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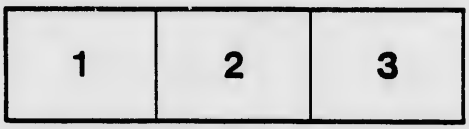
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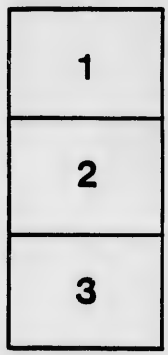
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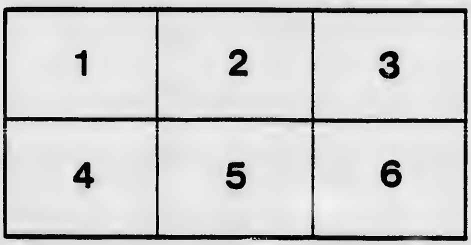
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BOARD OF AGRICULTURE.

REPORT

ON

the Results of Investigations

INTO

CHEDDAR CHEESE-MAKING,

carried out on behalf of the

BATH and WEST and SOUTHERN COUNTIES SOCIETY

in the years 1891-98.

BY

F. J. LLOYD, F.C.S., F.I.C.

Presented to Parliament by Command of Her Majesty.

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1899.

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Bath and West and Southern Counties Society,
4, Terrace Walk, Bath,
June 30, 1899.

To the Secretary of the Board of Agriculture,
4, *Whitehall Place, London, S.W.*

Sir,

I am directed by the Council of the Bath and West and Southern Counties Society to transmit to you, to be laid before the Board of Agriculture, the accompanying special Report, prepared, in compliance with the request contained in your letter of the 25th March last, by Mr. F. J. Lloyd, F.C.S., F.I.C., on the Results of the Investigations into Cheddar Cheese-making undertaken by the Society at the suggestion of the Board conveyed in their letter of 1st August, 1891. The Report reviews the progress of the Investigations from their commencement in that year to the end of the past season, and indicates the lessons of practical value to cheesemakers which have been elicited.

I am,
Your obedient Servant,
THOS. F. PLOWMAN.
Secretary.

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REPORT

ON

INVESTIGATIONS INTO CHEDDAR CHEESE-MAKING.

To the Secretary of the
Bath and West and Southern Counties Society,

SIR,

In the summer of 1891, I was instructed by the Bath and West and Southern Counties Society to carry out observations on the manufacture of Cheddar Cheese, and that the first object of such experiments should be—

(*a*) "The formulating of a complete scheme of investigation of the science which underlies the existing practice of the best cheese-makers."

I was also instructed to ascertain the:—

(*b*) Variations in quality of milk from cows feeding in different pastures.

(*c*) Causes of defects in cheese-making from quality of milk, &c.

(*d*) Effect of temperature in ripening of cheese.

When these instructions were given me the idea in the minds of those who prompted the investigation was that the problems to be solved were mainly of a chemical nature. As time went on and the facts ascertained by the observations increased in number, it became evident that the science of cheese-making had to deal not merely with chemical questions, but also, to a large extent, with bacteriological questions. The influence of the proper development of lactic acid, commonly known as "acidity," in each and every stage of the process of manufacture, was demonstrated, and a method of rapidly and accurately estimating this acidity was introduced. This apparatus has slowly come into use, not merely among makers of Cheddar Cheese, but also among those who are producing other varieties.

The general tradition that the soil and herbage of certain localities rendered cheese-making practically impossible in such places was investigated. Soils were analysed by the Society's Consulting Chemist, Dr. Voelcker, and the pastures most thoroughly investigated by the Society's Consulting Botanist, Mr. Carruthers, F.R.S.; but invariably without any explanation being found for the firm and wide-spread conviction that such soils and pastures were not suited for cheese-making.

It was found that defects in cheese-making would arise, at times, in dairies presided over by the most skilled and careful makers. Thus while on one day a cheese of excellent quality would be produced, on the following day one of very inferior quality would be made by the same maker, with milk the quality of which (chemically speaking) was similar to that of the previous day, while the temperatures, system of making, development of acidity, and every other condition, so far as could be determined, were apparently identical for the two cheeses. Investigation soon proved that during the making of a cheese there were other than chemical agents at work whose influence for good or bad might be quite as powerful as, if not more powerful than, the skill of the maker.

Bacteria, those infinitely minute vegetable growths which are now found to play so important a part in both the welfare and ills of mankind, were not absent from the milk and dairy, and were fighting either for or against the skill and intelligence of the cheese-maker. The study of these bacteria therefore received attention; some which played an injurious part in the manufacture of cheese were gradually discovered, and one or two of these were traced to their source. It was ascertained that trouble invariably resulted from contamination of the milk with dirt prior to its reaching the dairy, and that inferior cheeses were frequently due, not to any want of skill on the part of the cheese-maker, but to want of cleanliness on the part of the milkers. Dirty hands to milk with, and dirty cows to milk, probably caused more inferior cheese than all the other causes put together.

Thus the conclusion has gradually been forced upon me that the study of bacteria is the line along which future progress must be looked on. The object of this research work must be to get a complete list of the organisms which are found in milk whey, curd, or cheese; to compare the organisms found from year to year; to study the effect produced upon the curd or cheese by their presence; to ascertain their source; and if they are injurious, what means may be taken to prevent them finding their way into the milk, or how best to deal with the milk when they are present.

The results of my observations were each year reported on in the Journal of the Society, but, at the request of the Society, I have now prepared a general report for the Board of Agriculture on the work which has been done during the eight years of investigation, and have herein classified so far as possible the information obtained.

This task has proved infinitely more laborious than I had anticipated, and in spite of every endeavour to prevent needless repetition, I have found it necessary to restate here and there some of the facts to which attention has had to be prominently drawn.

I am indebted to Sir A. Geikie, the Director-General of the Geological Survey, for marking out the geological strata on the plans of the sites which have been so admirably reproduced by the Ordnance Survey.

To Mr. A. Sutton, of Norwich, for the illustration of the burette adjustment, Fig. 2, taken from his well-known work on Volumetric Analysis.

To Messrs. Newton & Co., Opticians, Fleet Street, for the illustrations of thermometers, Figs. 3 and 4, and hygrometers, Fig. 5.

To Messrs. Townson & Mercer, of Bishopsgate Street, for the illustration of the rennet measure, Fig. 6.

To Messrs. C. Griffin & Co., for the admirable illustration of bacteria, Fig. 7, which is taken from Dr. Lafar's excellent work on "Technical Mycology."

And to Mr. Samuel Lowe for the use of the illustrations of bacteria, Figs. 11, 12, 13, 15 and 20. The photographs were made from my slides by Mr. E. C. Bousfield, of Old Kent Road, and are most excellent specimens of photo-micrography.

After having briefly mentioned some of the existing methods of making Cheddar Cheese, I have described the methods of investigation adopted, the sites at which the investigations were carried out, and the influence of these sites, &c., on the milk and cheese yields.

I have then endeavoured to systematically describe first the chemical and then the bacteriological results. The bacteriological section runs to some length, and is necessarily somewhat technical, but the importance of this section must be an excuse for its length.

Then follow some results of experiments on various systems of cheese-making.

The Cannon system of cheese-making is fully described, and finally the conditions essential to the manufacture of Cheddar Cheese of high quality are considered.

In the preparation of this description of the Cannon system I have to acknowledge the help of Miss E. J. Cannon, the able teacher for the Society. But it is not her help in this respect which most needs my acknowledgement. Had it not been for her hearty co-operation, great interest in my work, and ready willingness at all times to carry out any experiments I needed, and to place at my disposal all her practical knowledge and skill, in fact, to give me every assistance in her power, I could not possibly have obtained all the information embodied in this Report.

I am, &c.,

F. J. LLOYD.

4, Lombard Court, London.

Part I.

SYSTEMS OF CHEDDAR CHEESE MAKING.

Origin of name and early notices.—The Joseph Harding system.—The Scotch system.—The Candy system.—The Cannon system.—Some effects of various systems.

Origin of Name.

The substance known as Cheddar Cheese is, and has been for many years past, one of the most important products of Agriculture in the West of England.

It probably derived its name from the village of Cheddar, which, owing to the remarkable cliffs and caves near there, has been from time immemorial one of the most celebrated sites in Somerset. Here many of the travellers who visited the cliffs would partake of some cheese, and, for want of a better name, would subsequently designate it by the name of the locality where partaken of. Hence, apparently, arose the name of Cheddar Cheese. I cannot gather whether this cheese was first made either in or near Cheddar, but all the district round Cheddar, or rather along the base of the Mendip Hills, was in the early part of the present century noted for its cheese.

Where made.—The manufacture of this cheese now extends throughout the whole length and breadth of Somerset. But it is not confined to this county, there being excellent makers in both Dorset and Wilts, while much good Cheddar is made in Scotland. In small quantities it has been made in many parts of England. Cheese of a similar type is manufactured in America, Canada, and Australasia. Hence it will be seen that wide variations of climate, of soil, and of surroundings are not prohibitive to the manufacture of Cheddar Cheese.

The early history of Cheddar Cheese-making I have been unable to search out.

The art of cheese-making must have attained to considerable perfection in the time of Tusser, for in his 500 points of good husbandry, 1557, he warns the dairy maid "Cisley" that she must carefully keep ten guests from her cheeses, and those who are acquainted with cheese-making will recognise the fact that probably no trouble now met with could be mentioned other than these ten.

A LESSON OF DAIRY-MAYD CISLEY, OF TEN TOPPING* GUESTS.

White and dry.	1.	Gehezie his sickness was whitish and dry, Such cheese, good Cisley, ye floted to nie.†
Too salt.	2.	Leave Lot with his pillar, good Cisley, alone, Much saltness in whitemeat is ill for the stone.

* Topping. Fine; here used ironically.

† Floated to nie. In Johnson's Dictionary this passage is quoted as "floted too nigh," and floted is old English for skimmed.

Full of eyes.	3.	If cheese in dairy have Argus his eyes, Tell Cisley the fault in her huswifery lies.
Hoven.	4.	Tom Piper hath hoven and puffed up cheekes ; If cheese be so hoven, make Cisse to seeke creekes *
Tough.	5.	Poore cobler he tuggeth his leatherly trash, If cheese abide tugging, tug Cisley a crash.†
	6.	If Lazar‡ so loathsome in cheese be espy'd, Let bayes§ amend Cisley, or shift her aside.
Full of haires.	7.	Rough Esau was hairy, from top to the foot ; If cheese so appeareth, call Cisley a slut.
Full of whey.	8.	As Maudlin wept, so would Cisley be drest, For Whey in her cheeses, not halfe enough prest.
	9.	If gentiles be crawling, call maggot the pie ; If cheese have gentiles, at Cisse by and by.
	10.	Bless Cisley (good mistress) that bushop doth ban, For burning the milke of her cheese to the pan.

If thou, so oft beaten, amendest by this,
I will no more threaten, I promise thee, Cis.

Thus Dairy maid Cicely rehearsed ye see,
What faults with good huswife, in dairy-house be.
At market abhorred, to household a griefe,
To master and mistris as ill as a thiefe.

William Camden, writing about 1600, in his description of life during the reign of Queen Elizabeth, states that Cheddar Cheeses were then made of such a size that it took two men to lift one on to the table.

Fuller, writing about half a century later, complains that Cheddar Cheese was so dear that it was only to be found on the tables of the rich.

Then comes a long gap, during which little can be found about Cheddar Cheese, though much was written about Cheshire Cheese.

The first precise description of Cheddar Cheese-making that I can find was written about 1856. A deputation was sent by the Ayrshire Agricultural Association to inquire into the methods of making cheese in the counties of Gloucester, Wilts, and Somerset. This deputation published a report, which was copied in the Bath and West Journal for 1857, Vol. 5. p. 158.

In this report the deputation wrote as follows concerning Cheddar Cheese:—

The Joseph Harding System.

We were indebted to Mr. Titley, cheesefactor, Bath, for an introduction to Mrs. Harding, Marksbury, and her nephew, Mr. Joseph Harding, Compton Dando, who make first-rate Cheddar Cheese.

In addition to the girls who do the work of the dairy, several men and boys are employed to milk the seventy-three cows belonging to Mrs. Harding at Marksbury. The men carry the milk, but they do not enter

---

* Seeke creekes. Make holes to let out the gas.
† Shake her well.
‡ Lazar. Nauseous ; probably refers to the fly.
§ Bayes. Appears to refer to the cloths with which the cheese is bound.

the dairy in doing so. It is poured through a sieve into a receiver outside, from which a pipe conveys it through the wall to the cheese-tub, or to the coolers. A canvas bag is also placed over the inside end of the pipe so that a double precaution is used against impurities entering with the milk.

The rennet is prepared much in the way that it is done in many Ayrshire dairies. Mrs. Harding steeps five vells at once, and this usually suffices for two weeks, in which time about twenty-one cwt. of cheese may be made. The vells appear to have been carefully cleaned and preserved. Pure, well-flavoured rennet is certainly indispensable in the manufacture of first-class cheese.

Immediately after the morning milking, the evening and morning milk are put together into the tub. The temperature of the whole is brought to 80 degrees by heating a small quantity of the evening milk. The thermometer is regularly used.

In spring and towards winter a small quantity of annatto is used to improve the colour of the cheese. It is put into the milk along with the rennet at seven o'clock.

After the rennet is added an hour is requisite for coagulation. At eight o'clock the curd is partially broken and allowed to subside a few minutes in order that a small quantity of whey may be drawn off to be heated. This whey is put into a tin vessel and placed in a boiler in an adjoining apartment, to be heated in hot water. The curd is then most carefully and minutely broken—Mrs. Harding and her niece performing this part of the work with utensils called shovel breakers. The servants are never entrusted with this duty. When the curd is completely broken, as much of the heated whey is mixed with it as suffices to raise it to 80 degrees, the temperature at which the rennet was added. Nothing more is done to it for another hour.

