the cream imperfect, there is no small amount of loss by the methods of removal (though of the two the greatest arises from skimming), by the disturbance and carrying away of some part of the collected globules. It is very difficult to estimate the average loss from these causes, but we have the best reasons for believing that it does not fall short of fifteen per cent. of the butter realisable by the best methods.

The long time required for all that can be done is also a source of damage. The number of pans, the size of the dairy, and the labour and time occupied in the management, are all affected by this, and at least two sets of pans are necessary,—generally three, sometimes four,—with corresponding expenditure. In the meantime, the ferments are at work, and so favourable are the conditions attending them that often the whole is near to coagulation before the cream has had its fair chance to rise. If the influence was confined to the friendly ferments, the harm to the cream would be trifling; but the wide exposure gives to other ferments the best opportunity of working their many forms of mischief, and what is started in the setting-pan is carried forward in the cream-pan. The skimmed milk is greatly reduced in value for feeding animals, and is unfit for human consumption. Finally, during the long exposure to the air, oxidation makes progress, and creates its share of waste ; and the drying of the cream surface makes it impossible by mere stirring to bring the whole back to the state in which the globules should mix with the proportion of the plasma proper to set cream. Such cream must be heated to restore the right condition ; and if this heating is carried beyond the temperatures favourable to fermentation, it checks, and if not allowed to pass that limit it favours, the ferments,—both good and bad. We have no practical control over conditions with this method, beyond taking what care we can to have pure air and clean milk and vessels. This, of course, we need in all cases ; but here the exposure is so long as to give the milk but a poor chance of escape. Nor can we import into it friendly ferments, as in ripening milk for cheese-making. Our need is in the direction of the lowest fermentation possible. Some makers skim at twelve hours, to secure cream with the largest globules and in the better condition, and make a butter of superior quality from it, leaving the rest to rise under the increasingly unfavourable conditions for an inferior result. So far as the satisfaction of making *some* good butter goes, this is better than the common practice ; but the best work so done does not bring the method near to a reasonable profitableness.

Such is the open-air shallow-setting method, when its followers aim at the highest yield of butter. Often, however, they are content with a lower yield, and—fearing to keep their milk in doubtful weather—skim it at twenty-four hours old, with a heavier loss of butter than in the other case. A large quantity of skimmed milk goes from English dairies with one per cent. of fat, or nearly one-third of the average proportion. This must needs be the case when a milk of fair quality yields only a pound of marketable butter to every four gallons of milk, as we have known it to do.

For many years dairyers, both in Europe and America, have practised cooling with shallow pans, and benefited thereby to some extent. Some have set the old style of pan in troughs with cold water running around them ; others have made them with two cases, and laid on water, running continually, to fill the spaces between. The results have been a greater rising of the globules, because of the increased differences in density due to the rapid cooling, and the influence of currents created thereby, and a better keeping of the milk, so that the yield has increased with less risk than in the old way. When the milk has been brought to the dairy immediately, and the water temperature has been from 50° F. downwards, the gain every way has been considerable. We have before us reliable evidence of such pans having been in use in America more than twenty years ago, and so well constructed that we have not since made any important improvements in them. The cold had also the effect of checking the production of fibrin, the existence of which was not then suspected. Some makers provided covers, either solid, with occasional means of ventilation, or with wire gauze of considerable surface—in either case intended to keep out dust and flies. The real value of such protection lay in the hindrance to a great extent of microbes from reaching the milk; and these inventions were, according to the most recent light, on the right track for improvement. There remained still a point which nobody seems to have touched until a much later time, viz., the propriety of raising the initial temperature somewhat, so as to extend the range of the falling. This has now been done, and not only can the cream be more quickly and perfectly obtained than with the cooling only, but the loss which arose out of the variations in the temperature of the air, the milk, and the cooling water is at an end. Sometimes for weeks together, in warm weather, the water has been nearly as warm as the air, and the advantage of its use correspondingly limited. This is an extreme case, but between that and the greatest possibilities with simple cooling, a reduction of effectiveness in various degrees must needs arise out of the variations referred to. As a consequence of these improvements, it is now easy to secure all but .35 to .50 of 1 per cent. of the original fat, according as the average size of the globules is large or small. This is equal to a gain of a quarter of 1 per cent., as against the old shallow pan as best used to half per cent. as worst used; or, roughly, an increase from 8 to 15 per cent. on the butter obtainable from average milk under the conditions given.

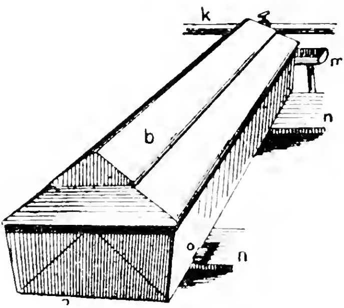


FIG. 166.—JERSEY CREAMER.

The "Jersey" and "Dorset" pans are well-known representatives of this best form of the shallow pan. They are identical in essentials, excepting that the latter does not provide a cover. The former will serve to illustrate the practice. It consists (Figs. 166, 167, 168) of a double-cased vessel *a*, having a cover *b*, a funnel *c*, overflow pipe *d*, and a water outlet *e* covered by a screw cap. A plug *f* fits into a pipe *g*, which again rests within the fixed pipe *h* for the removal of the skimmed milk, the pipe *g* having a strainer *i* of fine wire gauze, protected when in use by the ring *j*, which is removable. A pipe *k* supplies it with water, either from a special tank or—as in our ideal dairy—from a general supply, and the overflow is carried off by the shute *m* to the tank (Fig. 161) for use in the boiler. The quantity of water used in this or any other water-cooling system is considerable, and should not be wasted. The pan rests on a frame *n*, two projections, resting in the hooks *o*, keeping it in place, and allowing it to be tipped as in Fig. 168. The cover is roof-shaped, with an air opening half-way up each side, and extending its length at that point.

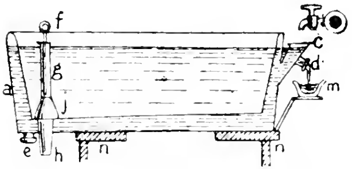


FIG. 167.—JERSEY CREAMER—SECTION.

In use the milk should be strained into the pan, and heated to a temperature which will give a fall of 50° F. by the use of the water at hand. Therefore in setting milk in any double-case pan, our first

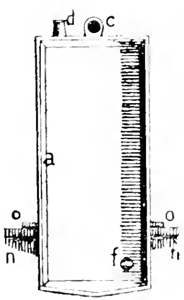


FIG. 168.—JERSEY CREAMER—TIPPED.

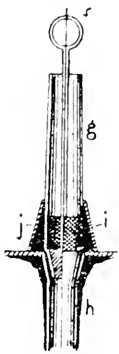


FIG. 169.—JERSEY CREAMER PLUG.

business is to take the temperature of the water to be used in cooling as a basis for determining what the starting temperature of the milk is to be. Allowing 3° F. for a margin, we may add 53° F. to the water temperature, and the result will give that for the milk:—Examples—(1) Water temp., 45° F. + 53 = setting temp., 98° F.; (2) water, 60° F. + 53 = setting temp., 113° F. The colder the water down to near freezing-point the better. This is liable to be disputed on the strength of alleged experiences, but these have an explanation which is of some importance. It is said that the use of water at 45° F. gives the best results, and that below that point the tendency is to loss. Doubtless, for in proportion to the increase of cold is the rapidity of the currents, and the disturbance of the cream layer; and if a proper speed be exceeded nothing is more certain. But if the water used is raised by the addition of warm water to 45° F. until a thermometer, set in the milk at the start, shows that the milk has been reduced to 55° F., the coldest water may be used with advantage afterwards. A bent wire stand, as Fig. 170, may be made to hold the thermometer in a nearly upright position. It will, however, be readily understood that from 45° F. downwards there is no necessity for limiting the setting temperature by the rule given. A range of 50° is essential to the proper working of the principle; but a longer range is still better if it is secured by a colder water, with an initial temperature not higher than that most favourable to fermentation. We may therefore set at 98° F. whenever the water is at 45° F. or lower.

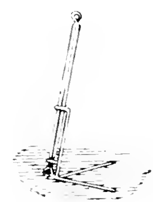


Fig. 170.
Thermometer Stand.

There is an objection to a higher initial temperature, and it increases in force as we rise above that point. The milk has to descend through the range of temperature favourable to the ferments; and while from 98° F. downwards it is getting out of, and away from, that range, from all higher points it is descending into, or within it. If, for instance, we start at 110° F., the milk has to pass through 12° more of the favourable range than as if heated only to 98° F.; and the increase of ferment encouragement is in proportion. This is the weakest point in the method. If we are to obtain the best results in all respects we must give the range of 50°; and as water becomes more than 60° F. in continued warm weather,—and ice is an aid too dear to be thought of in this country, and difficult to get as well,—we must run risks on one side or the other of partial failure. With the increase of temperature we have also to reckon with the fibrin. In the case before us we have no hesitation in advising the use of safe preservatives of the Boron class, which, if carefully stirred into the milk before setting, will carry it safely over the dangerous part of its descent, and that with a low proportion and at a trifling cost.

In heating milk for setting it is important that the water should not be hotter than 150° F. at any time. Boiling water has been recommended by some; but, as the milk cannot be stirred during the heating, the danger of local albumin coagulation arises with the higher temperatures. Water maintained at 150° F. by fresh supplies will soon raise the small quantity of milk which any pan of this kind will hold to the necessary point. Moreover, the longer time taken is compensated for by the more perfect effect on the globules. Our purpose in heating is to cause them to expand, but they respond more slowly to the action of heat than the plasma. If after the desired temperature has been quickly reached we immediately begin to cool, we check the still-continuing expansion of the globules, and the full benefit of the heating is not obtained on them. If on the other hand the heating is slower, their expansion keeps much nearer to that of the plasma, and ten minutes' maintenance of the final temperature will probably bring them to their outside limits of size at that temperature. The cooling will give immediately a greater difference between the densities of the globules and the plasma than would otherwise be possible, and a quicker rising of cream, with no greater force of the currents. There is also to be set against the more rapid heating, the greater rapidity of the currents created by it. The position of the inlet funnel makes

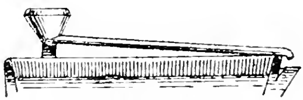


FIG. 171.—HOT-WATER FUNNEL.

it necessary to use a separate one (Fig. 171) for the convenient supply of hot water.

Another error is in supposing that the most rapid reduction of the milk temperature ought to be the main aim of the dairyer. This would have but the same effect as the first use of very cold water already observed to unduly increase the rapidity of the currents. There is a limit to the rate of reduction beyond which we, in part, defeat our purpose. The best practice is to run the cooling water freely for the first hour, and after that to reduce it to a stream of not more than one-tenth of an inch diameter, maintaining that until the thermometer shows that the milk is within a degree or two of the water temperature. After that, as more water cannot do any good, it is sheer waste to employ it.

The time required for the best yield will depend on the size of the globules. The milk of Channel Islanders will give up their cream well in twelve hours; with Shorthorns, from eighteen to twenty-two hours will be needed; with Ayrshires, from twenty to twenty-four hours—and so on. This means a shortening of the time required by the old use of the shallow pan by one-half. The economy is therefore great in all ways, for even the labour of heating and cooling the milk is less than that which the method casts out.

The plasma is drawn by lifting the plug *f*, when it will flow slowly out through the strainer *i* into the shute or pail provided to carry it away. Then the pan is tipped, as in Fig. 168, and the cream gently scraped downwards into a ripening-pan.

However many ingenious contrivances may be added to this method, it will always need judgment and attention to make the best of it. Occasional experiences show that its possibilities have not been commonly reached. We believe that with skilled management not more .35 to .40 per cent. of fat should be left in any milk of fair quality. This will only be attained by testing the efficiency of the work done by the thermometer, and the determination of the fat left in the creamed milk. (See Chapter XIX.)

Deep-Setting Systems.—These may be divided into (*a*) open and (*b*) covered methods. The former has long been pursued in America, where on many a farm the milk-house has been erected over a spring, a shallow tank made to receive the water, and the earthen crocks set in the latter with large stones to anchor them, and covered with thin pieces of wood. So far as the possibility of making a fine article was concerned, the conditions could scarcely be more favourable; and where the after-management has been in keeping, the results have been of the best. A conical dipper, such as we have recommended for sampling milk (Fig. 207), is used for skimming, being gently lowered into the milk until the cream can run into it. This could scarcely secure all the cream which had risen, even when skilfully used, but would not be so wasteful as the English skimmer. When the first American butter factories were established, the "pool" system was followed; a cylindrical can, 8 inches diameter and 22 inches deep, being used for setting the milk, and the skimming done as on the farm.

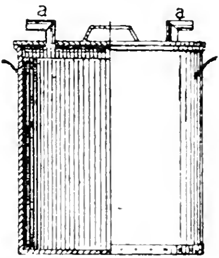


Fig. 172.
Swartz Creamer.

Akin to this is the Swedish "Swartz" method, in which the milk is set in a can of the form shown in Fig. 172, with its cover ventilated at *a a*, and plunged in water, which in summer is cooled by ice. The introduction of this system wrought a great improvement in the butters of Sweden, Norway, and Denmark, and shared largely in the beginnings of that modern dairy movement which has made them such powerful rivals to us.

(*b*.) The next step was the "Cooley" system which appeared in

1876, and submerged the milk in water within a closed cabinet. The inventor proceeded on two theories, viz., (*a*) that as cooling ought to be done from above, submersion was the best course, combining, with the benefits of the natural rule, those of cooling at the sides and underneath, and thus securing as rapid and complete creaming as at that time seemed possible; and, (*b*) that no harm could be done by setting milk warm from the cow in closed pails, provided the vapours arising from the milk could find their way to the water, and become condensed by it without necessitating the admission of air. The first theory as to the creaming was generally admitted to be sound; but the other, raised in the days of "animal heat" and "animal odour" creeds, was not trusted at first. This case was met by adopting the "diving bell" principle, and using a cover *a*, Fig. 173, which could be held in place by two curved handles *b b*, and which, being supported on the edge of the can by wire angles *c*, would allow an air space between it and the can. As the water would rise around the can, or the latter might be lowered into it in a level position, the water would enclose the air which was under the cover and within the can and slightly compress it. But the water exerting an equal pressure on the air at all points, could not rise to the top edge of the can. The milk would now be sealed down to contact with a small body of air, and the influence of the water and the vessel, and the absolute necessity for purity in all three must be apparent. The theory that all natural milk vapours would be harmless under such conditions proved correct, though there can be no doubt that bad ferments could damage the milk to some extent if introduced before setting. The cold could only hinder them, while the submersion would keep out others, but the invention could not altogether prevent the effects of bad management. The bottom of the can is made to slope towards a tap *d*, in which a syphon *e* is placed when the creamed milk is to be removed; and this being turned, as shown, into a vertical position, the creamed milk flows out, the cream sinking until its lower line is seen to have reached the lower edge of the glass window *f*, when the tap is turned off and the cream poured into a

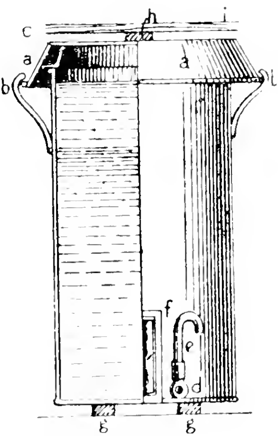


FIG. 173.—COOLEY CREAMER CAN.

ripening-pan. The bottom of the cabinet has strips of wood *g g*, which support the can so as to allow water to flow freely under it, and an inlet and outlets, one of the latter maintaining the water at a height of a few inches above the can cover while in use, and the other emptying the cabinet when required. The can is held in place by a strip of wood *h*, the ends of which catch under strips *i* fixed to the sides of the cabinet. This prevents accidents from the tipping of the can, when water would easily gain admission. This description gives the points essential to our purpose; but in recent years conveniences have been added, such as a rack to raise the cans out of the water, and others, saving time and labour, but not altering the principles of the invention.

Numerous patent cabinets have been brought out, some for cooling by water, others by air,—all, when the water becomes too warm, using ice, which is stored by all American butter-makers during their cold winters. These appliances need not be severally described, the Cooley represents them all in the points essential to successful creaming.

Shallow Setting and Deep Setting Compared. — The same principles are concerned equally in shallow and deep setting, but the conditions vary somewhat. In the latter case the globules have to rise through a longer distance to the surface, and it seems as if shallow setting would allow of the shorter distance being more quickly covered with a proportionately quicker creaming. This is not the case, however, for under equally favourable conditions the deep cans raise their cream quite as quickly and as perfectly as the shallow ones. The currents are much more powerful and effective, and the globules gather into groups and appear to help each other, as judged by their speed being greater than when separate. The cream is in thinner body than with shallow pans, and is therefore fit only for butter-making. It forms also a much deeper layer in proportion to its original milk. The Swartz and Cooley methods were at one time used in this country, but it was complained that deep setting in all forms did not separate the cream as well as the older practice, and we hear little of them now. We are convinced that sometimes it was the fault of the users, and sometimes the want of cold water. The same rules apply as for shallow setting; but few if any makers heat before cooling, though if this were done according to the directions given, it would have a similar effect in reducing the loss from variation of conditions.

There has been much contention between the followers of the two methods as to which offers the greatest body of advantage. We believe the deep setting cabinets have the best place, on account of the more perfect protection from the outer air, and the reduction of fermentation and oxidation, and that in all points of yield and economy they are equal when rightly used. Much has been said about the quantity of cream, but this is of no practical consequence where the creamed milk is fed on the farm, for the excess taken up in deep setting returns as buttermilk.

At different times attempts have been made to aid creaming by diluting the milk with water, under the belief that by reducing the viscosity the desired result would follow. But this theory left the reduction of the density of the plasma out of the reckoning, and disappointed its votaries. Experiments have proved that it is unsound even with milks known to be slow in creaming, and concerning the benefit to which expectation was strong.

The Devonshire System must be noticed, though it is not largely followed outside of its native county. By this is obtained the celebrated *Devonshire* or *Clotted* cream, names with which to conjure at the dinner-table, though they convey more to those who are not acquainted with the article than the reality would do, for with most people the taste for it has to be acquired. The reasons for this will presently appear.

Since heating is the main point of the method, a stove (Fig. 174) is commonly used, with a water space over it, and openings to receive the setting pans, which are like the old shallow pans but of less diameter and deeper. The usual practice is to raise the cream at the air temperature for twelve hours and then to remove it to the stove, unless it is originally set in place for heating as is done where the stove accommodation is sufficient. If carried, great care is needed to avoid disturbing the cream layer. The temperature is raised to 170° F., or a few degrees higher. The makers generally do not recognise any temperature as correct, but that given is the product of our own experience. The common rule is to heat to any point short of boiling, and continue it until a crinkled ring is formed at a point *a a*, Fig. 174, immediately above the angle formed by the side and the bottom of the pan. But it is found that when the heat is carried above the point

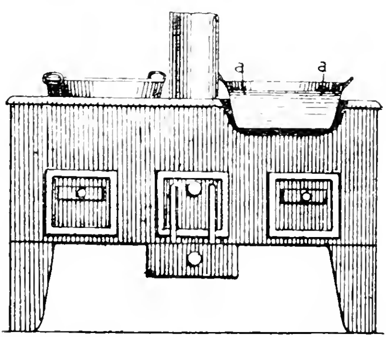


FIG. 174.—DEVONSHIRE CREAMING STOVE.

named the flavour exceeds the correct degree as fixed by public taste. This heating has four effects :—(*a.*) It affords an example of heating from beneath with the creation of upward currents, which modify the rule of the influence of rising temperature on creaming. This, to some extent therefore, helps up the globules which have not reached the surface, and the separation is greater than with the old shallow setting in air. (*b.*) The albumin is coagulated, and rises with and helps up the globules, forming a skin. (*c.*) The albumin acquires a heated or scalded taste, which is communicated to the cream, and in a less degree to the plasma as well. (*d.*) It kills the living ferments, and for a time checks the germs ; but as the milk descends through the range of favourable temperatures, fermentation commences afresh, and the end is but delayed. Sometimes the milk coagulates, but this can only happen under conditions specially favourable to fermentation, and in operation before the scalding takes place. When it does happen, the product is spoiled for trade purposes. There is scarcely less need for care and cleanliness with this system than with any other. After heating, the pan is set in a trough supported by strips of wood, and water is kept running round it, or cooled by any means which does not make it necessary to put it on a flat surface, for in that case the heat in the bottom of the pan is longer held, with increased risk of souring. Here it remains another twelve hours, the falling temperature giving a further help to the creaming, and by the end of that time there should not be more than .30 of 1 per cent. of fat left in the plasma. The system can be perfectly carried out with Jersey or other double pans, if made of sufficient depth, eight inches minimum, the stove being then unnecessary. The quality of the milk is a matter of importance, for depth is desired in the cream layer as far as can be consistent with thickness of body, and this combination is only possible with a rich milk. The milk of the Devon cattle is suitable to the manufacture, as are also the milks of the Channel Islanders, and the dairyer is advised not to attempt it with poorer milk. The scalded taste is objectionable to most people, and the article is in less demand relatively than it was, other delicacies passing it in popularity.

Mechanical Creaming.—We now come to a method of creaming in which centrifrugal force is employed to effect the speedy removal of the cream. This is brought about by the mechanical cream separator, which proceeds on the lines of our boy with the bucket of water, a vessel being made to revolve so fast as to cause the milk to press towards its circumference with great force. Here the plasma naturally presses away from the centre, by reason of its density increased out of all proportion to that of the globules, and these therefore pass to the inner surface of the body of milk and there form a layer of cream, which, as well as the plasma, is removed by various devices.

In comparison with the best setting systems, the most striking advantage of the separator is the quickness with which creaming is effected by it. In this they cannot hope to approach it. This makes it possible to obtain the separated milk in so fresh a state as to be better fitted for household use than that from the best creamed at twelve hours old. Under equal conditions, the keeping quality of the former is superior. This is not only because the fermentation is less advanced,—though with proper cooling the difference is not great in this respect,—but even more because the separator throws out any *solid* foreign matter which may be in the milk to the furthest point possible in the drum,—and there it is found, after the creamed milk has passed off, mingled with a small quantity of nitrogenous matter, probably nuclein, and forming with this a filthy slime. This we cannot doubt is due to dirty milking. Its removal is highly desirable, and not possible in the pans. The accumulation during the running through of a few hundred gallons of milk is astonishing and disgusting. There is a serious danger of the suppliers of factories assuming that this power to separate foreign matter covers their carelessness, and so they may become more careless. There is, however, no room for this. The effects of dirty management are by no means wholly removed in this way. The ferments and their products remain, as well as all soluble matter of dung or other forms of filth, and their ammonia, acids, &c. The reduction of possibilities is great, we know; but we know as well that the cream and skimmed milk from a cleanly milked and properly managed setting in a cabinet, is in better keeping condition than those from a dirty milking which has passed through a separator. If the milk be pure at the outset, the separator has the advantage; but it cannot give out a sound long-keeping product from any other original. The cream, in the absence of special treatment, is early spoiled in such a proportion of cases as to greatly reduce the profits of this more than usually profitable trade; and the same is true of the separated milk when sold for household consumption.

The yield, under equal management, is larger than with the best setting methods, but the difference is not so great as is commonly believed. It is usual to set the separator in comparison with the old style shallow-pans; and anybody who has used these, and later adopted the separator, will be justified in giving strong testimonials, with quotations of record showing 20 to 30 per cent. gain by the change; but manifestly such facts do not apply all round. The cabinets and shallow double pans press closely on the heels of the centrifugal machine; and, if well managed, will do better work than the latter can do in ignorant or careless hands. As a proof, the cabinet creamer has been known to remove all but .23, or less than a quarter per cent.; while .20, or one-fifth, per cent. is regarded as good work with the separator, and a little neglect will easily leave .30 to .40 of 1 per cent. of fat.

For the cream trade a thick article is demanded, and this the separator can give, though no setting system but the "Devonshire" can do so. For butter-making a thinner cream will answer, down to the consistency at which it churns best. An economy of time is gained by this, for the milk can be more quickly passed through with good work than when thick cream is wanted. Against this must be set the loss of the excess of separated milk taken with the cream, which can only be obtained as buttermilk.

We have now to fight some false notions concerning the separator. It is believed to injure the cream; this charge being based on the undoubted fact that in public competition its products are often beaten by those of setting methods. We have heard it repeatedly affirmed by persons whose opinions should carry weight, that such experiences are frequent enough to justify their preference for a good cabinet whenever butter is wanted for show purposes. The evidence so far has been strongly in their favour, but on being sifted it has been traced to error in the management of the cream and butter-making. It seems to be taken for granted that cream is alike whatever its source, and needs no variation in its treatment. That this is wrong will be presently shown. Microscopical examination of separated cream, and the practical handling of such under suitable conditions, alike prove that nothing happens in the process which can by any possibility damage the cream. It simply needs to be treated consistently with facts. Equally absurd is the belief that the separated milk is harmed, and rendered unfit for cheese-making. Some have actually asserted that cheese cannot be made from it! These are delusions, as may be easily proved. We have made cheese from it, and as good as from any set milk of equal quality, nor have we found any difference in the comparative behaviour of the curds.

On the other hand, unreasonable things are said in behalf of the machine, *e.g.*, that it can produce cream free from casein. This is practically impossible, apart from the setting free and gathering of the butter. The cream will not churn in any case without leaving a residue of buttermilk with a full proportion of casein; for though the free part of this constituent as it exists in the plasma may be reduced by making a thick cream, the proportion of that which forms the envelopes is increased relatively along with the increase of the fats. The separation in this way gives a strong proof of the envelope theory; for if this were not sound, there ought to be no difficulty in getting free fat by carrying the cream thickening as far as it will go. We have obtained it as thick as a fruit jelly, but never deficient in casein. The position of the separator is secure, and nothing can be gained by making unsound charges against it, or unsound claims in its favour.

Examples of the Separator.—We may now describe the leading forms of the invention, taking first the Danish-Weston machine, as one of the oldest now in any considerable use. The drum *a* (Fig. 175),

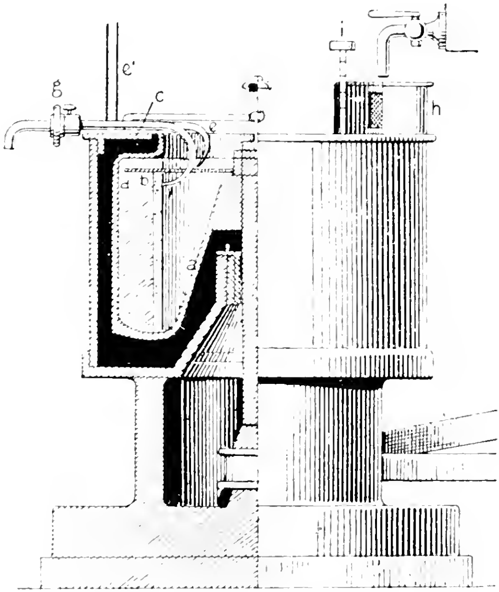


FIG. 175.—DANISH SEPARATOR.

is nearly cylindrical. A flange *b* is fixed a little below its upper ring *c*, and the creamed milk passes through the aperture *d* into the space between the two, from whence it is collected by a tube *e*, having a contracted and keen edge which is so set by a thumb-screw as to project into the milk as it revolves, and this then rushes into the tube with force enough to carry it upwards by *e* to a height convenient for capillary cooling. Another tube *f*, with a smaller end, collects the cream in the same way, but is provided with a screw *g* by which the proportion of cream to be removed can be regulated. The milk is fed from a tank into Prof. N. J. Fjord's regulator *h*, a vessel out of which a conical pipe leads the milk to the bottom of the drum, the flow being controlled by the graduated rod *i*, which being raised or lowered, enlarges or contracts the space for the milk passage. The machine is set low on its bed, travels at a comparatively slow rate (from 2000 to 2800 revolutions per minute), requires from one to three horse-power effective to run it, and creams from 60 to 260 gallons per hour, according to size. It is run from an intermediate motion, which consist of two pulleys set on a common shaft, the one being small and run from the main shaft by a belt; and the other being larger and similarly connected with the spindle pulley of the separator, the speed of this last being greatly increased by the arrangement. The means of separating the action of these two pulleys is provided in every intermediate by a clutch or a loose pulley, to which the main belt is shifted so that the machine may gradually run down when the engine has ceased to work. We need not therefore again describe this part of all separator outfits. The Danish machine does not serve for thick cream so well as some other makes on account of the mode of removal.

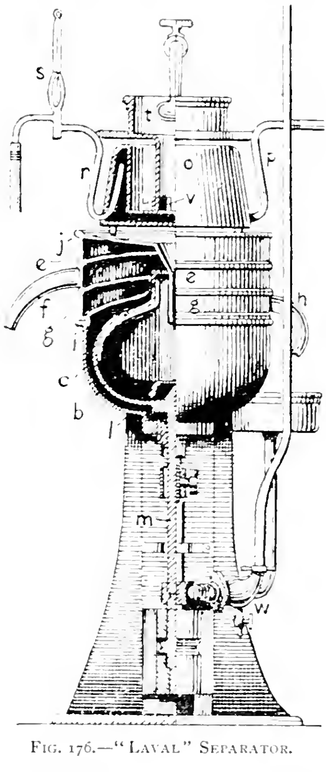


Fig. 176.—"Laval" Separator.

The "Laval" machine, Fig. 176, is of Swedish manufacture. Its drum *a* provides for the escape of the cream over the top of the neck *b*, and of the creamed milk by the tube *c*, through an opening in the neck at *d*, the flow being controlled by a screw which enlarges or reduces the passage as may be required. The cream is collected within a dish with a tube outlet *f*, and the creamed milk within another dish *g*, with its outlet *h*, the former fitting into the latter, and this again into the drum casing *i*, while into the cream dish fits the funnel dish *j*, which receives the whole milk from the heater and directs it into the cup *k* at the bottom of the drum. In entering this cup the milk strikes upon a cone which prevents frothing, and flies through the tube *l* to mingle with the other contents. A worm on the spindle *m* works a speed-counter *n*, by which the revolutions per minute may be easily ascertained. The spindle and drum are inseparable, and great care is needed to avoid bending the former, or otherwise injuring it in removal or returning. The lower end of the spindle rests in a box at the head of the pulley spindle. The heater consists of a double-cased vessel *o*, with a steam inlet pipe *p*, and an outlet *r*, in the track of which a tube holds a thermometer *s* to register the temperature of the out-flowing water. The pipe *p* is connected with the steam supply by gutta-percha tubing, of the quality specially made for steam use; and another length should lead the water from *r* to a proper place of discharge, otherwise it will become a nuisance, splashing on the machine and keeping the floor wet. A funnel *t* receives the milk, a float automatically regulating the passage of milk from the tap, while the lower end of the funnel tube rests in a box *u*, both having apertures *v* which correspond in size. By moving the funnel *t* around to right or left, these apertures are changed in their relations to each other, and make the spaces through which the milk may flow larger or smaller as may be necessary in regulating the inflow to the drum. The separated milk when wanted for the trade, or for cheese-making, can be carried to the height necessary for discharge to the cooler or vats by a pump *w*, worked by a worm on the spindle box. The motion may be derived from an intermediate, or a turbine, the latter being placed within an iron casing, and immediately on the lower spindle. Where an engine is in use the former is the better plan.

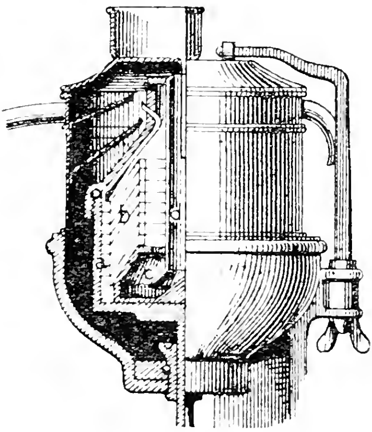


FIG. 177.—"ALPHA" LAVAL SEPARATOR.

Recently an improvement has been made by introducing a number of discs which divide the milk into thin layers, decreasing the agitation, and increasing the quickness and extent of the separation. Within the drum *a* (Fig. 177), the discs (*b*) are set above each other, the conical upper part of the drum being screwed on, and holding them in place. The cup (*c*) is larger than in the other case, and a tube (*d*) conducts the milk into it, preventing any splashing against the nearer body of cream. Both forms are made in various sizes from 12 gallons to 360 gallons per hour, running at 6,000 to 7,000 revolutions

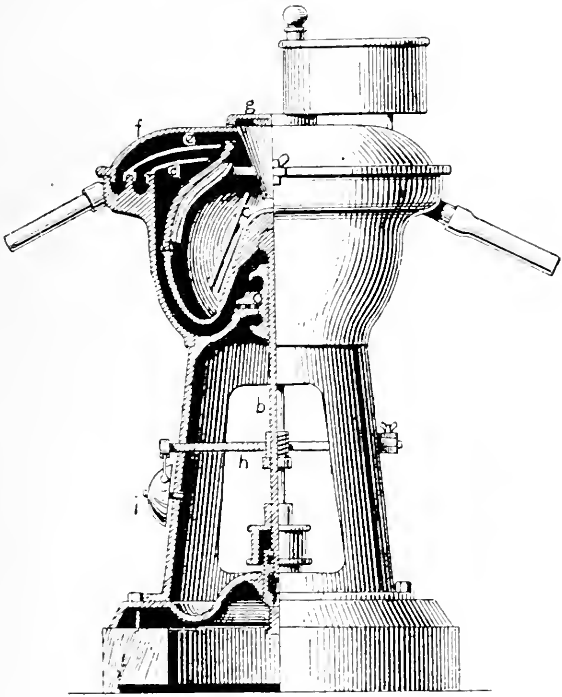


FIG. 178.—"ALEXANDRA" SEPARATOR.

per minute, with from one to three horse-power required for machines driven by an engine.

The most recent machine—the "Alexandra," Fig. 178,—has its drum (*a*) separate from the spindle (*b*), which makes it easy of removal for cleaning, ensures regularity of speed, and, in the event of any accident to the engine, or gearing, enables it to run down without damage. The spindle runs on ball bearings. The whole milk is conducted to the bottom of the drum by a funnel *c*, the cream discharges into the space between the covers *d* and *e*, and the creamed milk between the two covers *e* and *f* (the latter being of iron, and carrying the inlet funnel *g*), the cream and creamed milk collecting for discharge in grooves formed in the drum casing. A worm on the spindle *b* works a speed-counter *h*, the efficiency of which is increased by a gong *i*, which is struck by the hammer at regular intervals. The foundation is of wood, and needs no bolting to the floor as other machines do; this allows of the belt being tightened as it becomes slack by drawing the machine a trifle farther away from the intermediate motion, and of its being removed to allow the floor to be cleansed. The machines of this make range in capacity from 25 to 300 gallons per hour, running at 6,000 to 8,000 revolutions per minute, and requiring for power machines from .20 to 1.20 horse-power.

Management of Separators.—With these examples before us, we may describe the common principles of management. The three main points on which the efficiency and economy of the separator depend, are (*a*) speed, (*b*) feed, and (*c*) temperature.

(*a*.) There is to every machine a safe speed at which its best results are obtainable, and this should never be exceeded. In proportion as the speed falls below the best rate, will be the reduction of the centrifugal force and of the thoroughness of the separation. The drum should be got up to full speed before any milk is supplied, and as the best machines run by friction this will take a few minutes. The shaft pulley should be of such a diameter as, with the intermediate and spindle pulleys, will give exactly the correct speed when the engine is running at its best. There should be no danger of excess.

(*b*.) The rate at which milk is supplied to the drum governs the rate at which it must leave it, for the neck or ring of the drum gives the limit to the holding capacity, and when this is reached all fresh supplies must cause a corresponding discharge of previous contents. The greater the feed of milk entering, the shorter time can it remain in the drum exposed to the centrifugal force; and if the feeding is carried beyond a certain limit, there must be a more or less imperfect separation. Within the proper limits lies the regulation of the cream thickness. The slower the feed of milk and the longer therefore its stay in the drum, the thicker will be the accumulation of cream; this effect being reversed with fast feeding, which is commonly followed when the cream is for making butter. The relative rate at which cream and creamed milk can leave the machine is regulated in each case by special devices.