A little aften nine o'clock the work is resumed. A few pailsful of whey are drawn off and heated to a higher temperature than at eight o'clock. The curd is then broken as minutely as before, and after this is carefully done an assistant pours several pailsful of the heated whey into the mass. During the pouring in of the whey the stirring with the breaker is actively continued, in order to mix the whole regularly and not to allow any portion of the curd to become overheated. The temperature at this time is raised to 100 degrees, as ascertained by the thermometer, and the stirring is continued a considerable time, until the minutely broken pieces of curd acquire a certain degree of consistency. The curd is then left half an hour to subside.

At the expiry of the half-hour the curd has settled to the bottom of the tub. Drawing off the whey is the next operation, and the ease with which it is performed would astonish an Ayrshire dairy manager. The greater proportion of the whey is lifted in a large tin bowl, and poured through a hair sieve into the adjoining coolers. As it runs into the leads, it appears to be very pure. When the whey above the mass of curd is thus removed, a spigot is turned at the bottom of the tub, and the remainder is allowed to drain off, which it does very rapidly without any pressure being required. To facilitate this part of the work the tub is made with a convex bottom, and the curd is cut from the sides of the tub and placed on the elevated centre. It is carefully heaped up, and then left for an hour with no other pressure than its own weight.

After this interval it is cut across in large slices, turned over once on the centre of the tub, and left in a heap as before for half an hour. The whey drips away toward the sides of the tub and runs off at the spigot; and no pressure being applied, it continues to come away comparatively pure.

After undergoing these simple and easy manipulations, and lying untouched during the intervals that have been mentioned, the curd is ripe for the application of pressure. But great care is taken not to put it into the vat to be pressed at too high a temperature. If the heat be above 60 degrees, and it usually is higher at this time, the curd is broken a little by the hand and thrown upon a lead cooler, until it is brought down to the desired temperature. It is then put into vats and subjected to a moderate pressure for about an hour.

The next process is to take the curds from the vats, break them finely by putting them through a simple curd-mill, mix them with salt, and make them up into cheeses. A pound of refined salt is sufficient for half a cwt. of curd.

The cheese is put into the press at from two to three o'clock, and remains till the morning. Between the time of salting and six o'clock of the same afternoon, something near to one quart of whey is pressed from each cwt. of cheese, after which as much does not come as would wet a cloth. Next morning the cheese is reversed in the vat, and a calico cloth put upon it to give it a smooth surface, and the following morning another fine cotton cloth is put upon it. The third morning it is laid upon the shelf. The spring and early summer cheeses are ready for the market in September.

It was this report which first brought to notice the cheese-maker, Joseph Harding, whose name was destined subsequently to become a household word among Cheddar Cheese-makers throughout the world. Leaving the retirement of his home, he went far and wide, teaching Cheddar Cheese-making, and thus impressed his mark upon the methods of manufacture of the present day. As will subsequently be shown, the chief and characteristic difference between various methods of cheese-making depends on the course taken to obtain the curd sufficiently dry. At this time only two methods were known, the one by the use of heat, the other by the use of pressure; the latter was the system of Joseph Harding, the curd being subjected to pressure in the vat before being finally ground and pressed into a cheese.

In 1860, Joseph Harding contributed a paper to the Journal of the Royal Agricultural Society on recent improvements in dairy practice. Having described some of the chief mechanical improvements of recent years, he draws attention to two variations which had been introduced into the system of cheese-making, the one being slip-scalding and the other an attempt to make the cheese ripen more rapidly. He says:—

Slip-scalding.—The process is now conducted in the following manner. The morning's milk is mixed with the evening's at a temperature of about 80° (varying 2° or 3° in the spring and autumn), the rennet then is added, and an hour is allowed for the curd to form, when it is carefully broken up; and here commences the system of *slip-scalding*, now generally adopted in preference to the old method. The scalding whey is now added to the curd in its pulpy state, before it has had time to subside and get hard. Experience has shown us that a finer description of cheese is produced upon this principle, which is adopted by the best cheese-makers in this county. What is here called *scalding* is the raising the mass of curd and whey to the temperature of 100° Fahr. The curd is then allowed to subside, and, after the whey is drained off and the curd becomes dry, instead of being broken by the hand, it is passed through the curd-mill, after which salt is added and mixed with it in the proportion of 1 lb. to 56 lbs. It is then put into the vat and press, where it remains three days, after which it is taken to the cheese room. The cheeses are made from 9 to 14 inches in thickness, some even more. They are only turned twice in the press, and that is when the cloths are changed.

Rapid-ripening.—*The method of keeping the cheese in the cheese-room has also been improved.*

At one time we thought it desirable to keep them in a low and even damp temperature, but the cheese was then a long time in getting ripe, and a fine mellow flavour was not readily obtained. We now introduce them at once from the press to the cheese-room, which is kept at a temperature of from 50° to 70°, as the case may be; and we find that the cheese ripens faster, acquires a richer flavour, and can be sold much sooner; so that our thick cheeses are often cut over the counter at three months old, sometimes even less; though a few years since the same sized cheese would have required eight or nine months to acquire the same degree of ripeness.

It is a somewhat remarkable fact that the use of sour whey is not mentioned in either of these papers. It is first mentioned in a short paper by Alexander McAdam, who, having been a most successful exhibitor at Kilmarnock, in 1861, published in the "Scotch Journal of Agriculture," an account of his system. He says: "For various reasons I prefer making my cheeses according to the Cheddar system. I usually put in about 4 to 5 quarts of very sour whey to 140 gallons of milk."

It is now necessary to go back a little. The systems of cheese-making, up to 1850, had all been devised for the production in home dairies of one or at most two cheeses a day. In 1850* the factory system of cheese-making was started in America, and it soon became necessary to vary the methods of production so as to deal with a large quantity of milk with the least possible hand labour. Thus by degrees arose what is known as the American system of cheese-making. This system has taken no hold in the West of England, but it has been introduced into Scotland, where it has superseded the system of Joseph Harding. The instructor engaged for this work was Mr. R. J. Drummond, and the following is a brief account of the system he adopted as given by him in a paper published in 1889.†

The Scotch System.

In the year 1885 I was engaged as cheese instructor by the Ayrshire Dairy Association, to teach the Canadian system of Cheddar cheese-making. Instead of having the milk from 500 to 1,000 cows, we had to operate with the milk from 25 and not over 60 cows.

The system of cheese-making commonly practised in the county of Ayr at that time was what is commonly known as the Joseph Harding or English Cheddar system.

The Canadian or Factory System.

Our duty in this system of cheese-making begins the night before, in having the milk properly set and cooled according to the temperature of the atmosphere, so as to arrive at a given heat the next morning. Our object in this is to secure, at the time we wish to begin work in the morning, that degree of acidity or ripeness essential to the success of the whole operation.

* Arnold, "American Dairying."

† British Dairy Farmers' Association. Journal, Vol. 5, Part II, p. 67.

Great care should be taken at this point, making sure that the milk is properly matured before the rennet is added, as impatience at this stage often causes hours of delay in the making of a cheese. I advise taking about six hours from the time the rennet is added till the curd is ready for salting, which means a six hours' process.

We use from 4 to 4½ oz. of Hansen's rennet extract to each 100 gallons of milk at a temperature of 86° in spring and 84° in summer, or enough to coagulate milk firm enough to cut in about 40 minutes, when in a proper condition. In cutting, great care should be taken not to bruise the curd. I cut lengthwise, then across with perpendicular knife, then with horizontal knife the same way as the perpendicular, leaving the curd in small cubes about the size of ordinary peas. Stirring with the hands should begin immediately after cutting, and continue for 10 to 15 minutes prior to the application of heat. At this stage we use a rake instead of the hands for stirring the curd during the heating process, which lasts about one hour from time of beginning until the desired temperature of 100° or 102° is reached. After heating the curd should be stirred another 20 minutes, so as to become properly firm before allowing it to settle. We like the curd to lie in the whey fully one hour after allowing it to settle before it is ready for drawing the whey, which is regulated altogether by the condition of the milk at the time the rennet is added. At the first indication of acid, the whey should be removed as quickly as possible. I think at this point lies the greatest secret of cheese-making—to know when to draw the whey. I depend entirely on the hot iron test at this stage, as I consider it the most accurate and reliable guide known to determine when the proper acidity has been developed. To apply this test, take a piece of steel bar about 18 inches long by an inch wide, and ¼ inch thick, and heat to a black heat; if the iron is too hot, it will burn the curd; if too cold, it will not stick; consequently it is a very simple matter to determine the proper heat. Take a small quantity of the curd from the vat and compress tightly in the hand, so as to expel all the whey, press the curd against the iron, and when acid enough it will draw fine silky threads ¼ inch long. At this stage the curd should be removed to the curd-cooler as quickly as possible, and stirred till dry enough to allow it to mat, which generally takes from five to eight minutes. The curd is now allowed to stand in one end of the cooler for 30 minutes, when it is cut into pieces from six to eight inches square, and turned, and so on every half-hour until it is fit for milling. To determine when the curd is ready for salting, the hot iron test is again resorted to, and when the curd will draw fine silky threads 1½ inches long, and at the same time have a soft velvety feel, and when pressed in the hand the butter-fat will separate with the whey from the curd, it is ground.

I generally advise using 1 lb. of salt to 50 lbs. of curd, more or less according to the condition of the curd. After salting we allow the curd to lie 15 minutes, so as to allow the salt to be thoroughly dissolved before pressing."

This system is very largely adopted in America, Canada, and the Colonies, being more especially suited to the manufacture of cheeses on the factory scale.

Present Day System.—What system of cheese-making preceded that of Joseph Harding, I have been unable to discover. His, therefore, I designate

The Old System, of which there is at present no typical representative. It appears to have undergone more or less modification at the hands of nearly every cheese-maker, so that it would now be difficult to decide what the original was like, had it not been so minutely described. It continues to be adopted by many makers, and now and again some of these take a forward position as prize winners. But the result of any inquiry is the statement that the system they adopt is their own. In other words, they have in some slight manner modified the system they were originally taught, and now call it their own. This is greatly to be regretted, for these continual variations cause the original to be forgotten, and prevent that uniformity which it is most desirable should exist in the make of any one variety of cheese. The old system of manufacture having depended upon tradition, had, like most things which depend upon tradition, been imperceptibly altered until scarcely any of the original remained, and in its place certain well-defined systems had arisen.

These had been practised for years before my investigations brought me in contact with them. They, however, had never been described in print, but by degrees I persuaded the authors or best known representatives of the various systems, to give a full description of their method, and rendered them such assistance as was in my power to this end.

Excluding the American or Factory system the greater portion of Cheddar Cheese is now made on one of three systems.

1st. The Joseph Harding system, more or less modified, which has already been described. Secondly, the Candy system, and thirdly, the Cannon system.

The Candy System.

This system, founded on more or less traditional methods of making cheese, of which traces yet remain in the extreme South West of Somerset, has been brought to perfection by Mr. T. C. Candy of Cattistock, Dorset. Not only he himself, but many of his pupils, have been very successful prize-winners, and the system, owing to his teaching, is becoming widely adopted.

The following is a description of this system as given by its author.*

The Candy System.

My method of cheesemaking is the result of nine years of observation and experiment, and has been modified from time to time as experience showed me that it might be improved.

Ripening of evening's milk.—The first essential of success by this method is to secure in the evening's milk a proper degree of ripeness, for no sour whey is used during the manufacture, as is the case with some other methods.

In order to secure this ripeness, the evening's milk should never be allowed to get cold before it is brought into the dairy. This is far more difficult when the milk has to be brought a longer distance than when the farm is close to the dairy. During the heat of summer, there is little likelihood of the milk cooling down too rapidly, but in the spring and

* B and W. and S.C. Society. Journal, Fourth Series, Vol. 4, p. 127.

autumn special care has to be taken to prevent the rapid cooling of the milk. The system I adopt is based upon the fact that the greater the surface of a liquid exposed to a cold atmosphere, the more rapid will be the cooling of that liquid. I have, therefore, two tall tin vessels, each holding about thirty-six gallons, into which the milk is placed when brought in at night. The temperature of the milk is then above 90° Fahr. To secure proper ripeness, it should not fall below 78° Fahr. by 10 p.m., nor below 68° Fahr. by the morning.

I object to the method of maintaining the temperature of the evening's milk by covering it up in the tub with a cloth. This I believe to be one cause of much trouble in cheese-making, while it keeps in the odour of the milk which had far better be allowed to escape.

If the milk has been properly kept and ripened over-night, it is not advisable to further carry on this ripening. Therefore the evening's milk is not used for heating in the morning, but the temperature of the mixed milk necessary for renneting is obtained by heating a portion of the morning's milk. The heat to which this portion of the morning's milk is raised should not exceed 100° Fahr.

Renneting.—The temperature for renneting is 84° Fahr. The quantity of rennet used is about one-teaspoonful to eight gallons of milk in the summer, and a little more in the spring and in the autumn.

Accurately measured, the proportion of rennet to the volume of milk is in the summer about one part to 8,000, and in the autumn about one part to 7,000. The amount of rennet used will also vary according to the ripeness of the milk. If the milk is very ripe, less than the above-mentioned quantity must be used; but if not quite ripe enough, more rennet must be used. To judge this, and many other points in the manufacture, needs long experience, and no hard and fast rule can be laid down at present to guide makers who have not the necessary experience.

After adding the rennet and stirring it in for some 5 or 6 minutes, the tub is covered with a cloth, and the milk allowed to rest until set.

To facilitate judging whether the milk is properly set or not, a bowl is left floating upon the top of the milk, and when the milk is sufficiently set, the bowl, upon slightly raising one side, will come away from the curd quite clean.

If it does not, the milk must be allowed to rest longer before cutting. If the milk be properly ripened, and the right amount of rennet used, the curd should be set and ready to cut 45 minutes after adding the rennet.

Turning in the surface.—The top of the curd is now turned in, or over, by the use of a skimmer, the surface being cut to a depth of about two inches. The vat is covered with a cloth and allowed to remain until the whey rises. This should not take more than about 15 minutes.