(*c*.) The centrifugal force can be helped by a suitable temperature; for, though it is sufficient of itself to effect separation with slow feeding, it will do as well in less time if the milk as a whole is of somewhat lighter density than it would be as cooled for the factory. Between 80° F. and 90° F. the best temperatures for the various machines are found. The old style, still pursued in some cases, is to collect the milk in a double-case vat, heated by steam or hot-water, keeping it stirred the while. This is objectionable with all but very small quantities, because the required temperatures are within the range favourable to fermentation, and the keeping quality of the products is reduced thereby. In cases where the cream is for butter-making, and the separated milk will be used on the farm, this may not be of much consequence; but when they are for household use, the practice should be avoided. A much better plan is to use a heater over which the milk will pass on its way to the drum, and provide for the cooling of the products immediately after discharge, so that the exposure to heat may not last more than two or three minutes. In such case a temperature five degrees higher is necessary to bring the globules within so short a time to the density which they would gain with the lower heat and longer time. The heater should not be made warmer than the hand can bear before the milk is started; and the temperature of the outflowing water should not be more than five degrees higher than that suitable to the milk. The first milk is liable to be imperfectly creamed while the regulation is going on, and should be set aside to follow the last whole milk, and so to clear the bowl of cream while yielding its own remainder. The best of lubricants should be used, but not in excess, an error into which many people fall. At the great speeds named the damage arising, on the other hand, from neglect in this matter is great and soon done. Most separators require a syphon of $\frac{3}{10}$ inch to $\frac{4}{10}$ inch diameter to empty the drum, while others effect this by a special construction of the drum which causes it to discharge its contents when motion ceases. The trouble of the former method is not great, and its avoidance need not be sought where more important considerations are in the balance.

A good separator should possess the following advantages, viz.: (*a*) perfect control of speed and the means of correctly calculating it; (*b*) the means of regulating the milk feeding, the discharge of cream and separated milk, and the thickness of cream while the machine is in motion; (*c*) ease in emptying and removing the drum, and the parts concerned in collecting and discharging the cream and creamed milk; (*d*) as little agitation of the milk as is possible; (*e*) simplicity in construction, and ease in replacing damaged parts; (*f*) safety to the user, the parts in motion being well protected; (*g*) a low speed; (*h*) small demand for driving power, and (*i*) a reasonable first cost, with none for setting. We are well aware that all these cannot be obtained in the highest degree in any one machine; patents bar the way to such a combination of excellencies. A better separator than any in the market could be made by bringing together the special protected points of three or four of the best machines. In the meantime the reader is advised to weigh well the advantages present in each machine, and take that in which the most in number and importance are found.

The number of separators for a factory should be calculated to allow for two periods of not more than four hours' consecutive running in each day. Longer use means a proportionately earlier wearing, because of the heat produced by the friction, and it is strict economy not to work a machine up to its full possibilities.

We have taken it for granted that the separator will be used in all factories and wherever the cream and creamed milk are to be sold, but on farms where butter-making only is followed, and the by-products are fed to animals, the case is different. If a farmer is changing from the old shallow-pan system, and can provide for the proper management of a separator, he should adopt it ; but if he has already a really good setting system we are satisfied that the change is unnecessary. He can make first-class goods with what he has, and, with proper care, come within .05 of 1 per cent. of the average separator creaming. The difference in economy will take long to cover the first cost of the exchange.

Management of Products.—The cream, if intended for butter-making, should be cooled to 60° F. ; if for the trade, as much lower as is economically possible. The air will do something in this direction, but will generally need to be supplemented, and when plunging in cold water fails, it will need special treatment. Trade cream, we believe, usually has some preservative added to it, and—provided this be of a perfectly wholesome character—there can be no reasonable objection to the practice, any more than to the use of salt in cheese and butter. But this should follow the best cooling obtainable, and not take its place, for the effect of the preservative, or the quantity required, will depend somewhat on the temperature. The "Boron" class of such substances is recommended, and they should be mixed in a dry state with the cream by thorough stirring and before the pots are filled. The whole preparation should be carried through as quickly as possible. The best pots are of stoneware, but fancy shapes in terra-cotta are also used. The latter should be glazed on the inside.

Separated milk for sale may be treated in several ways to ensure its keeping well. When the air is below 55° F. cooling will answer alone ; with higher temperatures preservatives or partial sterilisation will be necessary. The latter will inevitably give a scalded taste in some degree, and this will create a difficulty with most consumers. The treatment in any case should keep the milk from perceptible sourness for twelve hours after it reaches the purchasers, many of whom will use it in cookery late on the day of arrival. The importance of pure air and vessels may here be afresh insisted on.

Creaming Whey.—In the Cheddar factory plan (Fig. 62) the separator (59) is provided for the creaming of whey immediately on coming from the vats, and we are persuaded that such a provision gives a desirable economy. The creaming in tanks is always imperfect, and if the whey is kept more than twenty-two hours the storing provision must be doubled, while experience has proved that the cream will be injured by lying so long on the surface. The large proportion of separated whey to the cream obtained makes most forms of the separator unfit for this work without structural alteration; but the Danish machine is an exception, the difficulty being met by regulation of the gathering tubes. As now made these will work to their estimated capacity for whole milk; while by the enlargement of the separated milk tube to treble its ordinary size, a corresponding increase of capacity will result, the cream tube collecting without alteration the product from the large quantity of whey removed by the other. The temperature at which whey is drawn is suitable to this process, and no heating is therefore required. Other facts relating to the economy of the whey butter manufacture will be found in the next chapter.

Blending Butters.—This is much practised abroad, in countries where the texture and body of the butters are high, and the necessary manipulation does therefore but little injury; but with the products of most English breeds the results would not be satisfactory. The butters are purchased in the markets, classified according to quality, and each class blended by machinery to a common state. It is not of sufficient importance to justify further description.

CHAPTER XVIII.

BUTTER-MAKING.

BUTTER is produced from cream, by setting the fats of the globules free from their envelopes, and gathering them into a solid form. This is done by churning, in which *concussion*, or the agitation given by blows, is applied to the cream, the repetition of this not only affecting the globules which directly receive it, but the rest also by collision with each other. Through the constant changing of the cream surface by the stirring which accompanies concussion, the globules share about equally in both forms of the action. In the course of time the envelopes are broken, after which, under the continuance of the same action, their contents adhere, and so become steadily larger until they can be seen. In the meantime the casein of the envelopes has been reduced to a fine state of division and evenly distributed; and the butter, being separated from it and from the water, is removed. The residue is *buttermilk.*

In removing the butter a quantity of buttermilk is removed with it. This contains casein in solid particles, as also both casein and albumin in gelatinous suspension, and sugar and ash constituents, in their proportions to the plasma of the original milk retained in the cream, and it is now desirable to extract this as far as is possible without doing damage by the means used for that purpose. Up to the present we know of no means which will effect a complete extraction; and commercial butter, therefore, contains a small quantity of casein and sugar, and minute traces of the other constituents referred to. For preservation, salt is generally employed; and with this, in sufficient proportion, butter will keep for a very much longer time than it could do without it. The water is removed to a certain limit, the grains of butter are consolidated by pressure, and the manufacture is complete.

Characteristic Qualities of Butter.—The product has certain qualities, varying according to the source of the fats and the management. These are as follows, viz. :—

(*a.*) *Flavour*, which has two main or inherent causes, and sundry others arising from without. There is first a delicate flavour which belongs to the fats themselves. Even stearin is not absolutely tasteless, though nearly so; palmitin and olein have slightly more flavour, and those volatile fats which have come from the cow's food are most pronounced of all. Nevertheless, they give altogether only a very faint taste; but this to a perfectly natural palate would be preferable to any which comes by special treatment or with age.

The second flavour is also composite, and arises from the changes which the fats undergo by fermentation, oxidation, and other natural causes which cannot be absolutely prevented under ordinary conditions, but which may be kept within certain limits. It is possible that some such changes commence quite early in milk, while the globules are still protected by their envelopes; but they must then be very limited, and there is every reason to believe that the ferments have no direct dealings with the fats until they have been set free. It is quite likely that the envelopes themselves, affected by fermentation, in turn affect the fats, and admit of the fermentative products in the milk at large doing the same, and this especially in view of the tendency of fats to absorb flavours and odours. But when the butter has been separated it may rapidly become a prey to its enemies, hence the importance of ridding it of all other matter fermented or capable of fermentation. There can be no doubt that much of the flavour of the butter of commerce is due to the remainders of such substances. But even if these were entirely removed, there would be nothing to hinder the action of air ferments,—the day of ruin would only be delayed by the best conditions practicable. The volatile fats are capable of being reduced to new forms, the normal butyric acid being one of the most pungent of these; and, with this, caproic acid and its relatives have been regarded as purely the products of the action of B.A.F. and kindred microbes.

It is naturally very difficult to settle the case beyond dispute, but a consideration of all the facts before us leads to the conclusion that there are volatile fats in milk before fermentation can affect it in the least, but of such a character, and in such small proportions, as to bear no comparison, by ordinary tests, with the products of fermentative change. Following this view, we may be sure that the development of these flavours of the second class will depend on the conditions attending the globules in the milk and cream, and those in the butter when made. We may now consider those which are inseparable from butter as best made and kept to be natural also, though not original; and the others as unnatural or excessive. The former give no trouble until they become excessive, the unnatural are always a source of commercial loss; the one sort leaves butter a luxury up to a certain age, the others spoil it early and beyond remedy.

Among the *unnatural* is *sourness*, arising from the retention of fermenting milk sugar in the original water of the milk, or—as is supposed from its proportion in some butters—as dissolved salt is held in some degree when the water dissolving it has been removed by pressure. The absorption of other fermentative flavours must needs be according to their kinds and proportions. Besides these, there is the *milky* taste given by buttermilk retained, but not yet showing advanced fermentation. This is much enjoyed by many people, innocent of the mischief lurking behind it.

The *flavours of foods*, as roots, cabbage, badly made hay and silage, noxious plants in the fields or hay, cakes, meals, and such like substances, are found in butter ; in some cases recognisable, in others so altered or blended as to differ from those of the foods, but evidently caused by them, and disappearing when they are no longer used. Other flavours accompany odours taken from various sources, such as meat, fish, or high game, cooked food (so often kept in the convenient dairy "because it is cool"), from paint, tar, decaying substances, and what not,—and found either in the milk, the cream, or the butter, or all, as may happen.

(*b.*) *Odour* arises from the same causes, and frequently agrees with flavour. The aroma of a perfect butter is delicate, and adds much to the enjoyment of its use ; but with deterioration this departs to give place to a nastiness finally intolerable. The value of butter is largely dependent on these qualities being of the finest ; it is this which makes the difference between a luxury and mere grease. The dairyer must watch all possible sources of mischief, beginning at the cow ; and all his processes must be governed by the necessity for their exclusion.

(*c.*) *Texture.*—As butter in the mass consists of compressed grains of that substance, these are said to form a "*grain*," though the term is not strictly accurate, and "texture" is a better word. The grains or granules produced by churning are fine, but in a degeee more solid than the mass which they form, when well managed, because they are not brought into such close relations as exist between their own particles. Hence when a piece of butter of good texture is broken off it shows a rough fracture like granite, and when it breaks smoothly it is said to have no grain. Texture proceeds from two causes. The one (*a*) is original, dependent on the cow. The larger the fat globules in her milk, the coarser will be the grain of her butter under good management ; and under worse handling, the less will be the damage done within the first limits of mismanagement. The butter of Channel Islands cattle have this quality at its best ; the Kerry, Devon, and Sussex breeds in lower, and the Shorthorns in still lower degree ; while the Ayrshires come nearly or quite at the bottom of the list. This gives a guide to inherent possibilities ; but it by no means follows that the butters of these breeds will stand in such relations as to this point. Much will depend upon the other cause, (*b*) the management. The exposure of the butter to too high temperatures, and too much handling, will reduce the texture to a corresponding extent by separating the solid and liquid fats.

(*d.*) *Body.*—Natural solidity, or resistance to pressure, accompanies the size of the globule in the original foundations of texture, though it it is not so easily discernible. It is also affected by such feeding as changes the relative proportions of the solid and liquid fats, for with the increase of the solid fats this quality rises.

(*e.*) *Solidity*, as produced by manipulation. In finished butter there should be no loose parts or crevices, confining air or moisture with favourable conditions for the ferments.

(*f.*) *Keeping quality.*—Fine butters, lightly salted, have been kept under the best natural conditions for five or six weeks without passing out of the good stages; the majority of butters would not keep so well for ten days, and many are spoiled within half that time. Failure in its various degrees is due either to (*a*) fermentation, (*b*) too much or improper handling, or (*c*) bad keeping conditions. The two former belong to the butter, but the last is to no small extent answerable for early deterioration. (*a.*) Fermentation scarcely needs discussion. If limited to the unavoidable it will take long to spoil our product. (*b.*) Too long working upon the butter, and especially with the human hand, helps in the same direction. In all moral certainty ferments are introduced in proportion to the fresh surfaces exposed and the time of their exposure to the air; and this may be the explanation of the fact that with the breaking down of the texture, the keeping quality is lowered in proportion; but it is likely that the volatile fats are separated by the same action, giving the ferments a better chance of attack. But when the hand is used, its heat tends to dissociate the fats still more, and the perspiration with its acids, and products of the waste of the human system, tend to spoil the flavour directly, as well as to introduce matter and conditions helpful to further fermentative changes. (*c.*) The exposure of butter to heat tends to the tallowing of the fixed, and the dissipation of the volatile, fats, besides encouraging fermentation. In damp places moulds appear upon it, with accompanying decomposition. Dry cold is beneficial, and will prolong keeping indefinitely at and below 40° F.

(*g.*) *Colour.*—The natural colour is due to the lacto-chrome, and varies with different breeds (Chapter V.); but whiteness, either in patches or distributed, may be given by an excess of casein, and the mechanical dissociation of the solid and liquid fats by over-pressure also produces a patchiness which is often attributed to buttermilk.

Discoloration comes with advanced fermentation. Annatto or other vegetable materials are used to colour butter. The average consumer is suspicious of adulteration with lard, mutton fat, &c., if his butter is white; and if it ranges somewhere between gold and a brickbat he thinks it must be the product of a Jersey cow. The obliging tradesman and dairyer at once humour and deceive him. He knows and he does not know—and the practice continues. When the consumer becomes enlightened, the annatto bottle will disappear from the dairy.

Composition of Butter.—This varies greatly with different samples. The accompanying table gives a good standard. The water is much

Water	9.50
Fat	88.35
Casein	.70
Sugar	.15
Ash (salt)	1.50
	100.00

lower than in common experience, which ranges between 12 and 15 per cent., but it is a matter for satisfaction that the tendency of present making in this country is towards reduction. Water weighs heavier than fat, and that is a great temptation to maintain the higher proportions; but it is mischievous to the keeping quality of butter by encouraging fermentation, and the consumers' interest is sought when it is reduced to the point given or lower, and he should be prepared to pay proportionately more for the better article. The casein is commonly 2 per cent. and upwards, but with good management there will be no difficulty in reaching our figure, with a relative increase of the keeping quality. The sugar will be in keeping with the water, and should not exceed the amount given. The ash is calculated at a quarter ounce of salt to the pound of butter, an old favourite proportion. The ash constituents of the original milk would scarcely be estimable in such a butter, and are not attempted by analysts.

The above refers only to goods made from raw or unscalded milk; and the Devonshire system gives a much higher proportion of albuminoids, mainly albumin, but with an increase of casein, totalling between them 6 per cent. and upwards.

The **Yield of Butter** from a given quantity of milk varies greatly, according to the management. The proportion of the fat originally in milk is not equally recoverable in all cases and under like treatment. This is probably due to the difference in the relative size of the globules and the corresponding resistance to the churning action, as also to the proportion and state of the diffused albuminoids. If so, it argues the necessity of a separate treatment of each cow's milk according to its churnability, if it is to give up its proper amount of butter. This, however, would exhaust the patience of the most devoted enthusiast, and we shall have to be content with a management which will give the best average result. The losses in creaming and in churning vary also according to the method and care in its employment, and the dryness of the products also affects the facts. A very common calculation is that an average milk will yield 1 lb. of marketable butter to three gallons,—and this is not far from the truth, under fair treatment, though doubtless the separator and fine work throughout will give more. With higher milk qualities the yield will be relatively larger, because retaining water in proportion. Therefore in this manufacture the richer the milk the greater is the profit beyond the original cost.

Sweet Cream *versus* **Sour Cream.**—At the outset arises the choice between *ripened* and *unripened cream.* Ripening, as in cheese-making, is the work of the ferments. It is found in practice that if a quantity of cream be divided into equal quantities of equal quality, and one-half be churned fresh from the separator or cold cabinet, and the other exposed to the air for a day or two, the latter will give more butter, and generally of better quality, than the former. This is doubtless due to the action of the friendly ferments, and is in proportion to the time of exposure up to a point near to coagulation, from which the butter quality usually declines. We believe that the C.F. has most to do with the changes wrought, these attacking the envelopes of the globules and reducing their cohesion, so that when the churning motion is applied it is earlier and more fully effectual in separating the butter. The casein of the envelopes in this state is also more easily removed, and the amount of it in the butter is less—with equal treatment—than in that made from sweet cream. It has been suggested that the L.A.F. does the work, but this is contrary to its action in cheese-making. The effects, attributed to it because they followed early on its use, were more likely due to the C.F., encouraged, as these are, by the presence of the L.A.F., with possibly some slight erosive action of its own. The result is a gain of from 15 to 20 per cent. more butter from ripened than from sweet cream, with the ordinary churn and proper temperature. The easier separation of the buttermilk-casein gives a longer-keeping butter—other points being equal—than from sweet cream; but when the cream is over-ripened, the free casein coagulates and increases the difficulty of separation, so accounting for much of the bad butter made from fermented cream.

A great battle is being fought over this question,—the one side asserting that sweet cream butter is the most natural, perfect, and long-keeping article, and must lead the markets; the other, that it can never be profitable to make it because of the inferior yield, and that the honours of keeping quality also belong to the ripened cream product. It is wholly a question of conditions. If the butters are made in ordinary churns, the concussion is insufficient to secure the butter from the smaller globules, which resist it more effectually than the larger ones can do, for a body of larger area is more easily broken than one of small size if they are equally thin. Of two sheets of glass of the same thickness, for instance, the larger one is broken with a less blow than is necessary to break the smaller one. Now, when the envelopes are made weaker by the ripening, the maximum concussion of the churn is effectual with the largest of these smaller globules. Under no conceivable conditions, with such a low breaking force, can sweet cream be made to yield nearly as well as its rival. In removing the buttermilk-casein from sweet cream butter special treatment will reduce it to fair limits, but will at the same time proportionately damage the keeping properties of the butter from another point of attack. Of this more anon. With present appliances the ripening has a great advantage in results.

There can be no doubt, however, that if a sweet cream butter can be made under conditions which preclude this loss and the work of clearing the casein reduced to proper limits, then the product will give it the victory. A perfect article of this kind will be more perfect than the best from ripened cream, because the original flavours will be enjoyed. That the public taste will have to undergo a great change is true, but the tendency is in the direction of mildness both with cheese and butter. What is needed is the concussion sufficient to set free the fats of the smallest globules in the cream, and divide the casein so minutely as to make its removal easy. For the present we must proceed to ripen our cream.

Management of Cream.—The best vessel for storing cream is a jar of stone, earthen, or brown ware, the last-named glazed on its inside. Tinned vessels, when their surfaces are worn by the acid, admit the fermentative products to their spongy iron or steel, with bad effects on the flavour of cream kept in them. The form shown in Fig. 179 is the cheapest and most useful, holding five or six gallons, and having a cover of two inches larger diameter, with two strips of wood or metal to support it, so that plenty of air can reach the cream, while dust and light are largely kept out.

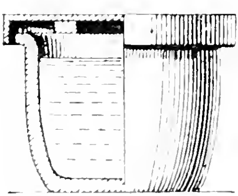


FIG. 179.—CREAM PAN.

Cream ripeness and ripening.—The standard of cream ripeness by the litmus test is M (Colour-plate). This is obtainable in fresh separated cream in forty-eight hours at an air temperature of 60° F., in a little less time with cream from cabinets; in much less with "open-air" cream not cooled in rising.

There are three methods of ripening, as with cheese-making:—(*a.*) Exposure to ferment action under atmospheric conditions when the temperature is 60° F. and upwards. The electrical condition of the air and its humidity also affect the rate of progress. The air should be pure, the room well ventilated, but no *draughts* allowed to reach the cream. (*b.*) Heating to suitable temperatures to encourage fermentation. At 55° F. heating the cream to 70° F., and letting it cool gradually to the air temperature, will give ripeness at the same time as with the air at 60° F. As the air temperature falls, that fixed for the cream must be raised in higher proportion, because the air at—say 45° F.—will more rapidly reduce a high cream temperature, and it is undesirable that the cream should fall lower than 55° F. at any time. The many variations in daily experience can be met by a simple calculation, based on the time at which the cream is required to be churned. More than two days in ripening is not desirable, the best results in flavour being got within that time; for when the air is so cold as to make a longer keeping necessary, there is a risk of bitterness, which increases with the cold. In heating, the cream should be set in the boiler (1, Fig. 161), or the hot-water tank (16, Fig. 163), and stirred. (*c.*) By the use of ripening materials, as whey is used in cheese-making. Ripe cream, whole milk, separated milk, and buttermilk, are all admissible, the two last serving as well as any, and costing less in case of accidental spoiling. This is much practised in Sweden and Norway. Its advantages are that it gives the friendly ferments a good start, and shortens the time; but there is a danger of error, and the inoculation of ill flavours in the absence of constant care.

The following table, based on the Colour-plate, will afford a basis for calculation:—

Condition of Ripener.	Condition of Cream as received.			
	A.	B.	C.	D.
	Quantity of Ripener.			
N. - -	4 oz.	2.4 oz.	1.4 oz.	.8 oz.
O. - -	3.4 ,,	2 ,,	1.2 ,,	.6 ,,
P. - -	2.8 ,,	1.6 ,,	.8 ,,	.4 ,,

These quantities (liquid ozs.) applied produce the desired result in from six to twelve hours, according to the original condition of the cream, and in shorter time by relatively larger quantities. The vessel in which the starter is prepared should be cleaned and scalded after every using of its contents.

Mixing Creams.—So far the directions have supposed that each cream is kept separate. But commonly those of several days, or even a whole week, are mixed together just before churning, it being considered unnecessary to churn oftener. The results are, (*a*) a want of uniformity in the butter, and (*b*) loss of fat in the buttermilk. The former arises out of the inevitable variations from the standard ripeness according to passing conditions. It is much complained of, and will never be cured while cream is churned according to convenience, and without reference to its actual condition. In the meantime, it is the uniformity of all those foreign butters, which are made on sound lines in this respect, that gives them the strong position they hold in our markets.

(*b*.) The loss arises because, while some of the creams mixed for churning are ripe or over-ripe, others are unripe. When the churning has early broken those globules which have been acted on by the ferments, a considerable proportion remain unbroken, and their fats cannot be gained by any continuance of the action until the butter made has been removed. The result is as much waste as with sweet cream, for much butter which might have been recovered under ordinary conditions is lost because its globules were not so responsive as those of the riper creams, and the youngest cream loses a larger share of its fat in the buttermilk than as if it had been churned by itself. The loss, as proved by experiment, amounts to about 15 per cent. as compared with the results of ripening.

The prevalent notion that the mixing brings the whole to a common level is erroneous. The acidity is levelled, doubtless, because the acid is dissolved in the water; but the effects on the envelopes cannot follow suit until the ferments have had time enough to work upon them. This will be sooner done than in sweet cream, but is not possible in the course of churning. In mixed creams, therefore, the standard by litmus is not applicable. The best results are obtained by churning each lot of cream separately when just ripe; but if mixing must be done, the creams should be managed so as to bring them all to ripeness at a given time. By keeping one day's lot so as to be ready at two days' age, the next to be ripe in one day, and a third in a few hours, they may be mixed when the last lot is ready, and the yield will be satisfactory. This is even better than mixing them at different degrees of progress some hours before churning as is so commonly advised. Salting, and the use of good preservatives, may be brought in to help in keeping cream when atmospheric or accidental conditions are adverse.

Another practice is to mix all the creams of each day in the common vessel; and this, though better in respect to the yield, produces greater irregularity in the fermentation,—generally by excess, and often with ill flavours brought by one cream to the rest, and which would have done much less harm if not mixed until churning time.

The influence of fermentation does not reach the fats to an injurious extent up to ripeness, but beyond it the effects become rapidly manifest in the higher flavour.

In the case of Devonshire cream—which in that county is not only sold as cream but also made into butter—the scalding makes the time longer, but the same rules hold good as to the necessity of ripening, and its standard. This system affords a strong proof for the envelope theory; for the scalding temperature does not make any difference to the necessity for churning this cream, nor is it churned in less time than might be expected in view of its condition in other respects.

While awaiting churning, the globules rise closer together; and the drying and oxidation tend to form a skin, as on exposed milk; while towards the bottom of the pan the cream is thinner, ending in a quantity of the plasma varying according to the original thickness of the cream, or the proportion of plasma taken in removing it. This leads to an uneven condition, physical and fermentative; an uneven churning, and consequent waste. The cream should be stirred in early morning, at noon, and late in the evening of every day, for a minute or two, with a Scotch hand (Fig. 195), which should not be left in it, but cleaned with a piece of horn and washed, otherwise it will speedily become a cream-spoiler. The effects of stirring are, (*a*) to mingle air with the cream, the O of which is helpful to the ripening action, oxidation being at the same time evenly distributed; and (*b*) the keeping of the globules in a free state, so that churning may act fully and equally on them all. The neglect of this treatment in cases where the milk condition is not at fault, shares with the irregular ripening in producing that frequent inferiority of separated-cream butters already noticed.

Churning.—The *temperature* for churning depends on several considerations. (*a.*) The air temperature, which affects that of the cream within the churn, the time required to obtain the butter, and—by way of the latter—touches other results later discussed. (*b.*) The relations of the solid and liquid fats. When the former preponderate, a higher temperature is necessary to secure the desired expansion of the globules, and the condition of the fats suitable for gathering them;

and the melting point, being raised correspondingly, the help may be given without risk. As variations depend on the feeding, this, and not the season, should guide the judgment. The feeding of cotton-seed meal has been proved to increase the solid fats considerably, and other dry foods do so in lesser proportions.

Air Temperature.	Solid Fats. Highest.	Liquid Fats. Highest.
66° F.	57° F.	54° F.
64° F.	58° F.	55° F.
62° F.	59° F.	56° F.
60° F.	60° F.	57° F.
58° F.	61° F.	58° F.
55° F.	62° F.	59° F.
50° F.	63° F.	60° F.

The figures are rather higher than are commonly given, but are justified by experience. In butter-making competitions, for instance, where the cream is carefully mixed, supplied in equal quantities, and usually churned in similar churns, we have found the best results in all respects follow their adoption.

When heating is necessary it should be done as with milk. Cooling is more troublesome, for it is most needed when the water-supply is too warm to effect it. When this is insufficient, and here the prospects of the evening will guide, the cream may be closely covered and lowered into a well to water-level, or placed in a cool cellar; and, by early rising, a higher temperature may be used, in keeping with the lower one of the morning.

To merely secure the proper temperature is not enough. The cream must be exposed to the heat or cold long enough for its globules to be brought to the expansion or contraction required. Cream which has been kept cold will not reach its proper physical condition for churning at the temperature proper for that process, for when that is reached the density of the globules is behind that of the plasma, and however beneficial that difference may be in creaming, it is altogether undesirable in churning, when the densities should be in equal natural relations. Whether heating or cooling is desired, the density of the globules must be brought to the utmost which the churning temperature can effect in that direction, and this can be secured by a maintenance of the churning temperature for twenty to thirty minutes.

The cream churns most perfectly when its thickness is such that a gallon will yield 3 lbs. of butter. When thicker, the concussion has too much resistance offered to it; and when thinner, the globules are too far apart to affect each other properly. In the former case it should be thinned by water; in the latter, allowed to rest long enough for the excess of plasma to sink to the bottom, and held back when emptying the pan. Water used for thinning should be added before the temperature is fixed, and when cooling is needed it will help it.

Colouring Butter.—If colour is used, it should be added immediately before the cream enters the churn. The practice is objectionable, and in any case should not exceed the natural summer

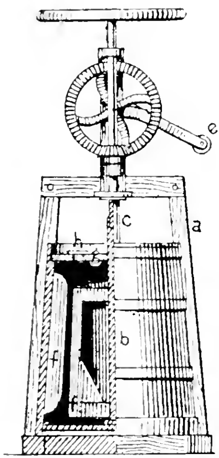


FIG. 180.—HOLSTEIN CHURN.

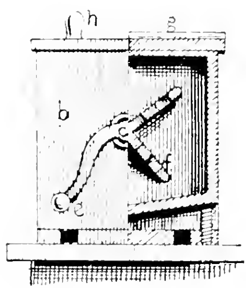


FIG. 181.—BOX CHURN.

References common to all the churns illustrated:—*a*, Stand; *b*, Body; *c*, Axle; *d*, Bearings; *e*, Handle or Crank; *f*, Dash or Diaphragm; *g*, Cover; *h*, Ventilator; *i*, Window; *j*, Buttermilk Plug.

tint of butter. Annatto is preferable to other colours, especially if prepared in spirit, which preserves it from fermentative changes. Preparations in oil are in the market, and are rightly claimed to be economical because they only associate with the fats, so requiring less than would be necessary of materials colouring the buttermilk. But there is a danger of rancidity, and in all cases the body and texture of the butter are interfered with, according to the quantity used. We have seen butters of good natural texture made to appear salvy by the presence of such colours. The other kinds are therefore preferable.

Churns may be divided into the following classes, viz. :—

(*a*.) *Fixed body with movable dash.*—The "Holstein" churn, Fig. 180, makes its dash to revolve with the spindle, fixed dashes

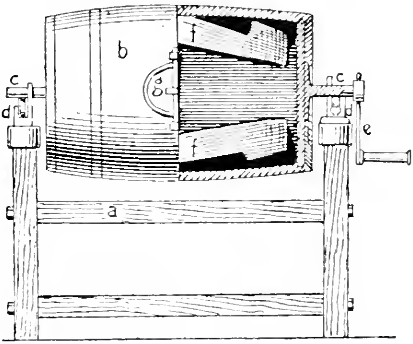


FIG. 182.—BARREL CHURN.

co-operating with it. The "box" churn, Fig. 181, is the smallest example of a sub-class which includes also the "Hibernia" churn of Bradford & Co. in this country, and the "Blanchard" and "Spain" churns made in America, but also sold among us.

(*b*.) *Movable body with fixed dash.*—In this class are found the

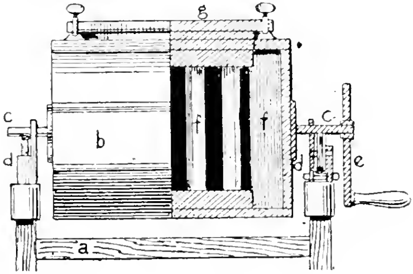


FIG. 183.—DIAPHRAGM CHURN.

barrel churns of Hathaway, Waide, Llewellyn, Tinkler, and many others. An example is given in Fig. 182, but the dash varies according to the maker. In the "Diaphragm" churn, Fig. 183, a removable frame of bars is so set as to produce "converging" currents in the cream, which are claimed to facilitate churning.

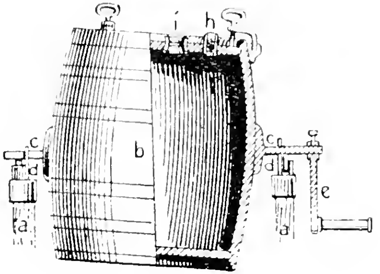


FIG. 184.—SHAKSPEARIAN CHURN.

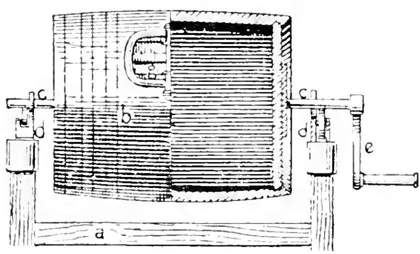


FIG. 185.—TRIANGULAR CHURN.

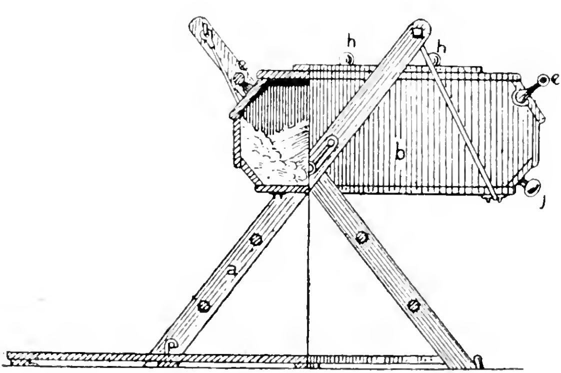


FIG. 18‍6.—SWING CHURN.

(*c*.) *Movable body without dash.*—This class contains the popular "End-over-End" churn, Fig. 184; Hathaway's "Shakspearian," Waide's "Victoria," and their kindred, so much used in the dairy schools. The triangular churn of Llewellyn is found in Fig. 185.

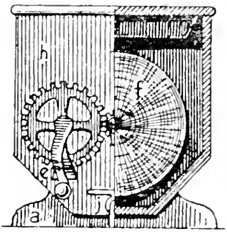


FIG. 187.—"DISC" CHURN.

Various forms of swinging churns have been brought out in America, of which the "Davis," Fig. 186, is a fair representative.

The most recent invention is the "Disc" churn, Fig. 187, which gathers the cream upon a disc of wood, driven at considerable speed, and throws it against the end of the case with great force. In its action it differs materially from all others given, though it belongs to the first class.

Points of Construction.—The special features of these classes shall next be described, while summarising the points of importance in a churn, which are as follows, viz. :—

(*a*.) *High Concussion in Relation to Speed and Power Required.*—The time needed to produce butter, and the extent of the separation of the fats, will mainly depend on the concussion, and in this respect churns greatly differ. Those having no dashes give the least; next above them stand those having fixed dashes; then the movable dashes; somewhat beyond these the swing churns; and the "Disc" churn claims to stand at the head. In all these there is some friction of the cream, but the makers aim to keep this within narrow limits. "Concussion, not friction," is a standing maxim with them, and rightly so with low-speed machines, in which the most possible of the former must be secured in order to effectiveness. Every churn has a speed at which it gives its greatest concussion, and no variation from this can give equal results. The churns in which the dashes are numerous or movable work best at forty-five to fifty revolutions per minute, and this rises through the lower degrees of the force to sixty revolutions in the dashless revolving churns. The "swing" churns do not move so quickly as their fellows of the same class, and yet give quicker results. Our common experience has been thirty to thirty-five minutes with the "dashless" and "fixed dash" classes; twenty to thirty minutes with the movable dashes; and fifteen to twenty minutes, generally the lower figure, with "swing" churns, the butter being equal in quality under a management equal in other respects, and varying but slightly in quantity. The speed and length of churning are in proportion, therefore, and make a considerable difference in the aggregate of a season's labour in their use. The "swing" churns prove the action of the globules on each other in churning, for these machines make the cream to dash into itself, as shown in Fig. 186.

(*b.*) *Aëration of the Cream.*—In a closed churn the cream swells because the motion raises its temperature, and the air is therefore compressed and in turn compresses the cream. Gases of fermentation also, and—in new cream, not thoroughly aired—the original gases of milk, are given off, and these add to the compression under the rising temperature. The limits of heat increase are narrow, but it produces sufficient compression to hinder the free motion of the cream, and correspondingly reduce concussion. All churns must be provided with the means of letting off such excess of air and gases. Those of the movable body and closed dashless types must needs have their means of airing made water-tight, or leakage would ensue. They are therefore either plugs, tò remove by hand, or spring valves which close instantly when the hand is withdrawn. Those having movable dashes can have constant aëration by small open tubes rising from their highest points, the swing churns can employ still larger openings and scarcely need covers, while the "Disc" churn enjoys the same advantage in an equal degree but different form.

Beyond the necessity for relieving the cream from compression, there are distinct advantages in aëration, touching the quality of the product. The action of the air is as with curd in cheese making, purifying it from the free odorous products of fermentation, and the greater the passage of air the more perfect is this. Oxidation necessarily accompanies, but within harmless limits, helping also to reduce the envelopes to the breaking condition.