Breaking.—This is now commenced, very gently to begin with. After first cutting the curd, it is well to wait for a few minutes before proceeding with the breaking. The breaker used is the old English shovel breaker, the edges of which I like to have as sharp as possible, so that it cuts the curd rather than breaks it. Moreover, I consider it necessary to move the breaker upwards, thus cutting the curd by its own weight, rather than to move the breaker in a circular direction round the tub, and break the curd by overtaking it with the breaker. No operation in cheese-making needs more care than breaking.

A good curd should be fit to break in 60 minutes from the time the rennet was first put in, and the time taken in breaking should be 50 minutes.

This time will, however, be correct only when all the conditions are at their best. It will vary as the conditions of the curd vary. When breaking is completed, the curd is obtained in a very fine condition, yet, when skilfully done, without loss of fat. It should be angular and not rounded; not like shot, but in sharp-edged fragments.

When finally broken, the curd is allowed to settle, being moved backwards and forwards in a place from which it is convenient to dip the whey for the scald.

The Scalds.—One of the chief characteristics of this system is the high scald to which the curd is subjected. This is obtained in the ordinary course by two scalds, but, when the cheese is going very fast, it may be necessary to have only one scald. In either case, it is essential that it should take as little time as possible to get the scald on, and to secure this, it is necessary to have proper means of heating the whey rapidly to the desired temperature. I use an ordinary boiler, the whey being heated in the vessels, previously described, in which the milk is ripened during the cool season, or else the whey is dipped out into large warmers, and these placed in the boiler.

While the first warmer is being heated, the second is being filled, and the whole of the whey is dipped off as far as possible. before any of the heated whey is put on the curd. By this means it is possible with one boiler to get the first scald on in about 15 minutes when dealing, say, with 160 gallons of milk. But when a larger quantity of milk is being dealt with, it is advisable to have two boilers for heating the whey. The temperature of the first scald is 94° Fahr. The whey to obtain this scald need not be heated above 120° Fahr. The curd is stirred in the scald for 2 minutes, and then allowed to settle. As soon as possible, the whey is again dipped off for the second scald. The whey is heated to 126° Fahr., and in about 15 minutes it is possible to have the curd in second scald at a temperature of 106° Fahr. Very little change is made in the temperature of the scalds to meet the varying ripeness of the milk; but, when the milk is not quite so ripe as could be wished, it is permissible to use a slightly lower scald.

The curd is stirred in this scald for 3 minutes, and then allowed to settle for 15 minutes. The curd now lies on the bottom of the tub in a uniform layer. It must next be moved up from the sides of the tub towards the centre by gentle yet firm pressure with the flat of the hands.

Skill and care are necessary to properly carry out this operation. The curd should be left in a solid mass on the centre of the tub, with a space of about six inches between the sides of the tub and the edge of the curd, and yet without any small pieces of curd, which have been broken off from the mass, floating in the whey. After this has been done, the curd is again allowed to rest, and should be fit to permit the whey being drawn 30 minutes after the second scald was on.

Here, again, experience must determine whether the condition of the curd will permit the whey to remain on for 30 minutes, or whether it will be necessary to keep it on for a longer time. When all goes well, the curd acquires in the 30 minutes a consistency which the experienced maker soon learns to judge. But this state may be reached in less time, especially in very warm weather, or when the milk is unusually ripe; or, on the other hand, when the conditions are reversed, it may take longer.

Cutting the Curd.—As soon as the whey is off, the curd lying on the bottom of the tub is cut into foot squares and turned over, the outer squares being placed on edge, and resting against the interior ones.

They are then covered with a cloth or thin cloths, and left for some minutes—the time varies, and is judged by the condition of the curd.

The shorter the time—say 5 minutes—the better the curd, and the resulting cheese. Each square of curd is now cut into two pieces and taken to the cooler. If the acidity is low, these slices are placed close together to keep in the heat; but if the acidity is developing rapidly, they are not packed closely. The curd is covered with light cloths only. The curd is turned upon the cooler after 20 minutes, again after 30 minutes, and once again before cutting. It is then cut into pieces 3 inches square, packed closely, and covered with a cloth. It is opened up and turned at the end of 20 minutes, again at the end of 30 minutes, and again opened and moved at the end of 40 minutes.

The curd is ground at 5.30 p.m., then spread over the cooler, covered with cloths, and left till about 8 p.m., when it is salted—2½ lbs. of salt being used for each hundredweight of cheese—and, if a firm curd, vatted.

If the curd is soft, it should remain 10 to 15 minutes on the cooler after being salted, and before being vatted. The temperature of the curd when vatted should be 70° Fahr., and the full weight of the press should not be put on until the curd has been in the press for 60 minutes.

Such is a brief outline of the system as carried out under the most favourable circumstances. But every operation will need careful attention, and have to be varied according to the weather and ripeness of the milk, in order to obtain uniform results in the cheeses. It is upon the knowledge and skill which the maker possesses, in judging the condition of the curd at each stage, and in knowing how to vary the operations of manufacture to meet those conditions, that success depends in this, as in every other, system of cheese-making.

The Cannon System.

Some 20 to 25 years ago, Messrs. Hill Bros., Cheese Factors of Evercreech, after setting out the ten principal points of cheese making, with a few "observations" thereon, had them printed, and circulated them privately. Each copy was marked "This communication is privileged, and for your service only," so that although possessing a copy I must not reveal the contents. Nevertheless, as this private effort has done much to improve the quality of Cheddar Cheese during the past quarter of a century, the fact ought to be recorded. One of these papers came into the hands of Mr. Henry Cannon, whose wife began to utilise the information, and to improve on the ideas, with the result that she became the same year a Prize winner.

The system finally adopted, which will be very fully described later on in this report, has since been practised and taught by Mr. Henry Cannon, of Milton Clevedon, Evercreech, and was brought prominently before the public in 1887, when a cheese made by his daughter, Miss E. J. Cannon, took, at Frome, the champion prize, in a class open to the competition of the whole world, for the best Cheddar Cheese. When, in 1890, the Bath and West and Southern Counties Society started a Cheese School in Somerset, it was decided that the Cannon system should be the one taught at the School, and Miss E. J. Cannon was appointed teacher.

The following is a brief account of the Cannon system, sufficient only to enable the subsequent pages to be understood. A complete description will be found on p. 207.

The Evening's Milk is brought into the dairy and strained through fine muslin into the cheese-tub.

In the morning, the evening's milk is skimmed, and the cream placed in the warmer with a portion of the evening's milk. This is heated so that the whole of the milk, morning's and evening's, is brought to the correct temperature for renneting. This temperature is 84° F.

A certain quantity of whey, which has been reserved from the previous day's make, is now heated in the warmer to 84°, and added to the milk to ensure sufficient acidity.

The next operation is to add the necessary quantity of rennet. When the curd has attained a certain degree of firmness, it is "cut" with a breaker. Subsequently the curd is allowed to settle until the whey has risen. When the whey has properly risen, the "breaking" of the curd commences. After breaking, the curd is allowed to settle for five minutes. Sufficient whey is then put aside for the morrow's cheese. The first scald is to 88° F., the second to 94°.

The curd is kept continually stirred in this scald until it has acquired a certain degree of firmness. It is then allowed to settle for 15 minutes, the whey is drawn off through a strainer into the whey leads, and the curd is cut with a knife into blocks about 6 or 8 inches square, and piled on the bottom of the tub. The piled curd is covered with thin cheese-cloths and wrappers, and left to drain, as a rule, until the whey drops from the tub. The curd is next cut into six or eight blocks, one half taken to the "rack" in the "cooler," broken with the hands into small pieces, and tied up tightly in a cloth. The remaining half is treated in a similar manner, and the two bundles are then placed one on top of the other, and subjected to pressure. The whole is wrapped round with cloths to keep the heat in the curd. The curd is left thus for half-an-hour, then taken out of the cloth, and cut with a knife into oblong pieces. These are well mixed together, and again tied up in the cloths. The curd is cut a second time, packed up as before, and subjected to pressure for half-an-hour. The curd is then opened up, broken into lumps, again tied up, and subjected to the same pressure as before for half-an-hour.

This operation is repeated until the curd is fit to grind.

Some Effects of Various Systems.

A close investigation of the Cheddar Cheese industry reveals the fact that the methods of manufacturing Cheddar Cheese are as numerous as are the localities in which it is made. The various methods differ not merely slightly, but to a very remarkable degree, so that at first sight it seems quite impossible that practically identical results can be obtained by such divergent means. Yet practically identical they are, that is to say, the result would in all cases be undoubtedly Cheddar Cheese, and no other variety.

Yet there is a difference between the cheeses made on the various systems. Some will ripen more quickly than others made on another system, while a third system may produce a cheese taking still longer to ripen. Thus a rapidly ripening cheese will be ready for the market three months after it is made, others will take six months to ripen, while formerly it was the custom to keep a Cheddar Cheese twelve months before it was considered fit for consumption.

Hence the extreme methods have become known as "rapid" and "slow" ripening systems. In flavour, there is not much variety due to the system of make.

The texture of a Cheddar Cheese should be absolutely uniform and solid. Some methods tend to produce this result far more certainly than others, the latter leaving a cheese more or less "open," that is, showing occasional spaces in the interior.

While some systems tend to produce a hard cheese, others produce a much softer and mellower curd, which is considered of importance as regards quality.

A Cheddar Cheese, when cut, should be soft and fat, neither hard nor crumbly. It should have both the aroma and flavour of a nut, the so-called "nutty flavour" so much sought after. It should melt in the mouth, producing not only an agreeable flavour, but leaving a most pleasant after-taste. It should taste neither sweet nor acid. If either in smell or in taste or in after-taste there is anything the least unpleasant, such taste or smell is termed a taint.

Part II.

The Origin of the Observations and the Methods of Investigation Adopted.

The scope and conditions of the enquiry.—The record of observations.—The determination of acidity.—Explanation of the record of observations.—The record of analyses.—The methods of analysis adopted.

The Origin of the Observations and Methods of Investigation Adopted.

In 1891 the condition of our knowledge of cheese-making was such as has been described in the preceding section. From time to time complaints had been made by those interested in the industry that it was founded entirely upon empirical rules. Joseph Harding had complained that "cheese-making, as a science, is not understood." He pointed out some of the information which he, as a practical man, wanted from science; including "a chemical knowledge of the constitution of the curd and whey throughout the process," and he finishes by saying that if only such knowledge were forthcoming, "cheese could be made (as it ought to be) upon principles scientific, and consequently unerring."

Such was the complaint of practical men in 1860. The late Dr. Augustus Voelcker subsequently wrote some articles on the chemical aspect of cheese-making, which exhibit the great ability that always distinguished his work.

In 1891 the Board of Agriculture decided that it was desirable to have research work made into the manufacture of cheese, and as regards Cheddar Cheese, approached the Bath and West and Southern Counties Society, to know whether that Society would undertake such research if supported by a grant in aid. The Society decided to accept this offer, and I was appointed by the Council of the Society to make observations on the practice of Cheddar Cheese-making, as carried out at the Society's Cheese School, with the view, if possible, of throwing some light on the many problems which arise from time to time in a Cheese Dairy.

Scope and Conditions of the Inquiry.

My instructions were as follows:—

"To pay special attention to any circumstances connected with the practical work of the School which might, from time to time, be brought to my notice by the head teacher.

"To visit the School not less than once a week, and undertake, at my own laboratory, such bacteriological or other researches as might be found necessary in connection with the School.

"To provide a competent assistant to remain constantly at the School, making daily such analyses, doing such work, and keeping such records as might be considered desirable."

As this was the first official attempt to provide a scientific side to a practical Cheese School, it was regarded in the light of an experiment, to be carried on for a limited time, to deal with limited objects. It had, however, for its main object—

> "(*a*) The formulating of a complete scheme of investigation of the science—of which it is not too much to say that at present very little is known—which underlies the existing practice of the best cheese-makers.

During the whole of the process of cheese-making chemical changes are constantly occurring which are very imperfectly understood; whilst the existence, development, and effect of various bacteria during the different stages of the process doubtless exercise a material influence on the cheese produced, and require to be carefully studied.

Amongst other subjects of inquiry it was desired that particular attention should be given to:—

> "(*b*) Variations in quality of milk from cows feeding in different pastures.
>
> "(*c*) Causes of defects in cheese-making from quality of milk, changes in temperature, &c.
>
> "(*d*) Effect of temperature in ripening of cheese."

It was an essential condition that the practical teaching given at the School should not be in any way interfered with.

The Record of Observations.

The first task I had to undertake was to draw up a system of daily observations which should leave no important operation in the manufacture of Cheddar Cheese unrecorded. Such a record would afford data upon every point of cheese-making, from which subsequent deductions might be made. No systematic investigation had ever been carried out in connection with Cheddar Cheese-making, prior to the commencement of these observations. At a school in France it had been proposed to carry out observations, and a form of record had been prepared, but the observations were never made and the form was not applicable to Cheddar Cheese. A system of recording the daily observations was prepared, and by degrees took the form shown in the following page, while in the Appendix, Table 1 is a reproduction of the Record Book for the month of June, 1892. After an experience of several years with this form of record, it has not been possible to find any facts which are omitted except the number of cows, the date when the cheese is sold (weighed), and the number of days which elapsed between the making and sale of the cheese. For sake of reference, each observation was numbered. In all, 60 observations were made daily, together with analyses of the mixed milk, of the whey, and of the curd.

RECORD OF OBSERVATIONS.

1	2	3	4	5	6	7	8	9		10	11
	Relating to Evening's Milk.										
Day of Month.	Name of Fields.	Volume of Milk.	At Night.				In Morning.				
			Time.	Temp. of Dairy.	Temp. of Milk.	Acidity.	Time.	Temp. of Dairy.		Temp. of Milk.	Acidity.
		galls.	P.M.					min.	max.		