(*c.*) *The most complete Churning possible.*—The differences in yield from equal creams by different churns of the ordinary types at their best are never great, and the claims sometimes made in this respect are based on trials made under unequal conditions; for example, of two equal churns, one may be handled by an expert, the other by one who is not a dairyer, or scarcely familiar with his machine. All sorts of circumstances enter into the matter, interfering with results. But that churns are unequal within a narrow range is certain, especially as to the extent and effect of aëration. The dairyer should therefore estimate the two points, already discussed, to secure this one.

(*d.*) *The Maintenance of Temperature.*—If the dairy is properly provided for in this respect, the churn need have no provision for it; but in cases where churning has to be done in cold places in winter, it should possess a chamber for hot water, as in Fig. 184.

(*e.*) *The Tendency to Gather the Butter should not be too great.*—Some churns do this much more quickly than others, those which have internal dashes being more liable than those which have none, though in this respect the "Disc" form is an exception. Strictly speaking this latter is not a dash, the concussion not being given by the disc but by the churn ends, as in the Swing churns, which share its freedom from this risk.

(*f.*) *Easy Filling, Emptying, Examining, and Cleansing.*—These are but conveniences, but they deserve consideration, as touching economy of time and labour, and reducing the risks of neglect. The closed churns have comparatively small mouths, and are defective in these respects.

(*g.*) The *material* should be *wood*, as sound and free from odour as possible. Metal is objectionable, because butter will stick to it, which it will not do to damp wood. Oak, commonly employed, needs special preparation before using. The best plan is to soak in cold water for a few hours, then in warm; either filling the churn, if one of the constantly ventilated kinds, or fixing the other kinds so as to expose all parts to the water for a time, and this will become darkly stained. This should be followed with boiling water, repeated until it comes off clear. Creamed milk or buttermilk should afterwards be used. This will absorb the odour, but will have need to be followed by further washing with water, boiling and cold, to remove the products of fermentation. The white, or colonial wood, though less troublesome in this way, will require similar treatment in its lower degree.

The *working capacity* of a churn is generally limited to one-third of its actual measure, though each has its own limit, to exceed which is to reduce the chance of concussion until a point is reached at which it is practically impossible to get butter. In any case the results are delay and imperfect churning, proportionate to the excess.

No churn ought ever to be scrubbed on its inside, and if properly managed it need not be. After use all particles should be swilled out with cold water, and then—and not until then—clean boiling water used to get rid of the effects of contact with the fermented cream. In a closed churn, after a few minutes' turning, the buttermilk plug may be removed, and the water driven out under pressure.

Instantaneous Churning.—For some years attempts have been made to graft on to the separator some device by which the fresh cream should be churned into butter, and delivered in a fine granular state direct from the machine instead of cream. The "Butter Extractor" was the first to claim notice. It consists of a separator, within the drum of which a circular wheel-frame of bars is placed, which can be carried by a lever into a position where its bars can strike into the rapidly moving cream, and made to revolve by its action upon them. The globules are thus broken, and pass off in place of the cream, with some buttermilk. The next step was taken by Dr de Laval, who attached to the frame of his separator a churn driven from the spindle, and receiving the cream as it issued from the outlet and passed over a cooler. For this it was properly claimed that the reduction of temperature before churning was an advance on the other machine, which either churned it at the separating temperature, or separated at one much too low. The machine, however, was withdrawn for perfecting, as it is reported, and is not now in the market. The most recent invention is the American "Accumulator," which is attached to the Laval separator,

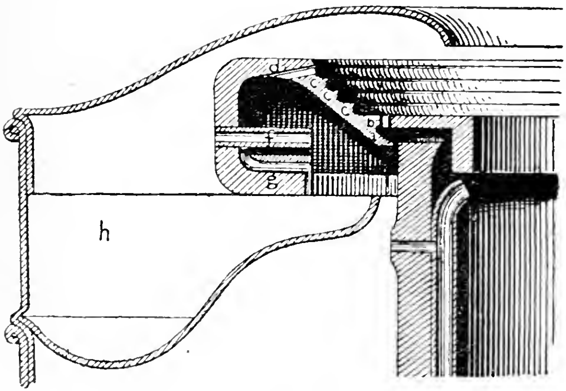


FIG. 188.—BUTTER ACCUMULATOR (Part Section).

but is of separate manufacture. As shown in Fig. 188 it consists of a collar, which is secured to the neck of the drum. The cream escaping from the drum flies into the angle *a*, and when this is filled rises through the aperture *b* to the terraces *c c*, filling the angle of each in turn, and then flying over its upper edge into the angle of the next. From the top terrace it passes through the tube *d* into the circular chamber, where the butter separates in fine granules from the buttermilk, and reaching the inner opening of the tube *f*, is discharged into the collecting dish *h*, while the buttermilk passes through the tube *g* into the same. This device appears to have "come to stay," as the Americans would say. There is doubtless room for improvement, but the principle will be developed, and make the production of first-class and long-keeping sweet-cream butter not only practicable but economical. There is every reason to believe that in the perfected machines the separation of casein will be more complete than is possible with the old appliances, and on account of the dryness of the butter produced, the after-manipulation will be greatly reduced with benefit. The special need now is a device for cleansing the butter from buttermilk as soon as it leaves the "Accumulator," and this must follow soon.

It seems to have been taken for granted that these results are due to a mere gathering of free fat, and that there is no churning; but we cannot conceive of higher concussion than is given in either case. In the "Extractor" and the "Instantaneous" machines the churning is evident. In the "Accumulator," the globules are subjected to powerful concussion at *a*, and in passing the edge of the terraces *c*, and this being administered to them when separated in the thinnest conceivable layers, they must needs be acted upon as powerfully as in the fifteen to forty minutes of churning under ordinary conditions. The effects of the "Accumulator" are no greater than might be reasonably expected on enveloped globules with a speed of 6,000 to 7,000 revolutions per minute, and the followers of the "free fat" theory cannot draw any proof in its favour from them.

It will always be necessary to have in one machine the alternative choice of cream or butter. The churn will in time give place largely to this direct production, though it will probably be long enough in doing so.

Preparing the Churn.—In preparing the churn for use, it should first be swilled with cold water; then treated well with boiling water; and at once, and lastly, cooled with cold to the cream temperature. The hot water causes the wood to swell, saturates it to a little depth, and allows the cold water to do so afterwards to an extent which would only be possible in such a case. The cooling leaves the pores, though contracted, full of water to the depth of penetration, and this resists the entrance of butter. Salt added to the cooling water increases its density, and correspondingly its resistance to the entrance of butter into the pores; and this explains why when butter has stuck to wood, if it is removed by melting with hot water, and the object afterwards washed in cold water and rubbed with salt, sticking will cease. The salt also adds to the penetrative power of the water. If a churn is properly managed from the beginning, nothing but water, hot and cold, need ever be employed within it. No such substance as soda should be used in a churn; for it is not easily removed from the wood, and, being alkaline, will give it in time the power to interfere with the churning by partially saponifying the fats at first breaking, or even the earlier saturation of the envelopes. From this sometimes arises the failure of churning.

Management in Churning.—The cream should either be strained into some vessel with a lip, and from this poured into the churn; or emptied direct into the latter, a strainer cloth being used to finally reduce it to a uniform condition, and to remove anything solid which may have accidentally fallen into it. The churn being secured against leaking or splashing, churning should be proceeded with at the speed suitable to the churn, the revolutions being counted for half a minute to ensure correctness. With this practice will come the mental habit of repeating the speed. It is generally advised that churning should start at a much lower speed; but experience with power churns, run at one rate throughout, has taught us that any such variation is unnecessary, there being no discoverable difference in the result. If, because of error in the initial and churning conditions, the churning is too quickly or too slowly completed, the tendency will be to softness; in the former case, because of the heat or speed; and in the latter, because the increase of friction which follows the decrease of concussion also raises the temperature.

With closed churns there should be at first frequent stoppings for ventilation; but when air ceases to escape on opening the valves, the work may proceed with very occasional attention to this until the change of sound which comes with the separation of the butter from the buttermilk, when the process will soon have to cease, and the state of affairs must be watched by means of the glass plate, or other appliance for that purpose, which every churn should possess. From the glass the cream will disappear, and very fine particles of butter will be seen with the free buttermilk. At this time the churn should be stopped, and cold water added to its contents in the proportion of one-fourth of the measure of the original cream. This cools and hardens the granules, gives a larger and thinner body of liquid in which they can float further apart, and therefore are prevented from gathering too rapidly. If more water is used, the gathering is unduly interfered with; for in a proper degree such gathering is necessary, in order that the butter may be removed without waste; but it should be slow, and the proportion mentioned is found to give the best results. The water also helps to free the grains from adhering fragments of casein, and makes less after-washing necessary. Any granules on the cover or sides of the churn should be swilled off with this water. After a few rockings of the churn the buttermilk should be drawn off, a hair strainer covered with a double piece of butter-muslin being held close to the outlet to intercept all granules, while the buttermilk passes into a pail or conductor for discharge. Fresh water, in the measure of the buttermilk and water just removed, should now be poured into the churn; this rocked again a few times, and the water—whitened with remaining buttermilk—drawn off; this being repeated until the water comes off clear. The amount of washing will depend on (*a*) the original size of the globules, and (*b*) the condition of the cream. (*a*.) The larger the globules are, the more quickly is the washing effectual. (*b*.) If the cream has been well stirred in ripening, and brought to a proper ripeness and consistency, the removal of casein will be earlier and more complete than when these have been neglected. Both under-ripe and over-ripe cream require more washing than that which is just right. No invariable rule can be given, therefore, as to the number of washings (though this is sometimes attempted), but that of final clearness of the water used, and no less will serve. From two to four are generally sufficient.

Some makers object to all washing, on the ground that the butter flavour is reduced by it. This is true, for the butyrin is soluble in water, and being in much higher proportion than the other solid fats, its loss in this way must needs have that effect. To avoid it, they make up the butter "dry," as they say, with the inevitable penalty of falling into two other occasions of trouble, of which more hereafter. Of the two courses, carefully considered in the light of experience, the washing is decidedly preferable; but in view of the loss admitted the treatment must be confined within necessary limits, and the size of the granules must be fixed at a proper standard, not being washed at any stage lower than the "pin's head" size commonly recommended. During the washing the butter granules will increase in size, and the loss in flavour will be trifling compared with the advantage of the reduction of casein.

The old practice, which has almost disappeared as the result of ten years' teaching, is to gather the butter in lumps of all sizes, from an inch to three or four inches. This was convenient for the old style of handling, but made the retention of too much casein unavoidable. No after-treatment could extract this properly, or even reduce it, without doing equal mischief by spoiling the keeping properties by too much washing and manipulation. The earliest removal is the most effectual; even a little advance on the limits prescribed carries the product away from the best possibilities.

The importance of pure water in this and every contact with the butter must be evident. Not merely should it be free from dirt or discoloration by solid or dissolved matter, but free from ammonia, acids, and other products of decomposition which give no proof of their presence to the unsuspecting. These substances, however, are often found in water from old wells containing decaying vegetable matter, and enter into injurious combination with the fats, especially of the volatile class. The last water used may be slightly salted, this assisting in the carrying off of the casein.

The temperature of the water should not be less than 45° F., when the air is at 60° F., or 50° F. when the air is at 55° F., with other variations consistent with these. It is a mistake to harden the butter beyond a certain point at which sufficient firmness to withstand the later manipulation, and a proper readiness to cohere, can both be secured. If it be exceeded in the direction of greater hardness, the consolidation cannot be effected without undue pressure.

Since much of the mild salting of butter is now-a-days done at this point, the general question may properly receive attention. The preservative influence of salt is desirable, its proportion being regulated by the composition of the butter, and the time it is desired to keep it, or by the demands of the market. It has, however, become fashionable to say that good butter needs no salt ; this assertion being based on the fact that the early spoiling of butter is mainly due to casein present, and the supposition that good management does away with this source of harm. But the casein is never entirely extracted from butter, and in good samples is sufficieut to justify the salt check. Even in the entire absence of this there is always the B.A.F. to reckon with, and it is useless to say that butter is not the better for such a salting as will preserve its fine qualities as long as is reasonable. When we say that the composition of the butter should rule the extent of the salting in part, we mean that, according to the water and casein, the proportions should be fixed, and the methods employed will be a guide to these. *Water* by itself greatly helps to decomposition,—the drier the butter is, the less of salt will it need; but however much may be present, *it should be saturated with salt.* The extent of casein extraction may be estimated by the state of the cream, the size of the granules, and the state of the last washing water; and if these are as advised, the salt necessary to saturate the water will be sufficient for preservative purposes. If error has made it certain that the proportion of casein is higher than usual, the butter must either be used early, or salted more heavily in another way, hereafter described. The markets sometimes demand a lighter salting than the standard given, or even a saltless article. In such cases it cannot be kept so long as is possible with proper salting. On the other hand, much bad work has been covered by heavy salting ; and this is objectionable—for the consumer ought not to pay for more salt than is necessary to the preservation of a well-made butter.

Salt does not penetrate the ultimate grains of butter. It has been proved that a saturated brine will not pass through muslin closely smeared with butter in a form so thin as to be almost transparent. The salt, then, is dissolved in the water, and when in excess of saturation, probably held by cohesion to the surfaces of the granules and compressed between them.

For mild salting, "*brining*" is employed with advantage. The butter is immersed in its granular state in a brine strong in proportion to the needs of the case. Water will dissolve 3.2 lbs. and upwards to every gallon (10 lbs.) according to the purity of the salt and the water, and every dairyer may test for himself. A brine of 2 lbs. to the gallon suffices for the mildest article. The quantity of salt retained in the butter depends on (*a*) the size of the granules; (*b*) the time of their exposure to the brine; and (*c*) the final dryness of the butter. The smaller the granules and longer their exposure, the more is held, the two items appearing to share equally in securing the retention. Fine granules will hold a quarter of 1 per cent. from the 2 lbs. brine in thirty minutes' exposure, in the same time a saturated brine will give nearly a half of 1 per cent. The facts strongly support the cohesion theory, and form a sufficient basis for calculating how to produce any desired effect.

It has been at times proposed to keep granular butter in brine for long preservation, and, when required, to work it up for the market. We remember that twelve years ago a friend sent us some casks of fine butter from America in saturated brine. It arrived in excellent condition, but much too salt for the local markets. It was removed into a strainer cloth and gently immersed in cold spring water a few times to wash away the excess of salt. This disappeared, and with it the flavour, leaving it a perfect fat, but almost tasteless. It was no case of original innocence, but of reduction of the flavour due to the volatile fats, leaving only the combination flavour of the stearin and olein. Except for short periods, therefore, butter should not be subjected to salt in such a form unless it can be permanently kept in it.

A portion of the brine, if this is used, or of the last washing water, should now be drawn off, until the butter can easily be gathered on a scoop (Fig. 189) and then removed. The last particles can be swilled down with water, and collected.

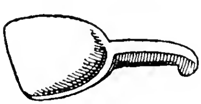


FIG. 189.—BUTTER SCOOP.

When the butter is at all soft, it should be put in a cool cellar until it is firm enough to bear the rest of the processes without injury. The cellar (Figs. 47, 62) is best where the water tank can be had; failing this, such a safe as is shown in Fig. 190 will serve with a little attention. Here is a metal box with a door *a*, made to fit closely by draught tubing, and having a trough *b* at the sides and back, while a small loose tank *c* rests on the top. Within, a removable shelf of slate *d* rests on two projections, and another lies on the bottom. In use the trough *b* and tank *c* are filled with water, and a coarse flannel cloth *e* is laid over the sides and back, its upper end dipping into the water in *c* and its lower end into that in *b*, so drawing it by capillary attraction as to keep the sides slightly wet. Placed in a free passage of air, the evaporation carries off the water as fast as supplied, and causes proportionate reduction of the internal temperature; the hotter and drier the air, the more rapid will the cooling be, so much so as to make it necessary, in special cases, to sprinkle water frequently over the cloth to supplement the supplies drawn by the attraction. If these latter are not enough the middle part of the cloth will become dry, and the heat will undo at that point what the cooling is doing elsewhere. One hour under the conditions indicated above will harden the butter to the safe point.

Working Butter.—The consolidation of the grains and the extraction of moisture in the correct degree, are carried out in one operation known as "working" the butter. The old practice is to do this with the hand; but this is happily vanishing, for it stands condemned on account of the mischief done to the flavour, texture, and keeping properties, by the heat and perspiration. The heat of the blood is 98° F., and while that of the skin is not so high in health, it is much too high for safety. We can raise the mercury in a standard thermometer to 94° F. at writing, when free from physical exertion; the average melting point of butter is 97° F.! The effect of a temperature of 70° F. is to partially dissociate the fats; and this in higher proportion with greater heat; while no after-cooling will ever restore their original relations. By wetting the hands and reducing the surface temperature by evaporation, the mischief may be lessened, besides which the moisture is interposed between the hand and the butter, but these things generally do little to save the delicate material. We have known cases in which this practice made so much difference as to become a matter of boasting. "My hand is a very good one for butter; I can make it as cold as an icicle." This was an exaggeration, of course, but true so far that the reduction of surface-heat was injurious to the boaster. What may be good for the butter is bad for the butter-maker in this case, and *vice versâ*. So the days of hand-working are nearly at an end; and there is the less excuse for their continuance, because the appliances to take its place are simple and cheap.

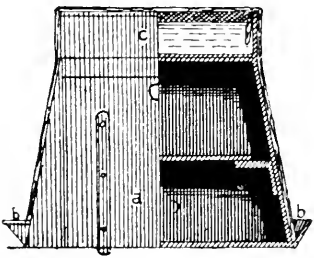


FIG. 190.—BUTTER COOLER.

With a "*trundle*" (Fig. 191), and a scoop (Fig. 189), small quantities can be worked perfectly, the scoop being held as in Fig. 192, and borne down upon the butter,—not as if kneading putty, but gently; not with a grinding, but a pressing, action. The hand

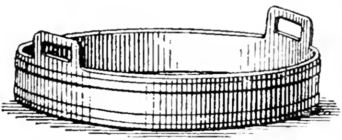


FIG. 191.—BUTTER TRUNDLE.

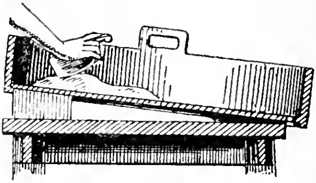


FIG. 192.—WORKING BUTTER WITH SCOOP.

will warm the scoop in time; it is therefore well to keep a pair, the one being in water while the other is in use. But the work can be more economically done in larger quantities from 20 lbs. upwards with

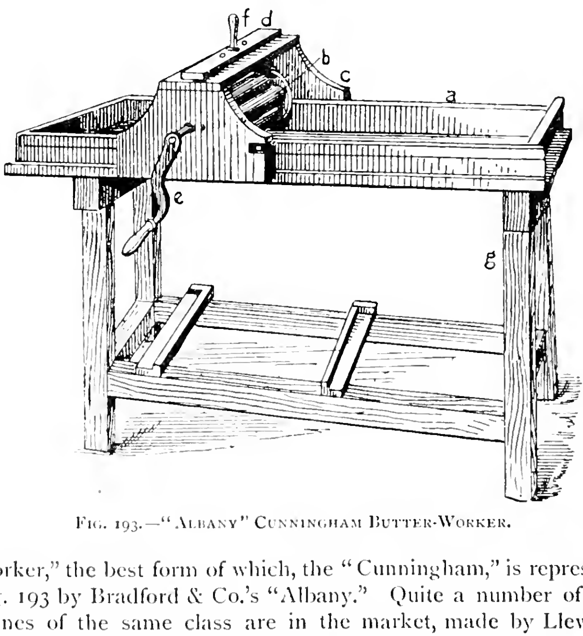


FIG. 193.—"ALBANY" CUNNINGHAM BUTTER-WORKER.

a "worker," the best form of which, the "Cunningham," is represented in Fig. 193 by Bradford & Co.'s "Albany." Quite a number of other machines of the same class are in the market, made by Llewellyn, Hathaway, Dairy Supply Company, and others, each having its special advantages in convenience. The table *a*, which should slope towards a point of discharge, is traversed by a corrugated roller *b*, running in a frame *c*, which is kept in place by strips of wood, and made to run easily by rollers of hard wood. Two pins act as bearings to the roller spindle, and press on the ends of a wooden spring *d*, allowing the roller to rise a little, and so to accommodate itself to varying thicknesses of butter. The roller is turned by the crank *e*, while the handle *f* is used to propel the frame. The machine is either supported by a stand *g*, or placed on a table.

In use, the butter should be piled on the middle of the table, and gently pressed down with a scoop until it is not more than an inch and half thick. Then the roller should be passed over it first upwards and then back, driving the expressed water towards the outlet. Just as in pressing cheese, the tendency of excessive pressure is to close in moisture; and though this may to some extent be pressed out later, it will not be perfectly done, nor without unnecessary working. As the granules draw together the crevices between them become smaller, but those within communicate with those nearer the surface; therefore the more gently and evenly the compression is, the more rapid and thorough will be the extraction. The motion of the frame and the roller must correspond. The roller catching in the butter would, of course, carry itself forward; but it should not be allowed to do so; nor should the frame travel faster or slower than will admit of the roller *pressing* the butter; for in either case *grinding* is inevitable, and this tends to the mechanical dissociation of the solid and liquid fats, and helps to the spoiling of the keeping quality.

The butter should now be rolled together by propelling the frame as before, but turning the crank *e* in the opposite direction, the result being as in Fig. 194. The roll so made, if it is firm enough to stand, should be cut in half, and set on end near the water outlet to drain for a few minutes, and then pressed with the scoop as before and reworked. This draining is equal to once working, and saves from the working-in again of the water set free in forming the roll. The use of clean muslin wrung out of cold water is admissible for the same purpose. Anything reasonable may be done to get the butter dry with the least working. The condition

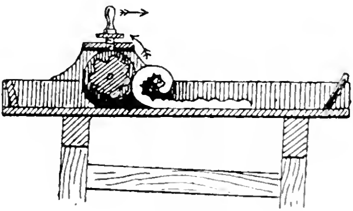


FIG. 194.—BUTTER-WORKER ROLLING.

in this respect may be tested at any time by pressing a little between two scoops, or "Scotch hands" (Fig. 195).

A worker should offer the following advantages, viz. :—

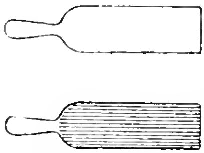


Fig. 195.—Scotch Hands.

(*a.*) The roller should be free to yield to any variations in the depth of the butter. Many workers are made without springs; their absence is a defect. This is especially mischievous in the circular power-workers, in which rollers run in fixed bearings. We advise the avoidance of these in spite of their economy of labour.

(*b.*) The corrugations of the roller should be so made as to make those in the butter oblique, so rendering the discharge of water easier.

(*c.*) The means of gathering the butter into a roll. This is not found in the lever machines, which in other respects do well. The scoops cannot readily bring it into a convenient form for draining.

(*d.*) The frame and roller should run easily, but without looseness.

(*e.*) The parts should be easily separated for cleansing.

The capacity of the machines of the type illustrated ranges from five to twenty pounds of butter at one working. If the butter has become soft by this time, further hardening should be sought. When brining has been followed, no more working will be needed; but in the case of dry-salting this should follow, the butter being laid out by the roller, and the salt sprinkled as uniformly as possible, then rolled together (Fig. 194) and worked without the draining or special drying. The salt should be in fine crystals and dissolve readily. Its even distribution cannot be effected without more working than is requisite with a brined butter, and only such as possesses a naturally high body and coarse texture will bear this without the beginnings of harm. The salt is most easily distributed at a quarter ounce to the pound; as the proportions rise above this or fall below it more working is required; and the evidence of damage is plain when the limit of three-quarter ounce to the pound is passed. It is also found that an excess over this does not keep the butter as well. But with this proportion a well-made butter will keep for six months in fine condition. It is a good plan to set the butter aside for a time to allow of a perfect dissolving of the salt, and finally work it once or twice before making up or potting. By this course the working required may be reduced.

Here we may close the salting question. The saving by the dry method is striking; for what can be done by half a pound of salt as brine on a pound of butter, a quarter ounce of dry salt will do in this way. For the finest results we must pay in this loss, and many makers of the "dry" class dispute the advantage. They set against the slight loss of texture that of flavour in the brining, and believe that they are nearly or quite equal. In such case, the argument is on the side of dry-salting.

With over-ripe cream and the "Devonshire" material, more work must be done to free the butter from casein than under the conditions described. Whatever may be said for the "clotted" cream, the butter made from it is not, and cannot be, equal to that made from raw cream.

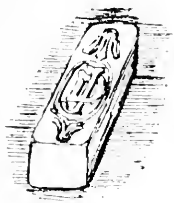


FIG. 196.—BRICK OF BUTTER.

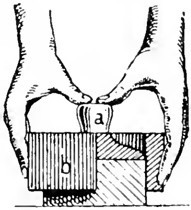


FIG. 197.—MOULDING BRICKS.

Forms of Commercial Butter.—Butter is commonly made up in ½-lb., 1-lb., or 2-lb. lumps, of various shapes, and often with more or less of decoration.

(*a.*) *Bricks* (Fig. 196) are made with the Scotch hands, some of which are plain, others fluted (Fig. 195); and very pretty designs can be made with these simple tools with a little artistic ingenuity.

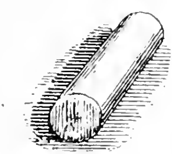


FIG. 198.
ROLL OF BUTTER.

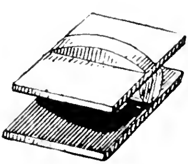


FIG. 199.
BUTTER-ROLLING.

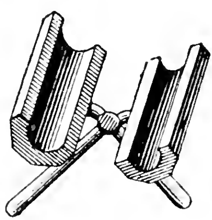


FIG. 200.
ROLL MOULD.

They may also be made with a mould, Fig. 197, the block *a* bearing a device, and this pressed on the lump in the frame *b*, the latter may be drawn up by the finger-tips while the thumbs keep the block and butter in place and the latter is set free.

(*b.*) *Rolls* (Fig. 198) are made either by rolling the lump between two boards, as in Fig. 199, or by compressing them in a mould (Fig. 200). Both forms of butter are easy to handle and pack, but are awkward for table use unless divided into halves, the butter dishes seldom being long enough to receive them.

(*c.*) *Pats* (Fig. 201) can be made according to form, by a "cup" mould (Fig. 202) for *a*, and by a "box print" (Fig. 203) for *b*, the

FIG. 201.—PATS OF BUTTER.

FIG. 202.—CUP MOULD.

FIG. 203.—BOX MOULD.

weighed lumps of butter being rolled with the Scotch hands into conical form before being pressed.

The scale (Fig. 204) for weighing butter should be provided with a porcelain plate, and have its bearings well protected. Care must be taken to provide against defective weight through moisture on the plate, either by constant removal or by allowance for it.

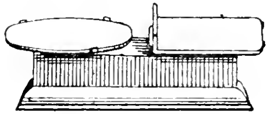


FIG. 204.—BUTTER SCALE.

Several attempts have been made to mould and print by complicated appliances, but we have found no satisfaction in them. The butter-moulding machine suitable to factory use we believe has yet to be invented.

Here let us put in our protest against the meaningless and easily copied figures of animals and birds, and a plea for artistic designs presenting names or monograms in forms which may be registered under the Trade Marks Act. A good reputation is worth such protection, information respecting which can be obtained from the Comptroller, The Patent Office, London. When the consumer gets a fine butter bearing a certain "print," he clings to that print with wonderful tenacity; never suspecting that, as is often the case, his favourite butter is unprotected, and a good many other people's butters bear the cow's head or swan, squirrel or shell, beside that which he first fell in love with, and that he does not always get the article he wanted. Such faithfulness ought to be cultivated; and the credit and profit to be enjoyed by the best makers, placed beyond the reach of the lower-grade men who want these good things without deserving them.

Beautiful imitations of flowers and other objects can be made for special purposes, and as they fetch fancy prices, are worth learning to make. It is not possible to give satisfactory directions in full in a book, but we may say that with two small tools—one of the Scotch hand and the other of the knife (Fig. 159) form—much fine work can be done. The butter, being taken in small pieces, is flattened out between the tools, and then laid around a centre-point, forming roses, lilies, &c., with comparative ease when a little practice has been built upon an art foundation.

Roofing slates form the best carriers, when covered with the pure muslin (free from chemical bleaches) specially made for butter, and on these the prints may rest until despatched. The cloths should be wrung out of clear cold water before use. Vegetable parchment forms the best wrapping material, and may bear the trade-mark. For marketing, butter needs better protection than it usually gets as sold by the farmer; and light and cheap boxes, non-returnable, are the best packages we know of for efficiency and economy. Even when made of common spruce, if they be lined with the parchment within and with common paper next to the wood, the butter will travel without injury. For returnable cases, poplar or colonial wood is preferable.

Potting Butter.—Heavily salted butter for keeping is put into pots, and hence known as "potted" butter. A really fine article, with three-quarters of an ounce of salt to the pound, needs no special treatment beyond the packing. The pot should be absolutely clean, and not previously used for any purpose liable to spoil it for our use. The butter should be pressed into it with a scoop, so as to leave no crevices; the top levelled, and covered with slightly wet muslin; and this, with half an inch of salt pressed down upon it, covered finally with stiff paper, and put in a cool dry place. There can be no doubt that any good butter keeps better in a pot than in any prints in contact with the air, and Americans do most of their business in this form.

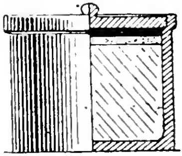


FIG. 205.—BUTTER IN POT.

It is believed that sunlight, apart from air and temperature, affects butter prejudicially, tending to convert the fixed fats into tallow and decompose the volatile fats. Storage in a low light will secure against such risks.

Whey Cream Butter.—In making cheese more or less of the milk globules are lost in the process of breaking the curd; and in the hard curd systems this is always enough to justify a reasonable outlay for securing it as butter. The loss will depend somewhat on the original milk quality, and especially on the skill of the cheese-maker, for a clumsy hand will waste much more than is necessary. The average of sundry analyses gives .33 of 1 per cent. as the loss by one system, while that of another—supported by manufacturing experience—shows .17, and even this must be regarded as too high.

Whey cream, as it is called, is regarded too much as a half-worthless by-product. Many American cheese-makers, and some of our own people, make from it a grease for use on cheeses, and fit for nothing better; but we have known the product when well made to fetch at the rate of 1s. 8d. per lb. avoirdupois (1s. 10d. per pound Derbyshire weight) for nearly three months in succession, with an average of 1s. 5d. for the season, and keeping only a penny per lb. behind the best milk butters. Those days may never return again, but the butter is worth making at 1s. per lb., or 10d. for potting, and makes the finest keeping article known to us. The cream differs in nothing from that of milk, excepting in so far as the conditions attending on the whey affect it. The whey is set in a tank, which is best made of wood or brickwork, and lined with lead. Neither cement nor cemented bricks will serve—the acid eats away the lime, and the combination affects the whey. We remember seeing the cream on a factory tank checked over strangely in a perfect pattern, and found that the bottom of the tank was laid with square tiles in cement; immediately over the joints there was no cream, and other observations have shown similar results. Next morning it is skimmed with a bowl. More care is taken to get all the cream than to exclude the whey. The cream ought to be so thin as to tax the skill and patience of the dairyer; then he can comfort himself with the reflection that all the rest is in the cheese. We have already recommended the separator for this purpose in cheese factories.

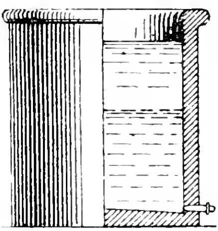


FIG. 206.—WHEY CREAM PAN.

With present conditions it is desirable to scald the cream to a temperature of 150° F., and keep it at that for twenty minutes, so destroying the living ferments, and checking further fermentation by salting the cream at the rate of two ounces to the gallon, and stirring the while. It should then be set in a glazed pan, provided with a tap or wooden plug at its lower edge (Fig. 206), but should not be filled beyond two-thirds of its depth, the rest being filled with cold spring water, and mix well. The cream will rise to the surface, leaving the whey removed in skimming mingled with the water; and these should be drawn off next morning. After this the management should be as with milk cream. The long-keeping quality is due both to the early fermentation and the after-check put upon it. The butter if made for table use benefits by being kept a few days.

There is not the room in butter-making for compensations for mismanagement which is afforded by cheese-making. Errors in ripening, for instance, cannot be set right to any appreciable extent, the effects being physical as well as chemical, and the latter are mainly brought in to help the former in their setting free the fats. The purely physical and mechanical laws, when transgressed, place the results almost entirely beyond remedy. But, on the other hand, butter-making is far simpler than cheese-making; in it there are more fixed rules, and fewer occasions where the judgment can err. The results are also more easily reduced to uniformity; and with the constant and widespread teaching which is being given on this subject, we ought speedily to put an end to the complaints made against us by the trade, and to the comparisons with foreign dairyers generally made to our disadvantage.

CHAPTER XIX.

TESTING AND ANALYSIS.

THE ability to determine the composition of milk and its products, to such an extent as will serve practical purposes, is a very desirable acquirement for the dairyer.

The prosecution by him of the ordinary chemical practice to its furthest limits is usually too great an undertaking ; not that it is by any means beyond his intelligence, but it costs too much, and occupies too much time, to justify it. There are, however, methods, some of which are used by the analyst, which are both cheap and ready enough to meet his case, and which deserve his confidence. These we shall describe ; but whatever may be their inherent value, much of their practical usefulness will largely depend on the dairyer himself. Accuracy in working, recognition of influential conditions, and reliability in inference, are essential to this. This is generally supposed to be the monopoly of men who have been trained in the science schools ; but to that we take exception. There is no finer training in the world in this direction than the constant forecasting and estimation of the conditions of the cheese-maker's daily experience, and this is true of butter-making in a degree proportionate to its greater simplicity. By the time the dairyer has learned to understand and to do his work as it ought to be done, he has necessarily passed through a mental and technical drill equal to that of the average laboratory. We are not thinking here of the empirical teaching of five-day courses of butter-making, but of the thorough study and practice which we are trying to promote ; and we are sure that any dairyer who can grasp the main principles and conditions of his art, and carry out its details faithfully, can also appreciate those which relate to methods of analysis.

The methods within easy reach vary in value, and there are with them, as with all, adverse conditions and accidental interferences which, if unrecognised or misunderstood, may make the results misleading or valueless. While we shall endeavour to anticipate common risks, it will be impossible to go further within our limits of space; and the dairyer who finds something amiss in his conclusions, must needs seek explanation by reasoning and experiment. In this case he will be in the excellent company of the greatest scientific authorities, who have frequently to confess failure and begin again.

Milk.—The purposes of the dairyer in wishing to know something about the quality of a milk are twofold, viz., (*a*) for the improvement of his herd, feeding, farming, or manufacture; or (*b*) for fixing the commercial value of a purchased supply. For these aims the examination of milk may be divided according as it regards (*a*) the whole quality, or the proportions of total solids; or (*b*) the fat.

FIG. 207.
SAMPLE DIPPER.

At the outset the taking and treatment of samples require notice. The whole benefit of any test is thrown away if the sample be not representative of the bulk from which it is drawn. Therefore it should, if possible, be taken before any cream has risen, and in any case the mass should be stirred to a uniform distribution of the globules. Even in a few minutes the balance of fat, and therefore of total solids too, is destroyed; for the upper milk will contain more globules than that lower down. Milk which has travelled from the farm to the factory will be fairly mixed in the receiving can; but even then the *sample dipper* (Fig. 207) should be freely used for stirring it.

The sample should be emptied into a jug bearing a number, which corresponds with the supplier's number in the factory book, or with the cow, or other reference, as the case may be. However short may be the time it stands after this, it must be thoroughly mixed again before being tested, and there is no better way than to pour it smartly from jug to jug as much as necessary. If the least cream appears at the milk level in the original jug, it should be carefully swilled down by shaking the milk upon it before the mixing is commenced. The capacity of this jug should be a pint, for though a sample of a quarter pint will generally serve, more will sometimes be needed, and there should be ample room to allow of pouring without splashing.