12	13	14	15	16	17	18	19	20	21	22	23
Morning's Milk.				Milk Heated.		Stale Whey.		Relating to Mixed Milk, &c.			
										Rennet Added.	
Name of Fields.	Vol. of Milk	Acidity.	Total Vol. of Milk.	Quantity.	Temp.	Vol.	Acidity.	Acidity before Renneting.	Time of Renneting.	Vol.	Proportion.
	galls.		galls.	galls.		galls.			A.M.	ounces.	

	24	25	26	27	28	29	30	31	32	33	34	34a	35
						Temp. of Scald.				Relating to Whey.			
Day of Month.	Time when Curd cut.	Acidity of Whey before breaking.	Time of breaking.	Acidity of Whey put aside.	Time Scalding commences.	1st.	2nd.	Time taken in stirring.	Time in Scald.	Temp. when drawn.	Acidity.	Volume.	Acidity of draining from piled Curd.
	A.M.		A.M.		A.M.			min.	h. m.			galls.	

36	37	38	39	40	41	42	43	44	45	46	47	48	49	
			Acidity of Whey during Treatment of Curd.								Salt Added.			
Time Curd remains piled.	Time Curd was taken from Tub.	Temp. of Curd when taken from Tub.	When taken to Cooler.	After 1st Cutting.	After 2nd Cutting.	After 1st Turning.	After 2nd Turning.	After 3rd Turning.	After 4th Turning.	Acidity of Curd when Milled.	Weight.	Percentage.	Temp. of Dairy.	
min.	P.M.										lbs. ozs.		min.	max.

	50	51	52	53	54	55	56		57		58		59		60
	Relating to Curd.			Relating to Cheeses.											
							Temp. of Cheese Room.				Hygrometer Reading.				
Day of Month	Temp. in Vat.	Weight when Vatted.	Time of Vatting.	Acidity of Liquid from Press.	Weight taken to Cheese Room.	Loss in Press.	Morning.		Evening.		Morning.		Evening.		Weight of Cheese when sold.
							Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	
		lbs.	P.M.		lbs.	lbs.									lbs.

RECORD OF ANALYSES.

Day of Month.	Composition of Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.

COMPOSITION OF CHEESES.

Made.	Sampled.	Water.	Fat.	Casein, &c.	Mineral Matter.

These tables together completely cover the whole process of Cheddar Cheese manufacture. It has been found possible to utilise them with slight variations in the study of other varieties of cheese, and in all such cases they have been found to afford a complete record, and to give a minute insight into the operations of manufacture, so that by subsequent study of the facts so recorded it has been possible to obtain a clear insight into the rationale of the system of manufacture. By so doing, it becomes possible to discover the causes of failure on the one hand, or of success on the other. It is greatly to be regretted that no complete record has been made of the process of manufacture of any one of the varieties of English cheese, if we except the work which was done by Mr. Smetham, with regard to Cheshire Cheese. It is not to be supposed for one moment that an ordinary cheese-maker could keep such a minute record as the above, which is only suitable for the purpose of investigation. But a condensed form of the tables, such as will be found on p. 226, might be kept in every Cheese Dairy with advantage, and would afford information that could not fail to be of the utmost value, and would well repay the time and labour of keeping it.

Determination of Acidity.

Practical cheese-makers have known for years that both in the manufacture and ripening of cheese, the acidity produced, which is known to the chemist as "lactic acid," materially influences the results obtained, but no method had up to the time of the commencement of these observations, been introduced for the accurate and easy estimation of acidity, either in milk or in whey.

Hot-Iron Test.—The only test that had been applied and practised was that known as the hot iron test. This was used to determine the acidity of the curd, or, perhaps, it would be more correct to say the condition of the curd when in the whey after the scald, and also to determine the acidity of the curd before grinding. This test has been very fully described on p. 14, under the Canadian or Factory system of cheese-making. The test appears never to have been thoroughly studied. The length of the threads so obtained is used by the cheese-maker as a guide to the acidity of the curd, but how far it actually depends upon the acidity, or how far it may be influenced by the moisture or fat in the curd, does not appear to have been accurately determined. The greatest drawback of all to the hot-iron test is the uncertainty of the heat of the iron itself. It is evidently impossible by the use of any uncertain standard to determine with accuracy, either the acidity or any other condition of curd.

The Soda Test.—I therefore adopted for the estimation of acidity a method which has been practised in analytical laboratories for years past, namely, the use of a standard solution of an alkali (soda), and of a substance termed an "indicator," which changes colour according to whether a solution is acid or alkaline.

The Indicator.—After making the necessary experiments, a substance termed "phenol-phthalein" was adopted as the indicator. This substance is produced from carbolic acid, it dissolves in alcohol, and produces a colourless solution. If a minute portion of washing soda is added to this solution, it immediately turns a bright crimson colour, but if subsequently some sour whey is added, the crimson colour will gradually disappear until a point is reached when the liquid has just lost its colour, and yet has scarcely become white. This would indicate that the liquid was neither alkaline from the presence of soda, nor acid from the presence of whey, but in a condition which, being neither acid nor alkaline, is termed by chemists "neutral."

Therefore the solution of phenol-phthalein is called an "indicator," for if the liquid is turned crimson, it indicates the presence of an alkaline substance, like ammonia or soda; if white, it indicates the presence of an acid, such as lactic acid.

Experiments have shown that the solution of phenol-phthalein must have a definite strength, and the one which was finally adopted contained 0·2 grammes of solid phenol-phthalein dissolved in 100 c.c. of a mixture of equal parts of water and alcohol. This solution must be kept slightly pink by adding to it from time to time one or two drops of the soda solution to be now referred to.

The Standard Solution of Soda.—If a solution of soda be so made that one cubic centimetre will exactly neutralise a definite quantity of lactic acid, such a solution is termed a standard solution. In my investigations, as is usual with chemists of the present day, the French system was adopted. A standard solution of caustic soda was employed, one cubic centimetre of which would exactly neutralise one-hundredth of a gramme (·01) of lactic acid. In all estimations ten cubic centimetres of milk or whey were taken for the test. If, therefore, this ten cubic centimetres took two cubic centimetres of soda to neutralise it, then it contained two-hundredths of a gramme of lactic acid, and there would therefore be two-tenths of a gramme in one hundred cubic centimetres; in other words, two-tenths per cent (·20) of lactic acid. Therefore, using ten cubic centimetres of the liquid to be tested, and a solution of caustic soda of this strength, each cubic centimetre of soda used represents ·1 per cent. of lactic acid, and each division of the c.c. represents one one-hundredth (·01) per cent. of lactic acid.

Precautions Necessary.—The standard solution of soda undergoes change if exposed to the air, and loses its strength. It is therefore necessary that the stoppers of the bottles in which the solution is kept should be well vaselined, and only a small bottle of standard solution should be kept for daily use.

Using the Test.—The method of estimating the acidity was as follows:—10 c.c. (cubic centimetres) of milk, whey, or other liquid in which it is desired to estimate the acidity, are accurately measured out by means of a small instrument termed a "pipette," and placed in a one-ounce glass phial or in a porcelain dish. It is desirable for the sake of comparison to put the same quantity of the liquid into another phial, so as to have a standard of colour when making the test. Two or three drops of the phenol indicator solution are added to one of the bottles. The standard solution of sodium hydrate, each cubic centimetre of which is capable of neutralising exactly ·01 gramme of lactic acid, is poured into a graduated glass vessel termed a "burette," on the end of which is a piece of glass coming to a fine point, and on the indiarubber which connects this glass point to the burette is a pinch-cock, which when pressed opens and allows the liquid in the burette to gradually come from the fine point. The burette holds 20 c.c., and has upon it 200 divisions. The 10th division is marked "1," the 20th "2," and so on. These figures 1, 2, 3, &c., represent c.c. of liquid. Upon cautiously adding the standard solution from the graduated burette to the 10 c.c. of milk in the small phial, a tint is produced, which upon shaking the bottle will disappear; when by the addition of a few more drops of the soda solution, the colour will remain permanent, this will indicate that all the acid present in the milk or whey has been neutralised. It will now be necessary to read the quantity of standard solution which has been taken from the burette to neutralise the acidity. To facilitate this reading, the burette should contain a white float, having a black line upon it, which falls as the liquid in the burette is withdrawn. Suppose the substance being tested was milk, and that it required 20 divisions, i.e., down to the figure "2," to neutralise it. Then the acidity of the milk would be 0·20%. If it took 22 divisions, the acidity would be 0·22%. The burette must be kept well corked when not being used.

Where the standard is to be used frequently, it is better to fit up the apparatus in such a way as to do away with the necessity of frequently filling the burette from a small bottle. The following method was adopted in carrying out the investigations, and has proved to be reliable and expeditious:—

The standard solution of caustic soda was contained in a Winchester quart bottle placed on a shelf well above the rest of the apparatus (Fig. 1). From this, by means of a glass syphon

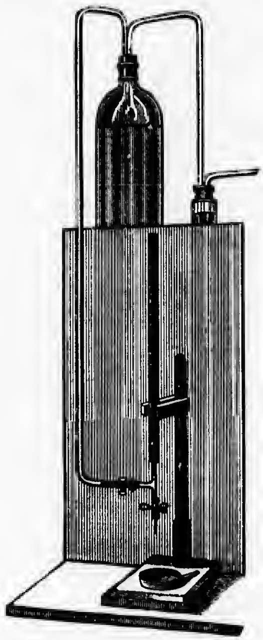

Fig. 1.—Acidity Apparatus.

tube, the solution was brought down automatically to the burette. As this standard solution, if exposed to the air, deteriorates by absorbing carbonic acid, it must be kept in an airtight bottle. But, unless the air could enter the bottle, none of the solution would syphon over. The air so drawn into the bottle of standard solution was therefore first made to pass through a small bottle of strong soda tinted with phenolphthalein.

This wash-bottle absorbs all the carbonic acid from the air before it passes into the standard solution, while the moment the solution in the wash-bottle loses its power of absorbing carbonic acid, it also loses its colour. This was found to work admirably, and the strength of the standard solution remained unaltered until used up.

The syphon tube containing the standard solution was attached to the bottom of the burette by a ⊣ joint, and the flow of the solution was stopped by a pinch-cock acting on a piece of indiarubber tubing, which connected the syphon and ⊣ joints. (Fig 2.) Upon opening this pinch-cock, the standard solution flows into the burette and carries up the float. When the line

Fig. 2.—Burette Arrangement.

on this float corresponds with the first mark on the burette, the pinch-cock is closed. The burette is now full.

The tests are then made exactly as above described.

Not only has the acidity apparatus enabled me to obtain considerable insight into the chemistry of cheese-making, but its use is no longer confined to mere purposes of investigation. It has been placed upon the market, and there are many cheese-makers now employing it daily. The evidence which I have received from cheese-buyers tends to show that its use has resulted in a considerable improvement of the cheese made, not only as regards quality, but also as regards uniformity. The use of the acidimeter might be taught with advantage in the schools of every county where cheese-making is carried on.

Dilute Standard Solution.—For the purpose of investigation, I have at times used a standard solution one-fifth the strength of the above, so that each c.c. represented only ·02 per cent. of lactic acid, and by means of this solution, some of the changes which are not so easily observed when using a stronger solution have been investigated. The use of this more delicate solution is attended with considerable difficulty, and cannot be recommended to anyone excepting a trained chemist.

Explanation of the Record of Observations (Appendix 1).

The Date of Manufacture, Col. 1.—It will be noticed that there are always two dates, the first represents that of the evening's milk, and the second that of the morning's milk. Where the day's make of cheese is referred to, it will always be by the second date, namely, that of the morning's milk.

Name of Field, Col. 2.—The object of recording the names of the fields on which the cows were pastured was to try and discover an answer to the second question put to me, namely, "if any and what variations in quality of milk aro from cows feeding in different pastures." Owing to the small size of the fields in Somerset, and the comparatively large number of cows kept at each of the cheese school sites, it was not possible to place the cows for several days in succession upon the same pasture; frequently it has even been necessary to keep them upon different pastures by day and by night.

It is desirable to keep a record of the fields upon which the cows are pastured for another reason. Those who are acquainted with cheese-making know full well that trouble frequently arises when cows are feeding in one particular field, hence it is well to keep a record so as to determine, if possible, not only whether any trouble may be localised to a particular field, but also, if any trouble arises from year to year, whether it is always associated with a certain pasture.

Volume of Milk, Cols. 3, 13, 15.—It is essential in cheese-making that the tubs should be accurately gauged, preferably with a loose gauge which can be taken out as soon as the volume of milk has been determined. In my early observations, the weight of milk was given, but as I found that farmers and cheese-makers were accustomed to volume and had some difficulty in calculating the volume from the weight, I subsequently recorded the volume only. It is easy to convert volume of milk into weight (lbs.) approximately, by multiplying the number of gallons by 10·3; on the other hand, if the weight of milk is given, this can be converted into gallons by dividing by 10·3.

Where there is a fixed apparatus for heating the morning's or evening's milk (Col. 16), this should also be accurately gauged by means of a movable gauge, similar to that used in the milk tub.

It is also desirable, for the purpose of investigation, to have a receptacle for the whey, which is gauged. But this I have not had, and my determinations of the volume of whey were merely approximations, and not sufficiently reliable to be inserted in the tables of averages.

Time, Cols. 4, 8, 21, &c.—In every dairy there should be a clock. The process of cheese-making is dependent upon time, temperature, and acidity, and it is not sufficient to pay attention to either one of these factors while neglecting the others. The cheese-maker must not be the slave of the clock, but use it simply as an instrument of precision.

Temperature, Cols. 5, 6, 9, &c.—In the dairy as also in the cheese room, there should be fixed to the wall a thermometer which indicates both the maximum and minimum temperature reached between each reading. Fig. 4. These thermometers are reset by the aid of a magnet. That in the dairy must be set every evening when the milk is brought into the dairy, and read the next morning. It will then show the maximum and minimum temperature to which the milk has been subject during the night (Col. 9). It should then be reset, and after the cheese is finished again read, and the maximum and minimum temperatnre of the dairy during the day recorded (Col. 49). The temperature of the milk, whey and curd should be taken with an accurate glass thermometer, preferably with one having a straight stem, which can be thrust into the curd without fear of breaking (Fig. 3). The use of a thermometer which is fixed to

Fig. 3.—Thermometer.

any wooden or metal support for testing the temperature of milk is a mistake, for it is almost impossible to thoroughly clean these supports, and the thermometer may then be the means of carrying a taint from the milk of the one day into the milk of the next. Floating thermometers have one advantage, inasmuch as they are less frequently broken, but it is difficult to obtain them accurate, and they generally have a round bulb which is a disadvantage.

A maximum and minimum thermometer, Fig 4, will be required in the cheese room to record the variations of Temperature

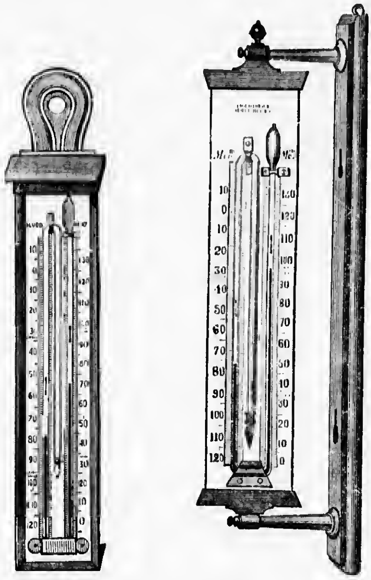

Fig. 4.—Maximum and Minimum Thermometer.

(Cols 56-57). This should be placed half way between the top and bottom shelves, for experiments show that the temperature is generally 1° F. higher at the top of the room and 1° F. lower at the floor than the medium temperature.

A hygrometer, Fig. 5, which is an instrument containing two thermometers, one with its bulb kept wet, the other with a dry bulb, is also necessary. The difference between the reading of these two thermometers shows the amount of moisture in the atmosphere (Cols. 58-59).

It is essential that the accuracy of the thermometers in use be made certain of. The majority of cheap thermometers are inaccurate, frequently two or three degrees out, and it makes very considerable difference, say in the temperature for renneting, if your thermometer registers 84°, while in fact the milk may be 87° F., or 81° F. During the past eight years

I have supplied Miss Cannon with thermometers, every one of which was tested against my Kew Standard Ther-

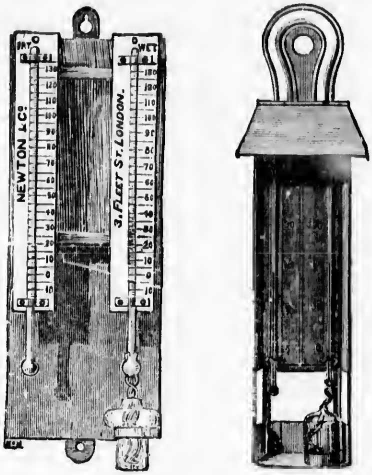

Fig. 5.—Hygrometers.

mometer, and proved to be within half a degree of absolute accuracy. Nearly every pupil attending the school was glad to obtain an accurate instrument. It would greatly promote the cheese-making industry if some system could be instituted to have thermometers tested for cheese-makers at a nominal charge.

Great attention should be paid to the temperature of the dairy and of the cheese room, for evidence points to the fact that temperature plays a part in cheese-making and cheese-ripening far more important than is generally supposed. It is, in my opinion, as necessary to have thermometers permanently fixed in the dairy and cheese-room as it is to use one in the actual operations of cheese-making.

Acidity, Cols. 7, 11, 14, &c.—The figures in these columns give the percentage of acid (lactic acid) present in the liquids, tested in the manner previously described.

Heating Milk, Cols. 16, 17.—To raise the mixed morning's and evening's milk to the requisite temperature for renneting a portion of the latter is heated.

The temperature of renneting is not recorded as it was uniformly 84° F. Why this temperature of 84° should have been fixed for the renneting of milk it is impossible to say, but it is interesting to know that it lies exactly half way between 70° F. and 98° F., which may be taken as the two extremes for the development of the lactic acid organism.

Stale Whey, Cols. 18, 19.—From time immemorial a certain quantity of whey taken from the tub the previous day, immediately after cutting the curd, has been kept aside and added to the mixed milk the following morning before renneting. The object has been to increase the acidity of the mixed milk, to introduce the lactic acid organisms, and so secure a rapid development of acidity in the subsequent stages of manufacture. The quantity of whey added to the mixed milk will vary, mainly according to the acidity of the mixed milk, which in its turn will depend upon the temperature of the dairy during the night. On occasions it is not possible to use stale whey, for if there was a taint in the previous day's curd, it would be wrong to put any of the whey from that curd into the milk of the following day. It would perpetuate the taint, for, as will be subsequently shown, taints are due to the presence in the milk and whey of certain micro-organisms or bacteria, and not to any peculiarity in the method of manipulating the curd.

Rennet, Cols. 22, 23.—These figures represent, Col. 22 the actual volume of rennet added, and Col. 23 the proportion this bears to the volume of milk or the number of ounces of milk to which 1 oz. of rennet has been added. Long before these investigations were commenced, I was struck with the very careless way in which cheese-makers measured out and used rennet. They sometimes employed a tea-spoon or dessert-spoon of no standard size, sometimes a broken cup or broken wine-glass was used, and frequently the actual quantity of rennet employed was neither known, nor did it vary with the volume of milk. This induced me to have a proper rennet measure made, whereby the rennet could be accurately estimated to the 100th part of an ounce. The following is an illustration of the rennet measure. Fig. 6. This measure

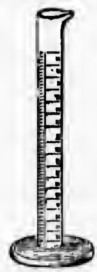

Fig. 6.—Rennet Measure.

has always been used at the school, and is now being largely employed in the county of Somerset, and elsewhere.

The figures in column 23 are obtained by multiplying the number of gallons of milk by 160 to convert them into fluid ounces, and dividing by the amount of rennet taken.

Example, August 27:—

```
                        Milk     ...      90 gallons.
                                         160
                                    ──────────
        Rennet ounces 1·7) 14400·0 (8470
                                   136
                                   ───
                                     80
                                     68
                                    ───
                                    120
                                    119
                                    ───
                                     10
                                    ───
```

This proportion is of considerable interest, and the lessons to be learnt from it are of importance. It will later on in this report be shown that the necessity of accurately measuring the quantity of rennet used in cheese-making is greater than might at first be supposed.

Acidity of Whey, Col. 25.—After the curd has been cut, and allowed to stand for a short time, a small quantity of whey rises on the curd from which it is easy to take sufficient for this estimation of acidity.

Temperature of Curd, Cols. 38 and 50.—The straight stem thermometer is forced into the curd for about 6 inches, allowed to remain there a few minutes, and then gradually withdrawn until the mercury is just visible. The temperature is then read. The thermometer should not be completely withdrawn, as the temperature would fall before the reading could be made.

Acidity of Drainings, Cols. 39 to 45.—At each stage in the treatment of the curd, when it is on the cooler, a sufficient quantity of whey drains from it to enable the acidity of this liquid to be estimated. All the drainings from each stage must be collected and well mixed before the acidity is determined. A clean vessel must then be employed to collect the drainings from the next stage.

Acidity of Curd when Milled, Col. 46.—This subject will be fully considered in a subsequent part of this report.

Acidity of Liquid from Press, Col. 53.—This is probably the most important estimation made during the day. It is desirable to allow either a definite quantity of liquid to come from the press, or a definite time to elapse, say 15 minutes, before estimating the acidity. On the other hand, it is not desirable to wait until all the liquid has come away, as in such case the acidity would develop in the liquid itself, and not accurately indicate the acidity which it possessed when in the curd.

Weight of Curd, Col. 51.—A weighing machine should be kept in the dairy. The vat should be weighed, and then the ground curd placed in it, and when ready for press, reweighed. The weight of curd is thus obtained. Each cheese when taken from press is again weighed (Col. 54), and the loss sustained in the press recorded (Col 55).

Weight of Cheese when Sold, Col. 60.—As cheeses are not sold at regular intervals, it is also desirable to record the date when sold.

The Record of Analyses of Milk, Whey and Curd.

The sample of milk for analysis was taken after the evening's milk had been heated and mixed with the morning's, but before the stale whey was added.

In 1891 the sample of whey was taken as it was being drawn from the tub, but subsequently the whole of the whey was collected in the whey tank before the sample was taken.

The sample of curd was taken immediately after it was milled, and before any salt had been added.

The Methods of Analysis Adopted.

The results of scientific investigation depend so much on the methods adopted, that I think it necessary to explain briefly the way in which the facts recorded in these observations have been obtained.

Analysis of Milk.—The total solids are obtained by evaporating down to dryness 5 grammes of the milk and keeping the residue at a temperature of 100° C., until constant in weight.

The fat in the milk has been estimated by taking the Specific Gravity, and from the solids and Sp. Gr. the fat has been calculated by means of Fleischmann's formula. This formula is as follows:—

$$F = T.\,S. \times 833 - \left\{ \frac{\text{Sp. Gr.} \times 100 - 100}{\text{Sp. Gr.}} \right\} 2{\cdot}22$$

Where F. = fat, T. S. = total solids, and Sp. Gr. = specific gravity. The results are fairly accurate, as I have proved by comparing them with numerous results obtained by other methods.

Sometimes the fat has been estimated by Schmidt's method, which is the most accurate method of estimating the fat in milk and other similar substances that I know of. Hence this method has been adopted for the analysis of the fat in the whey, curd, and ripe cheeses.

10 c.c. of milk are measured into a glass tube, which is like a large test tube, and graduated from the bottom to show from 20 c.c. to 50 c.c. then 10 c.c. of strong hydrochloric acid are added to the tube, and the whole is heated until the milk is entirely dissolved (except the fat), does not froth when boiled, and is of a brown colour. This solution is cooled down and 30 c.c of ether added, the two solutions are shaken gently until the fat is all dissolved by the ether, and again the solutions are cooled. The ether solution separates from the lower acid solution completely. 20 c.c. of this ether solution are then taken, placed in a weighed flask and the ether distilled off. The fat in the flask is dried at 100° C., and weighed. The amount of ether left in the tube is carefully read off and noted. The calculation is simple. Suppose the ether left in the tube is 10 c.c., and the weight of fat in the 20 c.c. taken is 0·2 grammes, then in the 30 c.c. of ether there would be 0·3 grammes, i.e., in 10 c.c. of milk, and therefore in 100 c.c., 3·00 grammes or 3%.

The casein in the milk has been estimated by taking 10 c.c., adding to 100 c.c. water, at 95° F., and precipitating by means of dilute acetic acid. The precipitated casein and fat are collected on a weighed filter, and dried. Subsequently, the fat is extracted by ether in a Soxhlet's apparatus and the true weight of the casein is thus obtained. This method, if carefully carried out, will as a rule give excellent results. The casein is completely precipitated in flocculent masses, which can be easily filtered and a brilliant clear filtrate obtained. But there are times when it is quite impossible to estimate the casein in this way. The precipitate is then not properly formed, it will not yield a clear filtrate, and when washed passes through the filter. In spite of numerous experiments, it has not been found possible either to determine the cause or to remedy the defect. As a rule, this condition of the curd is most frequent during the early months of the season. It is also found to be a characteristic of the milk yielded by individual cows at a time when others in the same herd are producing normal milk. The subject requires further study.

The albumin is precipitated in the solution from the casein by heating gradually. When the precipitation is complete the albumin is filtered off through a weighed filter, dried and weighed.

The mineral matter has been obtained by gradually heating the total solids until completely burnt. Care must be taken not to heat them at too high a temperature, or some of the constituents are dissipated.

The milk sugar is obtained by difference.

The estimation of total solids and ash in the whey has been done in a similar manner to these estimations in milk; the fat has been estimated by Schmidt's method.

In analysing curd and cheese, the substance is very finely minced, one portion is taken for moisture estimation and ash, which are done as already described, and the fat is estimated in a second portion (·5 grammes) by Schmidt's method.

These methods of analysis have not been selected as being the most accurate or best (upon which point opinions may differ), but because they were the only means which could be adopted under the conditions for carrying out chemical analysis which existed at most of the schools. The space at my disposal was very limited, and the absence of gas was a considerable draw-back.

Part III.

The Sites on which the Experiments have been carried out.

The Seven Sites. (Situation, Owner, Occupier, Size, and Plan of Farm, Names and Sizes of Fields, Botanical Report, Geological Aspect and Map, Chemical Character of Soil, Climate, Rainfall, Water, &c.).—The Scouring Land of Somerset.—The Effect of Liming Pastures.—On Soils said to be unsuitable for Cheese.

Site No. 1.—Vallis, near Frome, 1891.

The Society's Cheese School, in 1891, was located at Vallis Farm, about $1\frac{1}{2}$ miles from Frome, in a hilly part of the County of Somerset.

The farm is the property of Lord Cork, and was in the occupation of Mr. J. Armstrong. It consisted of about 320 acres, some of the fields in pasture being on the high land, others in the valley, and some between the two.

The accompanying plan of the farm is reduced from the ordnance map, 6 ins. to the mile. The permanent pastures are coloured green, the after-growth* brown.

The pastures on which the cows were fed were seven in number.

No. 1	Oxen Leaze	22	acres.	Mown and fed afterwards.
2	The Leaze	42	,,	Fed all the season.
3 & 4	Stevens	14	,,	do.
5	Summer Leaze	12	,,	Mown and fed afterwards.
6	The Mead	6	,,	do.
7	The Front	10	,,	Fed all the season.

The whole of the fields, except the Leaze, are very old permanent pastures, while the Leaze had been sown down over 20 years.

In addition to the food which they obtained from the pastures, the younger animals, about one third of herd, received from September 15th a mixture of 2 lbs. cotton cake, and 2 lbs. linseed cake each per diem.

Botanical Report of Mr. Carruthers, F.R.S.