(*a*.) The total solids are best determined by evaporation of the water from a weighed sample of milk, weighing the residue, and comparing it with the original quantity. For this purpose the following apparati are necessary, viz.:—

A chemical balance (Fig. 208), constructed to weigh finely, and consisting of a pillar *a*, on which rests a beam *b*, with pans *c c*, and screws *d d* to balance it, until the pointer *e* stands at the middle line of the scale *f*, when the pans are at rest. In use, the beam *b* is raised by a wheel worked by the milled head *g*, so that the pans swing clear of the bottom of the case *h*, this being done by a quick, but not jerky, motion. The whole is protected by glass to preserve the bearings from atmospheric damp, which would soon ruin them; and it is well to keep inside the case a small open jar of fused Calcic-

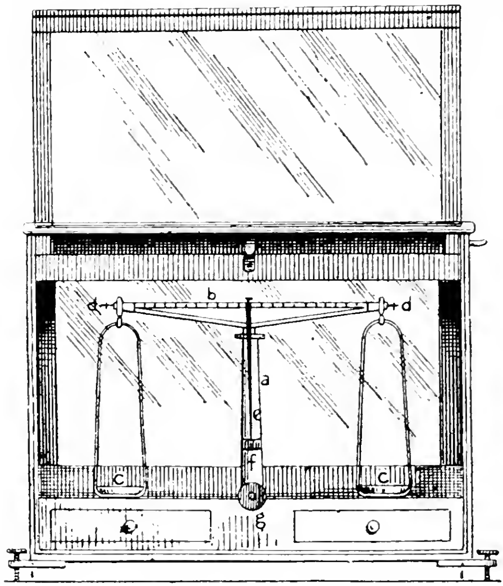


FIG. 208.—CHEMIST'S BALANCE.

chloride, which will absorb any moisture in the contained air, and so make "assurance doubly sure." Screws *i i* are provided, by which to set it perfectly level, with the help of a spirit level. The best weights are those of the metric system, the unit of which is the *gramme*, which is nearly $15\frac{1}{2}$ grains English weight. This is divided into lower weights, decigrammes (tenths), centigrammes (hundredths), and milligrammes (thousandths of a gramme), such being in the form of bent plates of platinum; and their decimal relations make them much simpler and more easily reduced to percentages than those of the English system.

A combined evaporating bath and oven (Fig. 209), consisting of a double-cased oven of copper, around which water is boiled by gas, oil, or steam, as may be convenient. At the top are openings *a a*, a tube *b* ventilating the oven, and another *c* by which water is supplied through a funnel, while by *d* any overflow finds its way to a proper place of discharge. Within the oven loose shelves of perforated copper rest on projections. A ventilator *e* controls the admission of air. When oil is used a chamber *f* is needed, with a flue *g* directing the heat into it, while apertures under the projections *j j* allow of a current of ventilation to the lamp *i*, and a window *h* gives a sight of the flame for regulation. The lamp must be kept very clean, and not allowed to smoke. In a factory steam will be economical, and if muffled at its inlet, and only turned on sufficiently to cause a gentle simmering motion, will answer perfectly. The variations of steam pressure will however have to be watched.

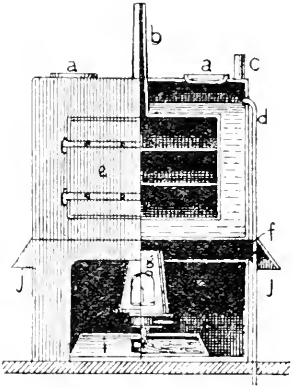


FIG. 209.
EVAPORATING BATH AND OVEN.

Porcelain dishes (*a*, Fig. 210) holding ten grammes, and nearly flat; a few pipettes (*b*) of bent glass tube, with fine points; and others (*c*) with coarser points, and capable of holding five cubic centimetres up to the mark shown. This measure is very nearly equal to five grammes weight of milk. One or more glass bell jars (Fig. 211) for cooling samples will also be required. This outfit will cost from £8 to £12, according to size.

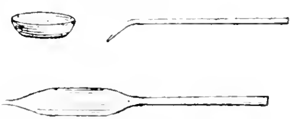


FIG. 210.—DISH AND PIPETTES.

The dairyer should place his scale on a firm table of ordinary height, and level it, arrange his sample jugs and mixing jug on his left, and his dishes—which have been previously well dried in the oven—on his right. Taking his seat,—for he must be comfortable, and have his hands free,—his first business is to weigh a dish. It will save trouble and time if he weighs his whole set, scratching the weight on each with a glazier's diamond, so that in weighing he may come within a

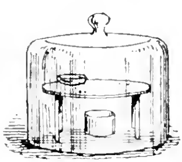


FIG. 211.
DESICCATOR.

fraction of the weight at that time by the first placing of weights. Raising the beam, the motions of the pointer *e* will show him if the weights need altering, and to what extent, for he will soon become familiar with the correspondence of the weights with the scale divisions. When the exact scale balance is secured, the beam is lowered (as it is also for all changes of weights and dishes), a sample is prepared by pouring from jug to jug, and the pipette *c* (Fig. 210) filled to the five-gramme mark by suction with the mouth, and run into the dish, which is removed from the scale for the purpose. In using the pipette, the best plan is to draw into it a little more than is needed, remove it from the lips, and quickly cover the upper end of the tube with the finger, as in Fig. 212, when by lifting this very slightly at intervals sufficient air will be admitted to discharge some milk,—even the most minute quantities, if desired,—and thus lower the contents nearly to the mark. The last milk in the point should be blown out. On replacing the dish in the scale, a five grammes weight is put on the other side, which will rise with the lifting of the beam, the milk being a little the heavier. The pipette *b* comes now into use, and there are three ways of using it. For considerable removals, the large end is placed between the lips and the point into the milk, and by suction enough is drawn up into it to turn the scale. It is then removed, the beam lowered to reduce its pans to steadiness, and when raised again, the milk from the pipette dropped into the dish under control of the finger as before. For finer adjustments, the point of the pipette is allowed to take up what it will by dipping; and for the finest of all, the edge of its other end is touched so lightly on the milk surface as to require once or twice doing to change the weight by a millimetre.

FIG. 212. MEASURING WITH PIPETTE.

This is delicate work, and requires patience; but any one can become so expert in doing it, as to be able within a week to weigh samples at the rate of one in two to three minutes. When all are ready the scale is closed, the water in the bath set at simmering point, and the samples placed over the openings *a a*, Fig. 209. There they remain until reduced to a dry yellow crust, when they will contain only a thousandth or less of their original water. They should now be placed in the oven, and kept there until they cease to lose weight; which may be tested by weighing two or three at three hours from the start, and replacing them for another half-hour. If they have lost weight during that time, they should be returned for another half-hour's drying, and so on; when they are found to be steady at their last previous amount, they can be removed finally. They should now be cooled under the bell jars, some fused Calcium-chloride being enclosed with them to absorb any moisture from the air. In an hour they can be weighed. In a rough book the calculations should be made as in the example given. As the dishes are weighed into the scale, the number of the sample (*a*), and the weight scratched on the dish (*b*), should be entered for identification. Leaving a line free, the actual weight of the dish is entered at *c*, and of the dish and dried solids at *d* (a supposed case, of course), and *c* being subtracted from *d* leaves the weight of the solids, which being the product of five grammes weight of milk must be multiplied by twenty, or doubled, and the decimal point removed one figure to the right to give the result from 100 grammes, which here is 12.52 per cent., or 12 grammes 5 decigrammes and 2 centigrammes, as it would read in weight. This method of drying the water gives a result the nearest possible to absolute accuracy, and is the first step in the practice of the regular analyst. The principle is simplicity itself, and failure—within the course and care advised—is practically beyond our power.

(*a*)	5
(*b*)	12.375
(*d*)	12.998
(*c*)	12.372
(*e*)	.626
	2
(*f*)	12.52

(*b*.) A third method has been offered, by which the total solids may be calculated from the density and fat, as determined by the ordinary tests for these. This proceeds on the belief that the solids —not fat—bear a constant relation to the fat and the density; but this not being the case, but so far from it that the formulæ and tables based upon them fall foul of common experience, it is idle to quote them. We have seen no table as yet on which we would dare to advise the reader to purchase milk.

Fat.—(*a*.) The simplest estimation of this constituent is obtained by the *creamometer* (Fig. 10), which gives the percentage of cream raised within a given time. Such, however, are the differences in milks in the matter of creaming, that the test is only useful as a "pointer," enabling the butter-maker to judge roughly of the profitableness of his cows, and showing by any sudden or special falling off of the cream proportion that something is wrong with the cow or her feeding. In order to its best results the tube should be warmed and afterwards cooled, as with the best creaming systems.

(*b*.) The *optical* test, performed with an appliance called a *lactoscope*, which consists of a vessel of some convenient form to test the opacity of milk, and thus to estimate its quality. Certain marks which are visible through a fixed depth of water are hidden by mixing milk with it; or a certain quantity of milk hides the marks which are seen when water has been mixed with it; the milk necessary to hide the marks in the former, and the water required to reveal them in the latter case, being calculated according to the fat present, so that they may indicate its proportions. The great simplicity of this test makes it a matter of regret that it cannot be depended upon. We have experimented considerably with it, and find that between two users the difference in eyesight is often so great as to enable one to see the marks when the other could not, even in some cases to the extent of a half of 1 per cent. of the fat in the whole milk, or 16 per. cent of the average fat proportion. The more frequent lower variations would make it necessary for each user to make a scale for himself, with the necessary experiments to that end, and with the means for doing this he could do more certain work. Moreover, the sight of the same person varies with age and light, and the results are affected also by the size or number of the globules, so that at its best it can only be an approximate test.

(*c.*) *Marchand's Method*, with the *lacto-butyrometer* (bu-te-rom-e-ter).—This is the simplest test which may be considered accurate, when used under proper conditions. The essentials are a tube *a*, (Fig. 213), divided into three parts at the lines M, E, and A, with a number of fine divisions for an inch or two above and below the last named; also two vessels (*b* and *c*) containing water, the one at 105° F. to 110° F., the other at 65° F. to 75° F.; and a supply of (*d*) *ether* (of density, .717), and of (*e*) methylated spirit (65 over-proof). The vessels in which these last are kept must be carefully closed when not in use, and not opened an instant longer than is necessary for pouring out required quantities. Neither must they be brought near to a flame, both being inflammable, the ether especially dangerous in this respect. With ether the waste by evaporation is very rapid.

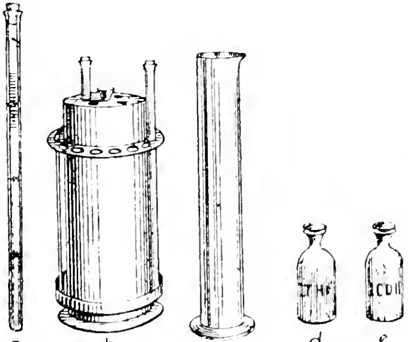


FIG. 213.—LACTO-BUTYROMETER.

The water-bath *b* is a modification of a design by Dr Bond, of Gloucester, which may be made to hold any number; but in practice one person cannot attend to more than four tubes at once. The funnel-tube in the middle leads nearly to the bottom, so that when warm water is poured in, it must rise through and mingle with the whole. A single jar like *c* will serve in the farm dairy.

Into the tube *a*, freshly mixed milk is poured up to the mark M followed by ether to the mark E, and these two mixed thoroughly together by tightly closing the tube with the thumb, as in Fig. 214, and vigorously shaking it vertically, with two or three turnings upside down at the start. Then the spirit should be added to the mark A, and another shaking given. The casein now coagulates in irregular patches, with a tendency to adhesion, which must not be suffered, the shaking being kept up until all are reduced to a very small and even size, and distributed throughout the whole mass. The pressure within must be relieved, by slightly lifting the thumb on the side furthest from the user, and only when the contents have been given a moment's rest. If this ventilation is not done with great care some of the contents will be lost, and the test spoiled. In order to afford room for the shaking, the tube should be long enough to give at least two inches of space above the alcohol mark. It should now be securely corked and placed in the vessel *b*, where the fat will separate with a portion of the ether in the form of an ethereal solution. The dissolved fat has its yellow colour, and can be seen rising rapidly in drops of varying size, and forming a distinct layer on the surface. The action of the ether, which rises, being lighter than either the alcohol or the water of the milk, depends on the temperature in which it has been kept or is being used. In warm weather its activity is great, and liable to blow out the stopper from the bottle or the cork from the tube. Therefore it should be kept in the coolest place possible, and the temperature of the water in the vessels *b* and *c* should be regulated according to the temperature of the laboratory, as in the accompanying table :—

FIG. 214.—HOLDING LACTO-BUTYROMETER TUBE.

Air.	Maximum.	Minimum.
65° F.	105° F.	100° F.
60° F.	107° F.	102 F.
55° F.	110° F.	105° F.

A glass thermometer should be used frequently to ascertain when more warm water is needed, and a little practice will enable the user to gauge the quantity necessary to raise the temperature the five degrees. The activity of the ether should be sufficient to keep the curd particles in gentle motion as long as the tube is in this vessel, and to prevent their settling; when this last happens the dairyer may be sure that more warmth is needed. On the other hand, it should not be so lively as to expel the cork, or even to dash the curd upwards on the tube-side; and at the first signs of such danger the temperature should be lowered by a degree or two by cold water. The observance of the temperatures given will generally secure a right action. When no more fat is seen rising, the tube should be removed to the vessel *c*, the temperature being as in the table below. The curd will now

Air.	Maximum.	Minimum.
65° F.	70° F.	65° F.
66° F.	72° F.	67° F.
55° F.	75° F.	70° F.

gradually sink; and the slower the sinking is, the better, for any remaining fat will the more easily find its way up between the particles. If the curd gathers in clots, it is liable to enclose some of the fat and carry it down. When no more fat is seen to rise, the number of lines by the scale may be read off, and the quantity of actual butter-fat learned by the table given. Each space represents one-tenth of a cubic centimetre. By capillary attraction the surface will not be level, but dip to the extent of one space, and the lower end of the fat layer will to some extent correspond. For this due allowance is made with this table, so that the measure may be read from the top edge to the lowest point of the lower dip.

Lines.	Fat.
1	1.3
2	1.5
3	1.8
4	2.0
5	2.2
6	2.4
7	2.6
8	2.8
9	3.0
10	3.2
11	3.4
12	3.6
13	3.8
14	4.0
15	4.2
16	4.4
17	4.7
18	5.0

The value of this test depends on the understanding of conditions, and a ready recognition of their signs, and on the thoroughness of the work. The ether and alcohol must be of correct and uniform strength at all times, or their action will be unreliable. The measuring of the quantities must be exact. The shaking must be vigorous, and continued long enough to ensure its results. It is not enough merely to mix the ether with the milk; the purpose is to set the fats free by churning, so that the ether may dissolve them; and in proportion to the churning up to the furthest limit, will be the success of the test. Then when the alcohol is added, the second shaking causes a fine division of the curd, and this also cannot be too thorough within possibilities. The temperatures under which the remainder of the process is carried on will determine the rest. Now there is nothing in all this beyond the range of ordinary intelligence; and if the dairyer will be so exact and thorough, he will find satisfaction in the results, which will correspond very closely to those of the best analyses.

This test can be applied to creamed milks, whey, and buttermilk, to show loss in setting, separating, or churning. Below one space of the scale, however, the amount cannot be determined; and it is necessary to make a higher quality sample for the purpose. This is done by well mixing equal quantities of the material to be tested and milk—of which the fat proportion has been already ascertained,—and testing the mixture. The proportion of fat in this must be doubled, and the proportion of fat in the earlier tested milk subtracted from this total, when the remainder will be the fat in the special material tested. Example:—A milk with 3.50 per cent. fat is added to a creamed milk which it is desired to test. The mixture yields $1.86 \times 2 = 3.72 - 3.50 = .22$, which is the fat in the creamed milk.

FIG. 215. BABCOCK TESTING-BOTTLE.

(*d.*) Centrifugal power has been combined with chemical means in the "Babcock" and "Beimling" tests, both hailing from America. The former has already been introduced by Messrs Lister & Co., of Dursley, Gloucester, in a handy form, with certain mechanical advantages over American patterns, and is here known as the Lister-Babcock method. In this sulphuric acid (H_2SO_4) is used in a mixture of about one-tenth water to nine-tenths of the strongest trade acid. These should be mixed in a stoneware or earthenware vessel,—not in one of glass, because of the heat evolved in mixing. The result, when cold, should be a density of 1.834 and no more. If this is exceeded, water must be added to bring it down. An *acidimeter* (which is a hydrometer, with a scale of proper range for acids) should be used to determine this. After cooling, the mixture should be kept closed from the air, which would otherwise weaken it, and interfere with the working of the test. Care must be taken to avoid contact of the acid with the skin or clothes. The vessel used is a bottle (Fig. 215), the neck of which bears a scale of percentages, with intervening lines marking divisions of two-tenths of 1 per cent. With a pipette (Fig. 210, *c*) marked to measure 17.6 cubic centimetres (briefly written *c.c.*),—but really delivering 17.5, because the balance adheres to the glass,—milk is discharged into the bottle, which is tilted to one side to receive it, so that it may run down the side leaving space for air. If more than one sample is to be tested, all should be placed in their bottles with means of certain identification. Then 17.5 *c.c.* of the acid mixture is poured into the bottle, and in such a manner as to wash down all the milk on the neck,—or if more than one test then all in rotation,—and this being heavier will sink to the bottom, the milk forming a distinct layer above it.

The centrifugal machine consists of a case (*a*, Fig. 216), which should be screwed down to a table for stability, with a cover (*b*), constructed to hold hot water for the maintenance of the internal temperature; and a disc (*c*) driven by a wheel-gearing (*d*), which causes the disc to revolve ten times for every revolution of its own. Around the disc the bottles (*e*) are arranged so as to balance equally, and each contained within a wire holder. Before being placed in the machine each bottle is shaken with a rotary motion,—not up and down, as with the Marchand tubes,—and without any attempt to close the mouth.

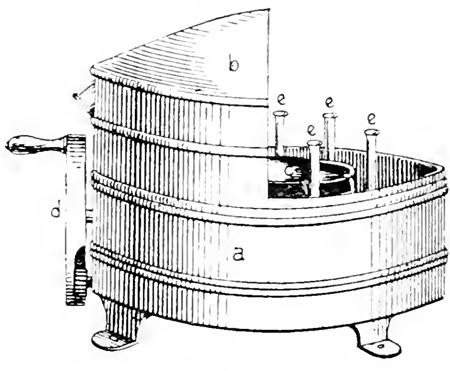


FIG. 216.—LISTER-BABCOCK APPARATUS.