The soil of the fields is a somewhat stiff loam, except in that called *the Mead*, a level field by the side of the stream, which has a rich alluvial soil. With the exception of the field called *the Leaze*, the pastures

* I have employed this word or the word "aftergrass" to denote the grass which grows after a crop of hay has been taken off the field, as the word aftermath would apply to this grass if mown and made into hay.

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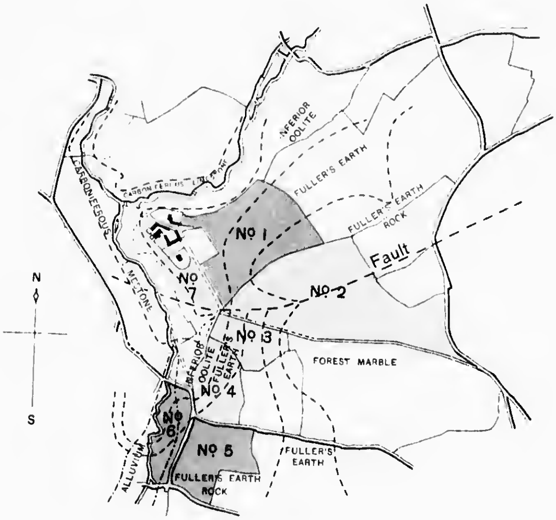
Site No. 1 Vallis near Frome



Alluvium	Silt
Forest Marble	Clay & Oolitic Limestone
Fuller's Earth	Calcareous Clay
Fuller's Earth Rock	Angular Limestone
Inferior Oolite	Limestone
Carboniferous Limestone	Limestone

XXX. S.W.
Sheet line
Somerset

XXX S.W
Sheet line
Somerset

may be looked on as natural, for, though the different fields show evidences of cultivation, it is not known how long it is since they were cultivated. *The Leaze* was laid down to pasture about twenty years ago.

The pastures may be classified as follows:—

I. Natural pasture on the rich alluvial soil of the valley.

The Mead.—The grasses are cocksfoot and fiorin, with some ryegrass. There is a fair amount of white and red clover. But there are many weeds, some liked by stock, like the cow parsnip, locally called "eltrot," and others injurious, like the larger plantain, the common daisy, and the buttercup.

This very rich soil, notwithstanding the weeds, produces a large amount of very nutritious food

II. Natural pasture on deep stiff loam.

Summer Leaze.—The grasses are cocksfoot, hard fescue, yellow oatgrass, dogstail and timothy. There is a considerable quantity of white clover, a little red clover, and some yarrow and cow parsnip. The worthless weeds are buttercup, daisy, and ox-eye.

Stevens.—The grasses are cocksfoot, hard fescue, yellow oatgrass, rough-stalked meadow-grass, and smooth-stalked meadow-grass. There is a good bottom of white clover, some red clover, and a good deal of yarrow.

Stevens' Second field.—The grasses are the same as in the adjoining Stevens' field, but in the bottom of the field the cocksfoot largely predominates, and there is no clover.

Oxen Leaze.—The grasses are cocksfoot, dogstail, yellow oatgrass, rough-stalked meadow-grass, and ryegrass. There is some white clover and yarrow, a good geal of rib-grass, and some of the larger plantain.

The chief characteristics of these four pastures are the large quantity of cocksfoot in them, and the fair amount of clover and yarrow.

III. Natural pasture on shallow stiff loam, resting on limestone.

The Front.—The chief grass is hard fescue, and with it is associated cocksfoot, ryegrass, fiorin and dogstail. There is a good deal of clover both white and red; a considerable quantity of yarrow, with some rib-grass, buttercup, and the larger plantain.

Stevens' second field, Upper Part.—The grasses are hard fescue, cocksfoot, and dogstail, with a good deal of white clover and a little red. Daisy and buttercup abounded in this field.

The chief characteristic of these two fields is the predominance of the hard fescue.

IV. Pasture laid down twenty years ago.

The Leaze.—The grasses are ryegrass, dogstail, Yorkshire fog, and yellow oat grass. There is a very good bottom of white clover and a good deal of red clover. There are also a good many many weeds, chiefly the larger plantain, daisy, and dandelion. There was no cocksfoot in this field.

The farmer had noticed that the cows were very fond of this field. It stands by itself in the character of the vegetation. It would be interesting to determine the quantity and quality of the cheese made when the cows were feeding in this field.

The other fields have practically the same herbage; but the rich growth in *the Mead* yields probably a larger quantity of rich milk than any of the other fields.

Geological aspect.—The farm is situate, partly on the oolite, partly on the mountain limestone; the soil is very varied, some being clay, but mostly consisting of loams.

Samples of the soils of the various fields were taken and forwarded to Dr. Voeleker, who supplied the following analyses and report.

REPORT OF DR. VOELCKER.

COMPOSITION OF PASTURE SOILS FROM VALLIS FARM, FROME.

Soils dried at 212° F. contain	Oxen Leaze.	The Mead.	The Front and Ste[illegible]	The Leaze.	Summer Leaze.
Organic matter and water of combination	17·12	15·13	12·95	13·87	14·43
Oxide of iron ...	3·33	5·61	1·56	1·88	6·64
Alumina	5·45	7·28	10·31	14·59	8·41
Lime...	10·32	2·07	·96	4·56	2·25
Magnesia	·77	·55	·37	·36	·72
Potash	·77	·55	·65	·65	·65
Soda	·16	·16	·30	·79	·20
Phosphoric acid ...	·29	·74	·32	·27	·25
Sulphuric acid ...	·23	·14	·24	·13	·13
**Chlorine	·13	trace	·002	·01	trace
Carbonic acid ...	6·60	·69	·23	2·14	·95
Insoluble silicate and sand	54·33	67·67	72·11	60·75	65·37
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·77	·54	·51	·51	·54
Equal to ammonia...	·93	·66	·62	·62	·66
Nitric acid	·0035	·0035	·004	·003	·0035
**Equal to chloride of sodium.	·22	...	·004	·014	...

Dr. Voeleker in his report said:—

The soils appeared to be rich brown loams, not varying much in colour. In Nos. 1 and 2 small pieces of lime were discernible, and No. 4 contained quite large pieces; in Nos. 3 and 5 none were noticeable. The soils Nos. 1 and 2 especially contained a considerable quantity of rootlets.

The soils were all more or less heavy loams approaching, in the case of No. 1, to a marl.

Taking them generally, the soils were all extremely rich, and the analyses evidently show that the land must be old and rich pasture. The richness is specially seen in the large proportion of organic matter and accumulated nitrogen, this latter being, with the exception of naturally peaty soils, far more than would be found in any arable field, or in any soil, I should say, but one which had been for a very long time down in pasture.

The proportions of iron and alumina together are large in each case, though varying *inter se*. No. 4 contains much the most alumina, then No. 3, and both of them much less iron than the other three.

In all the soils there is abundant lime, the least quantity being in No. 3, although there is ample there, I think, for all needs. No 1 contains the most lime by far, and No. 4, in which big pieces of lime were noticed, also has a considerable quantity.

In phosphoric acid the soils are exceptionally rich, the lowest amount being 0·24 per cent., namely, in No. 2, but here, even, there is quite double what is met with in good arable soils. All the soils are, again, well supplied with magnesia.

It is, perhaps, in potash that the soils one and all show unusual richness; indeed such high proportions will be seldom met with in five soils taken together as these were.

I have remarked on the richness in nitrogen, and therefore one is altogether justified in considering the soils as very fine ones indeed, so far as abundance of plant food is concerned, and I should be inclined to think nothing is needed or could even be done to improve their condition by any manuring.

I have also determined in them the chlorine, and this brings out one exceptional feature in the case of No. 1, namely, that it contains 0·13 per cent. of chlorine, equal to 0·22 per cent. of chloride of sodium, a quantity which one would be inclined to consider large.

Rainfall.—I am indebted to the Frome Water Company for the rainfall as taken by them during the three months of the observations, of which the following is a copy:—

RAINFALL.

August.		September.		October.	
	in.		in.		in.
1 ...	·04	1 ...	·39	1 ...	·06
2 ...	·02	5 ...	·05	2 ...	·24
3 ...	·23	7 ...	·04	6 ...	·72
4 ...	·01	8 ...	·02	7 ...	1·80
5 ...	·14	14 ...	·52	8 ...	·21
6 ...	·02	15 ...	·13	9 ...	·34
9 ...	·14	18 ...	·09	10 ...	·61
10 ...	·44	19 ...	·16	11 ...	·37
11 ...	·13	20 ...	·15	12 ...	·24
12 ...	·08	21 ...	·03	13 ...	·14
15 ...	·03	22 ...	·20	14 ...	·58
18 ...	·61	23 ...	·01	15 ...	·51
19 ...	·11	24 ...	·01	16 ...	·54
20 ...	·28	25 ...	·06	17 ...	·25
21 ...	1·37	26 ...	·05	18 ...	·05
23 ...	·05	28 ...	·03	19 ...	1·14
24 ...	·04	30 ...	·10	20 ...	·15
25 ...	·08			21 ...	·28
27 ...	·89			22 ...	·76
28 ...	·54			23 ...	·79
29 ...	·17			26 ...	·04
30 ...	·13			27 ...	·57
31 ...	·35				

Analysis of Water.—The water supplied to the farm was analysed with the result shown in the following table. It is a very pure water and also a hard water, which is, in my opinion, a desirable quality in water drunk by cows whose milk is to be converted into cheese.

COMPOSITION OF WATER.

	grains.
Organic matter and water of combination	1·54
Oxide of iron and alumina	1·40
Carbonate of lime	20·02
Magnesia	0·42
Sodium chloride	1·15
Other alkaline salts	1·35
Sulphuric acid	0·60
Silica	0·14
Total solid matter per gallon	26·62
Free (saline) ammonia	·0015
Albuminoid (organic) ammonia	·0035

The quantity of solids was estimated from time to time, and was not found to vary greatly.

Site No. 2.—Axbridge, 1892.

Compton House, Axbridge, near to the now celebrated village of Cheddar, lies at the foot of the Mendip Hills, and was in the possession of Mr. Charles Tilley.

The accompanying plan shows the disposition of the fields, those coloured green being fed throughout the season, those coloured brown being first cut for hay.

The fields upon which the cows were pastured were 13 in number, and lay in the low level land, about one mile from the house.

Fields at Compton House Farm, Axbridge.

No.		Acres.	
1	Large Leaze ...	22 ...	Pasture
2	Seven acres ...	7 ...	"
3	Eight acres ...	8 ...	"
4	Ten acres	10 ...	"
5	Botany Bay ...	6 ...	Aftergrowth
6	Ten acres	10 ...	"
7	Six acres	6 ...	Pasture
8	Four acres ...	4 ...	Aftergrowth
9	Six acres	6 ...	"
10	Moor House ...	14 ...	Pasture
11	Twelve acres ...	12 ...	"
12	Sharnhams ...	15 ...	"
13*	Fourteen acres ...	14 ...	"

This land has evidently once been marsh land. It would appear to have been reclaimed from the sea some centuries ago,† and whether the herbage is distinct or not is a botanical question, which I regret Professor Carruthers did not investigate, he, unfortunately, not being able to visit the farm.

* Accidentally omitted from Plan. It is the field bordered N and W by Nos. 1, 2 and 3.

† This I gather from a work entitled "A General View of the Agriculture of the County of Somerset." By John Billingsley, 1798.

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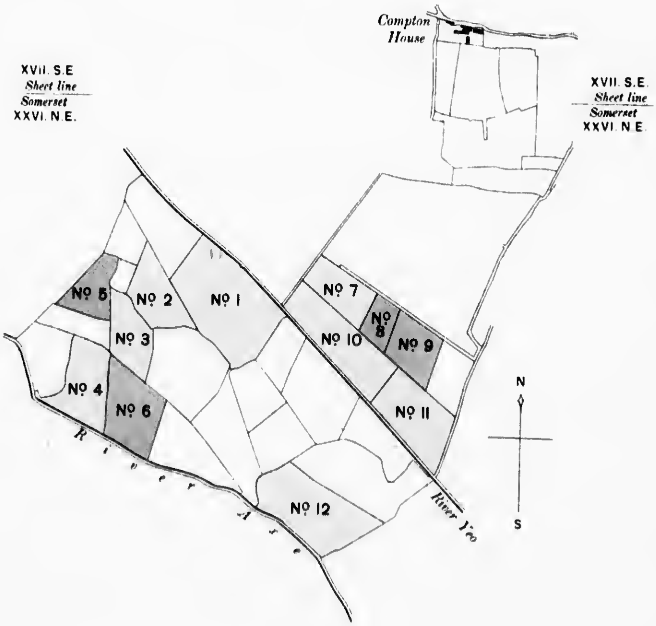
Site Nº 2. Axbridge

[Alluvium]



To me the grass appeared of rough quality, and there seemed to be many useless plants in the pastures.

Geologically, the land is alluvium, and the nature of the soil is best shown by the analyses and report of Dr. Voelcker, to whom carefully mixed samples were sent for analysis.

REPORT OF DR. VOELCKER ON THE SOILS.

The results of analysis of the five soils are as follows:—

Soil dried at 212° F. contain—	10 Acres.	14 Acres.	Moor House.	7 and 8 Acres.	Large Leaze.
*Organic matter and water of combination	13·99	15·67	15·23	15·60	17·98
Ferric oxide	2·60	3·81	3·78	4·02	3·81
Ferrous oxide	1·49	·94	·73	·66	1·09
Alumina	5·42	6·28	6·19	6·54	7·06
Lime	·87	1·01	·90	·90	1·03
Magnesia	1·17	1·50	1·10	1·27	1·30
Potash	·73	·71	·65	·85	·86
Soda...	·37	·46	·87	·47	·66
Phosphoric acid	·19	·23	·22	·18	·22
Sulphuric acid	·10	·10	·11	·14	·14
Sulphur (as sulphides)	·04	·02	·02	·04	·02
Insoluble silicates and sand ...	73·03	69·27	70·20	69·33	65·83
	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	·60	·65	·69	·66	·75
Equal to ammonia	·73	·79	·83	·80	·91
Nitric acid...	·0025	·0025	·003	·003	·0035
Chloride of sodium	·005	·005	·005	·005	·005

Dr. Voelcker, in his report stated:—

The samples contained a great deal of rootlets, which tended to show high results in organic (vegetable) matter and in nitrogen resulting therefrom.

The five different soils were very similar in appearance, being of a greyish-brown colour, and of the nature, I should say, of a clay loam.

The analytical results brought out the fact that all five soils were strikingly alike in general composition. Indeed, there is no one point that markedly distinguishes any one soil from another, and remarks made on the composition of one will apply almost equally to all.

I have noted on the high amounts of organic matter and nitrogen. Lime also is present in ample quantity in all, though there are no cases of the occurrence of the amounts found in the Frome soil (Vallis Farm) in 1891.

The soils further show richness in potash, and both in this respect and in that of the supply of phosphoric acid, all the soils are in good fertility.

The separate estimation of chlorides did not bring out any case in which any excess of salt was shown, such as occurred with one of the Frome soils.

On the other hand, I found a good deal of iron present in the ferrous and not merely in the ferric state, and consequently I estimated the amounts separately. Analysis also showed that sulphides (probably as pyrites) were present to a small degree.

These two last-named points would lead me to think that the soils were not in the best condition of cultivation possible, but that further aeration and opening of the soil would be beneficial. Whether they are effectually drained or not appears to me worthy of consideration.

Water Supply.—The water was supplied to the cattle by means of dykes or ditches in which, owing to the dry season, it ran at times very low. The water appeared to be of very varying composition, mainly consisting of surface drainage water, which is not, in my opinion, well adapted for cows in milk. Such water is as a rule deficient in lime, too soft in fact, and it is well known that, owing to the considerable amount of lime secreted by the cow in her milk, hard water is a desideratum.

Site 3.—Butleigh, near Glastonbury, 1893.

For the work of the Cheese School this year two farms were requisitioned to supply the milk. They were situated at Butleigh, about four miles from Glastonbury, on the property of Mr. R. Neville Grenville.

This part of the county is noted for certain land, which is termed the scouring land of Somerset, but the cattle were never fed upon this scouring land.

The milk was supplied by Mr. H. G. Bethell, the tenant of Lower Rock Farm, and by Mr. Hunt, tenant of Bridge Farm, whose fields adjoin Mr. Bethell's. The fields upon which the cattle were pastured for the greater portion of the season were on the low-lying lands which border the River Brue. But during the first three weeks of April the cows were on "Beggars Well" and "Park Gates," and were then receiving hay, roots, and cake. The cake was fed up to May 17th. During these first three weeks there was no taint in the milk or curd.

The following plan shows all the fields on which the cattle were fed. There were in all 13 of which the following is a list:—

Fields at Butleigh.

		Acres.	
1.	Southmoor or 12 acres } ...	The 30	... Pasture.
2.	Southmoor or 18 acres }		
3.	River (or Clapps corner) Common ...	13	... Aftergrowth.
4.	9 acres Common...	9	... Pasture.
5.	Common mead	8	... "
6.	12 acres (or Inside) Common	12	... "
7.	Common 5 acres...	5	... Aftergrowth
8.	Reynolds' Common	6	... Pasture.
9.	Hyatt's Common	6	... "
10.	Lower Horseys	12	... "
11.	Gilbert's Duck Pool	5	... "
12.	Periams and Horseys	8	... Aftergrowth.
13.	Moor's Horsey's	11	... "

Both Mr. Bethell and Mr. Hunt were firmly convinced that no good cheese could be made from some of their land, and they

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Aftergrowth.
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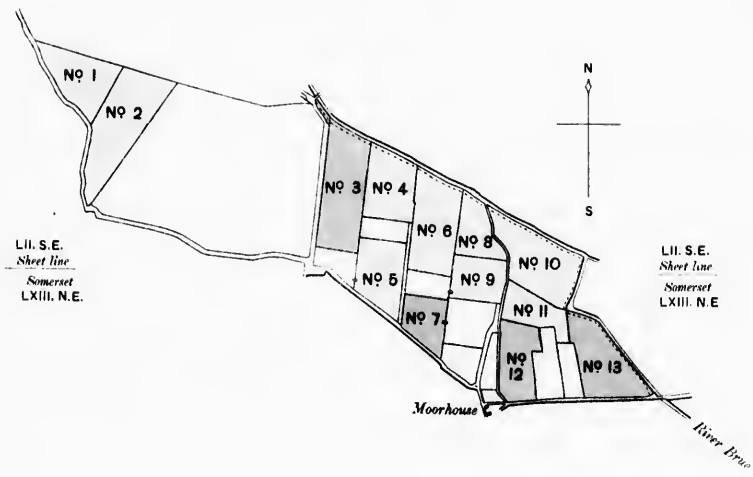
Site No. 3. Butleigh (Alluvium)



pointed out certain fields which were noted as causing the milk to be unsuitable for cheese-making. It was evident that the cause might reasonably be expected to be found in the nature of the herbage growing upon the land. Mr. Carruthers was therefore requested to visit the farm and inspect the herbage, which he did on the 27th June.

The following is Mr. Carruthers' report:—

BOTANICAL REPORT OF MR. CARRUTHERS, F.R.S.

I visited these farms on the 27th June, and examined with care the vegetation of the ten fields in which the milch cows graze. All these fields are on the flat alluvium of the valley, which consists throughout of a fairly uniform stiff loam. With but slight modification, the vegetation is also singularly uniform.

The principal grasses are wild barley grass, broom grass, rye grass, and false fiorin. Less frequently are found meadow fescue, tall fescue, sheep's fescue, cocksfoot, and Yorkshire fog. The most abundant grasses are those of inferior quality, but the rich alluvial soil produces a vigorous growth on which the cows thrive. The only grasses that are permitted by the stock to run to seed are rye grass, barley grass, and false fiorin; very few heads were to be seen, the whole pasture being very closely eaten down.

A fair amount of white clover exists in all the fields, being very thick in some places. A few scattered plants of red clover are present in all the fields. There was a considerable quantity of the yellow bird's foot trefoil on Mr. Hunt's farm.

The most abundant weed was buttercup; this weed was specially observed in Lower Rock Farm. There was an absence of yarrow in all the fields of this farm. On the other hand, yarrow was present in all the fields of Mr. Hunt's farm, and with it "all-heal" and some thistles. One field on this farm contains a good deal of yellow rattle.

I compared the vegetation of the fields which (it was said) always supplied good milk with that in the fields in which the milk was of inferior quality, and made inferior cheese. There was no difference in the vegetation to account for the difference in the quality of the milk.

Geologically, the land at Butleigh was similar to that at Axbridge, being all alluvium. But a comparison of the analyses of the soils shows that those at Butleigh contained far more clay than those at Axbridge. In my opinion, the soils were very similar in appearance, and Mr. Carruthers, as will be seen from his report, formed the same opinion. Samples of the soil were taken from every field, but subsequently I selected only a few of the most typical samples.

Thus the "Thirty acres" of Mr. Bethell was a little lighter in colour and more ferruginous than the other soils. It was considered the best of all the fields. Hyatt's Common, which was considered the worst field, appeared identical with Mr. Bethell's worst field known as "Horseys." The other soils were very similar; but I selected two which appeared to me least like one another.

These four samples of soil were then forwarded to Dr. Voelcker, and it will be seen from his report that chemically, and as regards fertility, the "Thirty acres" is the best soil, and "Hyatt's Common" the worst soil.

REPORT OF DR. VOELCKER ON THE SOILS.

The four samples of soil from fields, at Butleigh, gave the following results :—

Soil dried at 212° F.	Inside Common, considered the poorest of 3 Commons, mainly subsoil 2–8 in.	Hyatt's Common, Mr. Hunt.	Clapps Corner Common.	Thirty Acres.
Organic matter and loss on heating...	17·48	14·69	19·54	20·88
Ferric oxide	5·20	7·17	4·88	6·36
Ferrous oxide	2·01	·88	1·28	1·03
Alumina	13·93	8·41	13·63	15·10
Lime	·87	1·30	·99	·89
Magnesia	1·10	·90	1·03	·90
Potash	1·02	·85	1·02	1·45
Soda	·24	·34	·56	·92
Phosphoric acid	·36	·41	·37	·40
Sulphuric acid	·16	·15	·17	·14
Insoluble silicates and sand ...	57·63	64·90	56·53	51·93
	100·00	100·00	100·00	100·00
Nitrogen	·61	·55	·73	·81
Equal to ammonia	·74	·67	·89	·98
Nitric acid	·008	·008	·008	·008

Each soil contained a trace of chlorides, but not more. The four soils were very similar in appearance, and are all of a distinctly clayey nature.

Although, as is but natural in the case of different samples, the four soils show in their respective analysis certain small differences of chemical composition, yet it must be said generally that they resemble one another very fairly indeed, and, so far as I can see, there is no such striking variation between any one of them and another as to in this way account for the superiority claimed locally for this or that soil.

The most marked difference which occurs is in the small quantity of alumina in No. 2, and in the slightly increased amount of lime which it contains. This soil would appear to be somewhat the lightest of the four.

The fact that No. 1 shows a larger proportion of ferrous oxide than any of the others, may possibly be taken as some indication of its being in a less fully-oxidised condition, and this may have to do with its being considered the poorest of the three common soils. Beyond this, I see no possible reason, on the chemical side at least, to account for inferiority in it.

I should not at the same time be surprised to hear that No. 2 was reckoned the better soil, owing to its being lighter, to the larger amount of lime in it, richness in phosphoric acid, and more fully oxidised state of its iron salts.

All four soils are very rich alike in phosphoric acid, potash, and nitrogenous organic matter, and the differences in any of these shown by the respective soils are not sufficiently marked to account for any superiority of one over the other.

It will thus be seen that neither a botanical examination of the herbage, nor yet a chemical examination of the soils, found any reason for the local opinion as to the unsuitability of the land for cheese-making, nor did they throw any light on the difficulty met with in practice. The results of subsequent investigation lead me to think that the trouble at Butleigh was due very largely to the character of the drinking places for the cattle, the importance of which will be demonstrated later on in this Report.

Rainfall.—The following table, for which I am indebted to Mr. Neville Grenville, shows the rainfall as recorded by him at Butleigh during the seven months of the observations.

	April.	May.	June.	July.	August.	September.	October.
	in.	in.	in.	in.	in.	in.	in.
1	·03	·03	...	...	·02	...	·09
2	...	...	...	...	...	...	·60
3	...	...	...	...	·41	...	·08
4	...	...	·08	·54	·21	...	...
5	...	...	·03	...	...	...	·32
6	...	...	...	...	·06	·42	·30
7	...	...	...	...	...	·03	·40
8	...	...	...	·15	...	·55	·12
9	...	...	...	·10	...	...	·03
10	...	...	...	·08	...	...	·29
11	...	...	...	·41	·04	...	·20
12	...	...	...	·12	...	...	...
13	...	...	·04	·25	...	...	·07
14	...	·07	...	...	...	...	·19
15	...	·03	...	·79	...	...	...
16	·03	·17	...	...	...	...	·06
17	...	·19	...	·10	...	·06	·15
18	...	·20	...	·02	·10	·17	...
19	...	·05	...	·85	...	·25	...
20	...	...	...	...	·23	·06	...
21	...	...	...	·10	...	...	·12
22	...	·03	·30	...	·28	·21	·03
23	·02	·09	·40	·41	...	·13	...
24	...	...	·10	...	...	...	...
25	...	...	·04	·05	...	...	·19
26	...	...	·15	...	...	·15	·37
27	...	...	·17	...	...	·05	...
28	...	...	...	...	...	·36	·05
29	·09	·02	...	...	...	·11	...
30	...	...	...	·09	...	·05	...
31	...	...	...	·06	·08	...	...
Total inches ...	·17	·88	1·31	4·12	1·43	2·60	3·66

Water supply.—The cattle drank from the river Brue, which, in spite of the very dry season, always afforded them an ample supply of water. Whether this was of good quality I did not determine, it not being until subsequently that I discovered the effect of sewage in producing those taints which were so prevalent at Butleigh.

Site No. 4.—Mark near Highbridge, 1894.

The north-west of the county of Somerset consists of low-lying lands bounded by the Bristol Channel on the one side, on the nort-east by the high range of the Mendip Hills, and on the south-west by a range of hills, the Quantocks, which run almost parallel to the Mendips. Between these two hills lies a valley, exceptionally flat and level, and at the head of the valley, inland, is the town of Glastonbury. From there the valley gradually widens, and very gently slopes down to the sea, where it ends in a long stretch of low-lying land, reaching from Weston on the north to Bridgwater on the south. The farm selected for the School was that of Mr. John Peters, of Mark House. The parish of Mark is situated in the broad part of this valley, about five miles from the seashore, and almost half-way between Weston and Bridgwater.

The acompanying plan shows the farm, or rather that portion of it devoted to milch cows. The fields were 15 in number, of which two were in the moor, and at some considerable distance off, while the others were nearer to the house.

The following is a list of these fields:—

No. 1.	Eight acres.	Size 8 acres.	Aftergrowth.
,, 2.	Two acres.	2	,,
,, 3.	Four acres.	4	,,
,, 4.	Sixteen acres.	16	,,
,, 5.	Three acres.	3	Pasture.
,, 6.	Five acres.	5	,,
,, 7.	The Pen	2	,,
,, 8.	The five acres.	5	,,
,, 9.	Church Path.	9	,,
,, 10.	Crib House.	6	,,
,, 11.	The twelve acres.	12	,,
,, 12.	The ten acres.	10	,,
,, 13.	Yarrow ground.	5	After growth.
,, 14.	But Lake.	9	Pasture.
,, 15.	Tile House.	9	,,

Mr. Carruthers visited the farm, and inspected the fields on the 7th of August, and reported thereon as follows:—

BOTANICAL REPORT OF MR. WM. CARRUTHERS, F.R.S.