Sufficient heat is evolved in this mixing to turn the casein to a dark coffee colour; and this heat must be made the most of, for the perfect action of the test depends on the temperature; and if this process is done quickly, time and trouble will be saved later in special heating. The cover-space being supplied with hot water and the bottles arranged, the machine is set in motion and kept at full speed for ten minutes, after which it is brought to a standstill, but gradually, or the bottles will most likely be broken. The bottles are now to be filled with water at 200° F. to 205° F., exactly to the 7 per cent. mark by the pipette, and again set in motion for two minutes, and by the time it comes to rest the fat should be found clear and well separated from the other contents in the neck. If cloudy it will need more heat. When the proper condition in this respect is reached, each bottle is raised to a level with the eye, and the measure of fat is calculated.

The figures are estimated to show the amount of butter realisable from the milk by separation, and if it is desired to know the full proportion of fat in the milk .4 of 1 per cent. is added. When creamed milk buttermilk, or whey are to be tested, they should be treated as advised with Marchand's process. To prepare the bottles for further use they should be turned upside down, and so whirled round as to make the contents pass out with a funnel-shaped air-space through the middle, and two rinsings of hot water discharged in the same way will cleanse them effectually.

The *Beimling* test proceeds on very similar general lines, but 15 cc. of milk are used, with two compounds, one of equal parts of Amyl alcohol ($C_5H_{12}O$) and hydrochloric acid (HCl), first mixed by shaking; and then sufficient sulphuric acid to reach the 7 per cent. line, this last being added at twice, and a shaking with each, with care to avoid an action sufficient to produce foaming. The heat is so great that a dozen samples, if quickly prepared, may be carried through without hot water. After being kept in motion, by a machine similar in principle to the "Babcock," for two and a half minutes, the results are found by a table specially prepared, the scale not giving percentages.

(*e*.) Where the drying and weighing method is employed to determine the total solids, it is easy to carry the process further, and learn the amount of fatty and non-fatty solids, by extracting the fat from the residue of the drying. For this purpose the dried solids may be treated with benzoline, about the quantity of the original milk being run into the dish with a pipette, and the whole placed over the bath with the water maintained at 112° F. Though at 100° below boiling point of water, the benzoline will boil, extract the fat, and, like ether, dissolve it. When it has boiled away to half its original quantity, it should be taken off, and after being allowed to settle, so that the liquid may be free from any particles of a solid character, emptied—with all care to avoid loss of such,—and the process repeated until no more fat is forthcoming. This may be known by using ether finally, and allowing a drop after use to fall on unsoiled white blotting or filter paper; if no stain is observable, the work is completed. The second residue should now be dried on the bath (Fig. 209) and in the oven, as for total solids, but will take only a third of the time, the spirit being rapidly evaporated. After a time in the desiccator (Fig. 211), its weight may be taken, and this subtracted from the original total solids will give the fat. Other methods of extraction, when that alone is desired, are practised by analysts, but they are of no better value than these given.

We are now in a position to discuss the purchase of milk by quality, in which matter it was our privilege to do pioneer work. To-day our American cousins are taking it up in all directions, and finding in it a great and manifest encouragement to the production of good milk. The foundation of the whole lies in the self-evident fact that the dairyer can get no more out of milk than it contains of realisable solids. In view of the variations in the composition of milk, no fixed price can be just both to seller and buyer. It is nothing but simple justice that a farmer who supplies a good milk should be paid more for it than his neighbour is paid for a poorer milk, and it is just as reasonable that the factory owner should refuse to pay for the latter the price proper to the former. Careless men, whose sole aim is to get for a poor article as much as another can get for a better one, will probably quarrel with the principle, and in doing so proclaim their character to their fellows; but there are men wise enough to test the case for themselves, and the result is not uncertain. We have already pointed out that good breeding and feeding give larger profits beyond a certain limit of judgment and economy, and the surest way to bring these principles into common use is to put a premium on good milk at the factory. After exhaustive calculations, we recommend the following basis for valuation in *cheese-making*, viz., the making 12 per cent. solids the minimum quality receivable, and the fixing of a minimum price for such a milk, with the addition of a farthing per imperial gallon for every half of 1 per cent. of solids above that point. It does not serve to make up milks below the minimum at all, but if not returned they should be subjected to a fine of one penny per imperial gallon beyond the price due for the quality. In the cheese factory, the drying method should be adopted, because the yield of cheese varies less from the total solids standard than from the fat proportion. It has also the great advantage of simplicity; the supplier can understand how the mere drying of the water must needs leave the valuable portions behind. For *butter-making*, in which fat will naturally be the basis, the cost of production must be taken as higher, because no account is taken of improvement in the casein, and the burden of cost is thrown upon one item; but as fat increases at a much greater rate than the other constituents, the difference cannot be great, and one-third of a penny per half of 1 per cent. above the minimum meets the case fully and fairly for both parties. The lowest limit should be fixed at 3 per cent., for poorer milks are unprofitable to all concerned. The "Marchand," "Babcock," or "Beimling" tests will answer admirably, and—though employing chemicals—can be made clear to ordinary intelligence. Prejudice may oppose for a time, but if the dairyer is frank about his method, and willing to let his suppliers see it in use at any time, he will win their confidence. To the supplier the profit on the production of a 12.50 per cent. milk will be greater than on one of 12.00 per cent. of solids, and it will cost less in proportion to the time, labour, and materials used to make the former into goods than the latter. Even when the milk is made up on the farm, the economy in both ways is just as great.

Cheese.—It is desirable that the amounts of water and fat in this product should be ascertained for guidance of the maker in the retention of whey and other points of management. A sample of ten grammes, chopped very fine with a keen knife, and dried like a milk sample, will show its loss of water; and by treating the residue with benzoline and ether, the proportions of fat, and solids not fat, can be learned. The fat may be ascertained without separating the water by chopping up five grammes weight of cheese, and adding to it 13 c.c. of water in a Babcock bottle. By warming and shaking it the cheese becomes softened, and ready when cooled to receive the acid, as for milk, after which the work proceeds as in that case, the result as per scale being multiplied by eighteen and divided by five, when the final product will show the fat proportion. Further than this we need not go herein, for the processes require more apparatus and are much more difficult of performance.

Butter.—In determining the water in butter, a sample of fifty grammes (a little less than two ounces) is necessary. This should be heated over a spirit lamp *a*, Fig. 217, in a dish *b*, supported by a wire stand *c*, and kept at from 212° F. to 220° F., being stirred meanwhile. For these temperatures a thermometer with a scale rising to 240° F. is necessary. The water escapes as steam with a fizzing sound. When the curd settles to the bottom the sample should be removed, first getting off any which clings to the thermometer. It should then be placed in the desiccator (Fig. 211) until the air temperature is reached and then weighed. The result subtracted from the fifty grammes will show the loss of water. The curd and salt may now be estimated by scraping them from the removed butter, and treating with benzoline and ether until no fat is left. Their weight can be taken together, and the percentage of the original weight calculated. Finally, the amount of salt may be found from the proportion added in making, and this subtracted from the total of the two constituents will give the casein with practical accuracy.

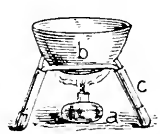


FIG. 217.
TESTING BUTTER.

The great value of such tests and simple analyses as we have described, apart from the application of some to commercial matters, lies in the knowledge which the dairyer can gain from their bearing on his processes, enabling him to act and speak with confidence where he would otherwise be in some doubt. He may, with such knowledge, pursue the work of improvement to its utmost limits, and find in it a constant inspiration and pleasure.

CHAPTER XX.

RECORDS.—EXPERIMENTS.—CLEANSING.

THIS closing chapter may be devoted to a brief notice of three matters of no little importance to the dairyer, though in different ways.

Records.—The philosophy of records may be summed up in a sentence—"Learn by experience, and—to that end—record your experience." For want of such records, every generation has to go over the ground of its predecessors, with trifling advantage and slow advance. If any lesson is prominent in this work, it is that the endless variations in the conditions attending on the practice of the dairyer make it necessary that he should study these as they occur in his particular experience; and that, while holding fast to first principles, he should make the finer modifications suitable to his case by the light of his judgment. It is in the recognition and correct manipulation of these delicate points that the highest success lies, where advantage increases at a much higher rate than the efforts necessary to secure it. We may furnish the teaching which will guide him in the main, but he can only learn how to apply it perfectly by observing, reasoning, practising, and keeping records. The practice of putting down the facts of his daily work helps to his better remembering them ; and he will be sure to compare one set with another, and so get that inestimable breadth and reliability of judgment which only such a practice can give. Then he will make fewer and fewer mistakes, and steadily increase the uniformity of his results.

Several causes have combined to discourage the keeping of records. (*a.*) The want of a definite aim, and a knowledge of foundation principles. When the varying conditions of daily experience are ignored, and the same practices exactly repeated, the monotony of recording them becomes unbearable; but when those variations are recognised, and the practices varied to meet them, every entry becomes instinct with light and friendliness.

(*b.*) The want of a true conception of the unity of the system pursued, and the relative bearing of distinct practices on the common product. The details of working have been viewed too much apart from each other; and the records attempted have accordingly been fragmentary, and have not taught what was wanted. If a record is to be of any practical service, it must show at a glance not merely the times or temperatures, but these and other items in their mutual relations, and in such a form that the dairyer can read between them, and see the reasons for, and consistency of, the course pursued. The absence of this coherency could not fail to rob the records of their value and interest, and make their keeping a useless task.

(*c.*) The want of cheap and convenient forms, which will make the work pleasant. We have prepared suitable forms for publication, in which the items are based on the scheme of this work, and with all needful tables attached. It is, therefore, only necessary here to give general advice as to their management. Records of *cows* and their *feeding* should recognise their age, breed, and parentage, and the milking record of their dam, these items being entered in the early part of the book, with date of last calving, and any special facts touching their health and value. Then may properly follow some pages of feeding notes, in which the materials, their quantities and qualities, may be given, with the nutritive ratio of the various combinations, and supplementary facts. Following these may be the *milking records*, in which the cow's name is prefaced by the number of days since calving, and followed by the symbol of the feeding, and the milk given by her morning and evening during the time, covered by an opening of two pages.

In *cheese-making*, the first entries should be (*a*) natural conditions, the temperature and humidity of the air in the dairy, and weather prospects, as these must always affect the work. (*b.*) The milk, its quality and condition, should follow next; and if the total solids and fat can be stated in figures, so much the better. The progress of fermentation should be stated according to the colour scale; and in order to finer distinctions than are there made, shades intervening between the standards given may be expressed by figures B1 or C2, representing a slight advance on B, and a larger one on C. (*c.*) Times at which various processes commence. These should be made out roughly on a scrap of paper during the progress of the work, when the dairyer cannot conveniently leave it, the time of day only being written against the number of the item. When leisure comes these should be entered in the better form of time occupied (in minutes), so that all entries may stand in comparison without a moment's calculation. An example of the two forms will show the advantage of each for its purpose. In these *a* represents the time of renneting, *b* that of coagulation, and *c* that at which the curd was found ready to cut. In columns

	1	2	3	4
a	7.21	—	7.15	—
b	7.41	20	7.37	22
c	8.21	60	8.21	66

1 and 3 are found the facts stated in the rough notes of two days. He enters the facts in his record as in columns 2 and 4, where the difference between the two curds in time of coagulation and becoming firm are readily seen; while in the other form, they must have been worked out mentally in order to comparison. (*d.*) The quantities of materials used should be reduced to proportions, and expressed as simply as possible. (*e.*) The ranges of temperature—as in making and curing rooms—should be given, as they relate to the processes with the cheese of any day. The curing temperature will not be procurable until the goods are despatched, when the date of manufacture being ascertained it is easy to find the daily readings in the pages devoted to the matter. (*f.*) The loss in curing, the price obtained, and its relation to cost and quality of milk, and other items of practical interest, should be procurable from the entries made. In butter-making, the creaming and ripening (if practised) should be first noticed, and the facts throughout treated on similar lines to those of cheese.

In the long evenings of winter the dairyer can find leisure to reduce his records to totals and averages in their closing pages, and put them in comparison with those of previous years; and we believe that they will grow in his estimation with the lapse of time.

Experiments.—Every dairyer should be, within safe limits, an experimenter. The field is not yet half explored, and everybody may do something in the way of inventing or perfecting processes or appliances, or even in establishing new systems and products. In the ways first mentioned so many are at work as to make any extended reference to them and their efforts a hopeless task. It would seem as though nothing new could be brought out; but the recent appearance of the "Disc" churn, so different from its predecessors, is proof to the contrary. In new foods we may instance the "Little Gloucester" cheese, introduced by Dr Bond, of Gloucester, the system coming between the Stilton and the "Limburg" in principle and results, and winning for itself a high reputation as a delicacy. Where, however, one man may do something startling, the mass will not get beyond the quieter, but no less valuable and honourable, work of improving their own manufacture and the means thereto; and if they bring their contributions of knowledge to the common fund, they will deserve as well of their generation as the inventor. The following general rules for research in dairying are always applicable:—

(*a.*) The dairyer should thoroughly master his system before he begins to experiment beyond its usual limits. He cannot know too much of the practice from which he proposes to change.

(*b.*) He must study and follow natural law constantly, learning all he can, and reasoning, first on established facts, and, in a secondary degree, on probabilities also; digesting what is known, before he seeks the unknown. Experimenting is not leaping in the dark; and while by doing this one may occasionally find something worth finding, the real progress is made by those who "make haste slowly."

(*c.*) The essential principles of the system must always be kept in view when the purpose is to improve it; and if some discovery is made which takes the experimenter out of his original lines, and justifies a new system being adopted, then, having satisfied himself of its value, he should put it on the world on its merits, and with a distinctive name.

(*d.*) Definite aims should also be before him. Groping may be necessary sometimes, but we should know whither we are going. Scarcely anything is more discouraging than aimless work, and the total benefit from its findings is small. The common notion seems to be that there is a great deal of chance in research, and that a fool is more likely to drop on a fortune, than a thinker is to earn a competence. This is a delusion. Genius, which everybody covets, has been said by a high authority to be "the capacity for taking pains."

(*e.*) Conditions must be watched everywhere and always. Nothing in the universe exists apart from conditions; some evident, others unseen but no less influential, as witness the microbe! When some unaccountable fact comes under observation, it should be reasoned upon and followed up. There is a cause for every effect, and the unknown cause may trip the experimenter at any time. When he wants to know which of certain practices is best, these must needs vary, but all other conditions should be reduced as far as is possible to uniformity. If, for instance, it is desired to determine which of two creaming systems is the best, they should be tried together, receiving equal quantities of carefully mixed milk, stirred while being distributed, and equal opportunities given to both throughout. Often we meet with statements concerning experiments in which systems and practices are pitted against each other under conditions so utterly unfair to one or the other, or so lacking in definiteness, as to make the results worthless.

(*f.*) This work needs unwearying patience, and much repetition, before new theories can be regarded as safe to follow. The questions which we propose to nature have need in many cases to be put in two or three different ways. Nature is often ambiguous, and we must take care to know exactly what she means.

(*g.*) Accuracy in observation is essential to real value. Ofttimes we deceive ourselves by not looking at a fact long enough. In all weighings, measurements, and testings, nothing short of exactness will be of use.

(*h.*) The man who discovers a new principle does more good than he who merely improves its application. The one opens a gate to a multitude of advantages, the other only makes use of some of them. In this way the discovery of James Watt did more for the world than the last improvement in some detail of the steam-engine. The dairyer should ever be on the look-out for more light, as well as making good use of what he already possesses.

(*i.*) What we learn we should teach. We have had frequent occasion in this book to reflect on the "mystery" policy which has so long cursed our work in this country. Whether it covers ignorance or selfishness, it matters not—it is altogether bad. The great advance which our American rivals have made has been due in no small degree to their willingness to help each other. We have great need of conferences, held not at the height of the dairy season but in winter, when the many who are free from cheese-making, or but lightly occupied with butter-making, can gather at suitable centres to exchange their experiences. From the individual we have advanced to the community and the nation. The reputation of every dairy district is in the hands of its dairyers, and that of the nation as a whole; and whatever tends to the enlightenment and spread of knowledge is worthy of our intelligent and patriotic enthusiasm.

Cleansing.—In this, as in all other departments of dairy work, scientific rules should be followed, not only that the work may be perfectly done, but for the sake of economy as well.

In dealing with all vessels and clothes which have been used with milk, cream, or whey, they should be first washed out with cold water. Such as are greasy should go into a bath of water in which some suitable washing powder has been dissolved at boiling, thus forming a soap out of the fat and the alkaline powder, while for those which have been used with curd, such as cover and pressing cloths, the alkaline solution should be cool enough (90° F. will serve) to avoid the hardening of the curd, which speedily loads them, spoiling the cloths by making them smell unwholesomely. These methods of first treatment should be carried out in a tub and never in the open boiler or steam-heater, which should be kept for clean water only. With cloths, soda tends to give a bad colour and early spoiling, and is fit only for cheese-hoops and presses, while a good borax washing powder gives the best results known to us.

Brushes of various shapes for scrubbing are needed ; and all such should be of the best bass, which is more effective and more easily kept clean than hair. The short milk-can brush (Fig. 218) is specially useful as saving the hands when boiling water is being used ; and one with a longer handle is useful in reaching to points where the hand cannot do the work comfortably.

FIG. 218.
MILK-CAN BRUSH

All dairy appliances and aids need as much airing as they can get : hence our suggested provision of projecting roofs near the making-room, where they can be dried in wet weather, and in the case of wooden objects at all times away from the sun's direct heat.

We are glad to be able to close our account of the work of the dairy by referring afresh to this all-important matter of cleanliness. During the day, each appliance should have been cleaned as soon as possible after passing out of use, and when the work is done, the cleansing of the dairy itself should be as thoroughly performed as that of its contents. When the dairyer can leave it to its airing, in a fine state of sweetness, wherein the evening's milk may rest beyond the danger of taint, with everything in place, and within his own breast the consciousness of duty done, wisely and well, he will deserve success to his toils, and rest after them. Then he may remember—and he *should* remember to encourage himself to further efforts—that he has wrought within this department of service in harmony with that Divine Will which calls for every man's best, and also for the benefit of humanity. We wish him—heartily and always—the noble, though humble, elation which fills every whole-hearted worker when he recalls the truth so worthily expressed in the famous lines—

> "Who sweeps a room as by God's law
> Makes that and the action fine."

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