The soil is a rich alluvium, and supports a vigorous vegetation. There is great similarity in the elements of the pastures in the various fields. The principal grasses are Cocksfoot (*Dactylis glomerata*), Rye-grass (*Lolium perenne*), Dogstail (*Cynosurus cristatus*), and Squirrel grass (*Hordeum pratense*). These four grasses exist throughout the farms in nearly equal proportions. Cocksfoot is one of the best grasses. It is deep-rooted, and consequently draws its food from a larger and deeper mass of soil than many other grasses, and therefore grows rapidly, producing a large amount of nutritious and palatable food. Rye-grass and Dogstail occupy a lower platform, supplying a lesser quantity of good food; as, however, the bents in pastures consist, to so large an extent, of the seeding heads of these two grasses, they cannot be considered as favourite food of stock. Squirrel tail is a very inferior grass which in ordinary pastures runs rapidly to seed. But on a rich soil like that at Mark, this grass produces a large amount of nutritious food. Sheep and cattle prosper on some pastures in Somerset where Squirrel tail is, by a long way, the predominant grass. Early in the season it produces a considerable quantity of foliage, which is eaten

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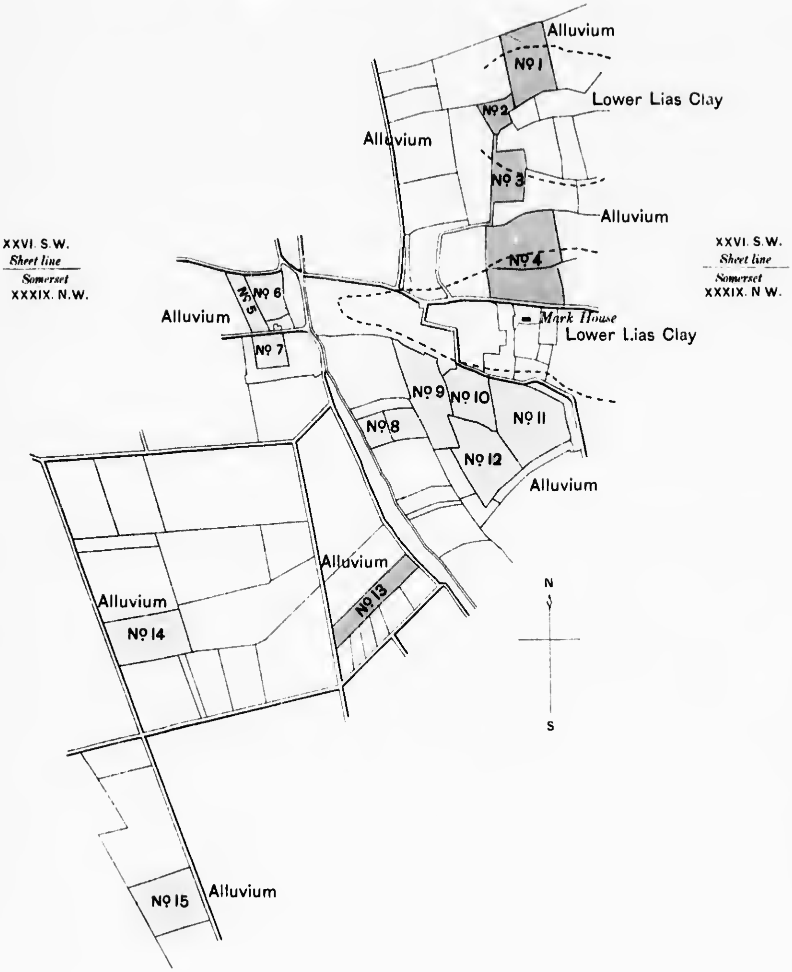
Site No. 4. Mark



down in such rich pastures, though when it flowers the long sharp awns which bristle round the head prevent the stock from touching it.

There were in the pastures at Mark also the following grasses: Timothy (*Phleum pratense*), Fiorin (*Agrostis alba*), and Yorkshire fog (*Holcus lanatus*), though in much less quantity than the four grasses already named. Occasional plants of Golden oat-grass (*Avena flavescens*), Brome grass (*Bromus mollis*), and Meadow Fescue (*Festuca pratensis*), were found in the pastures.

All the fields had a thick bottom of White Clover (*Trifolium repens*), and there was throughout some Red Clover (*Trifolium pratense*).

A little Yarrow (*Achillæa Millefolium*) was met with in all the pastures.

As I have already stated, there was very little variation in the different fields. In the three divisions of "Church path ground" there was a larger proportion of Cocksfoot and Yarrow, and the Cocksfoot was somewhat more abundant in the "ten" and "twelve acre" fields.

Excepting the Buttercup, which is seldom touched by the cattle, there was no weed in the fields which could injuriously affect the milk.

The vegetation was vigorous, so that even the inferior grasses supplied a nutritious food to the cows.

Geologically, the land at Mark is similar to that at the preceding sites, namely alluvium, except the few fields close to the House, where only the aftergrowth was fed.

It was remarkable how closely the soils in all the fields approached one another in character, so much so that I at first hesitated as to whether it was necessary to send more than one sample to the Society's Consulting Chemist for analysis. I decided, however, to select the two most dissimilar samples, and these were forwarded to Dr. Voelcker, who reported upon them as follows:—

REPORT OF DR. VOELCKER ON THE SOILS.

The soils are very similar in appearance, and they give, moreover, very similar results upon analysis. Indeed, there is no difference between them which calls for special comment.

In appearance the soils were of a greyish-brown to black-brown colour, and they seemed to be somewhat heavy loams of rich nature.

The analytical results were as follows:—

SOILS DRIED AT 212° FAHRENHEIT.	Butlake.	Crib House.
*Organic matter and loss on heating	20·11	18·64
Ferrous oxide	1·10	1·24
Ferric oxide	4·21	4·05
Alumina	8·28	7·76
Lime	1·43	1·23
Magnesia	1·23	1·13
Potash	1·02	·88
Soda	·66	·62
Phosphoric acid	·26	·24
Sulphuric acid	·13	·11
Insoluble silicates and sand	61·57	64·10
	100·00	100·00
*Containing nitrogen	·83	·78
Nitric acid	·0055	·005
Chlorine	trace	trace

It will be at once seen, by anyone conversant with chemical analysis, that the above results represent soils of great richness. In character they are rather heavy, but their mechanical condition is excellent, the rootlets radiating in every direction and keeping the earth open and friable. The samples are very rich in organic vegetable matter, the accumulation, probably, of long continued pasture growth, and they contain much nitrogenous matter derived therefrom.

In phosphoric acid they are also very rich, they have plenty of lime, without the defects of soils too rich in that material, and they are exceedingly well supplied with potash.

Site No. 5.—Haselbury, near Crewkerne, 1895.

Haselbury House is situated about three miles from Crewkerne, and is in the possession of Mr. G. D. Templeman. The farm consists of 554 acres, of which 344 are arable and 210 pasture. Being mainly upon hilly land, some of the fields lie high, but others are down in the valley.

The following is a plan of the farm, showing the fields which were utilised for feeding the dairy cows.

In all there were 12 of which the following is a list:—

Fields at Haselbury.

1.	Hams	56	acres.	Aftergrowth.
2.	Great Leaze	21	,,	Pasture
3.	Inner Leaze	15	,,	,,
4.	Clover Wood	17	,,	,,
5.	Beat Wood and Gamblin	30	,,	,,
6.	Water Meadow	13	,,	,,
7.	Oat Close	5	,,	Aftergrowth.
8.	New Mead	4	,,	,,
9.	Hanging Hill	10	,,	Pasture.
10.	Gravel Sleight	19	,,	,,
11.	Lower Solomons	6	,,	Pasture.
12.	Middle Solomons	6	,,	,,

The reason why so large an acreage was fed, was the great scarcity of grass due to the dry season.

Mr. Carruthers investigated the herbage on the 22nd of July, and reported as follows:—

REPORT OF MR. WM. CARRUTHERS, F.R.S.

This farm contains different qualities of pasture due to the varieties of soil.

One is a rich alluvial soil filling up the bottom of the valleys. This produces a large crop of good grasses, principally Cocksfoot and Hard Fescue; with these are small quantities of Rye-grass, Meadow Fescue, and Fiorin (*Agrostis vulgaris*). There is a fair amount of White Clover and a little Red Clover. Yarrow is fairly abundant. "Lower Haggett Meadows" and "Hazel Ditches" belong to this group. They are both clean and valuable pastures.

The fields "Middle and Lower Solomons" have a somewhat similar soil and a more varied vegetation. The principal grasses are Hard Fescue, Rye-grass, and Cocksfoot; the Hard Fescue is most abundant, and the other two follow closely after it. There is in addition a fair amount of Dog's-tail and Sweet Vernal, and a little Timothy. Here, as generally

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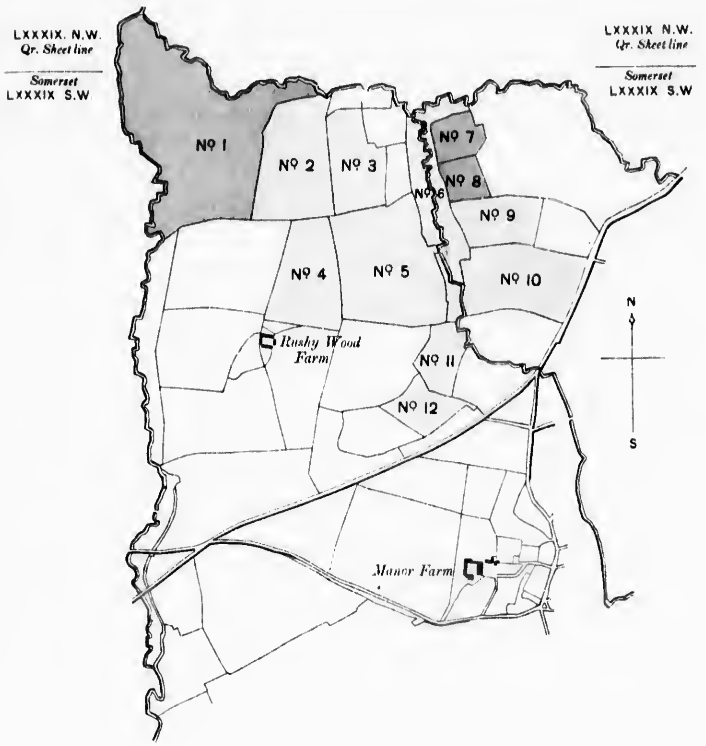
Site Nº 5. Haselbury

[Marly Clay & perhaps a little Marly Limestone]



in the other fields in the farm, there is very little Clover. Yarrow is fairly abundant, and Ribwort is present.

The higher lands of the farm are covered with a thin soil, and are covered with a poor and starved pasture containing many weeds. The chief grasses are Hard Fescue and Rye-grass; there is a little Cocksfoot and scattered plants of other grasses. To this group belong the "Gravel Sleight Field" and "Hanging Hill Field."

The "Beat Wood Field" has a similar soil and position, but the pasture is very much worse. It was laid down by a previous tenant about eight years ago, but nothing is known as to the kind of seeds he employed. It yields now a very poor crop of starved grasses, and is full of weeds. It appears to me to have been laid down for a one or two years ley, and the short-lived grasses as they disappeared have been replaced by self-sown grasses. The Rye-grass and the few plants of White Clover, Timothy, and Cocksfoot which are found in the field, represent probably the remains of the original mixture, while the bulk of the pasture, consisting of Bent-grass (Fiorin), Yellow Oat-grass, and Brome-grass are the produce of blown seeds.

In the lighter soils, but especially in the "Beet Wood Field," weeds abound. All the pastures would be greatly improved by a little more White Clover.

Chemical Character of Soils.

Geologically, the land at Haselbury consists mainly of marly clay.

On the different parts of the farm which were down in grass, the soils varied slightly in appearance, so samples which were typical of the whole were sent to Dr. Voelcker for analysis. The following is the result of his examination of these samples.

REPORT OF DR. VOELCKER ON THE SOILS.

Soils dried at 212° Fahr.	Middle Solomons.	Gamblin.	Beat Wood.	Hams.
*Organic matter, Carbonic acid, and loss on heating ...	11·94	18·90	13·13	11·95
Oxide of Iron	3·80	4·35	3·53	3·59
Alumina	4·54	6·81	7·92	7·30
†Lime	1·20	1·27	1·03	3·23
Magnesia	·40	·53	·46	·76
Potash	·34	·97	·45	·75
Soda	·20	·44	·11	·16
Phosphoric acid	·16	·16	·16	·14
Sulphuric acid	·09	·17	·14	·08
Nitric acid...	...	·03	·002	·002
Insoluble siliceous matter ...	77·33	66·37	73·07	72·04
	100·00	100·00	100·00	100·00
*Containing nitrogen	·22	·81	·513	·406
Equal to ammonia	·27	·98	·623	·493
†Equal to carbonate of lime ...	2·14	2·27	1.83	3·93

No. 1. *Middle Solomons* was a light brown-coloured loam. It is the lightest of the four soils.

No. 2. *Gamblin* is darker coloured, and a heavier loam than No. 1. It has rather more clay in it.

No. 3. *Beet Wood* is much like No. 2, but is rather lighter in colour. It has flints interspersed in it.

No. 4. *Hams* is, in appearance, somewhat similar to No. 1. It has a good deal of flint in it.

The analyses show that No. 4 is a different soil to the other three, containing, as it does considerably more lime.

As a whole, the soils are not anything like so rich in character as those at Mark Farm—the site of last year's experiments. They are, with one exception, poorer in potash and nitrogen, while all of them are markedly inferior in phosphoric acid to the Mark Farm soils.

In none of the four does the amount of phosphoric acid reach above an ordinary quantity for soils in fair agricultural condition.

No. 1 has a comparatively small percentage of potash, while, for pasture land, it is decidedly poor in nitrogen, and not rich in organic (vegetable) matter.

No. 2 has much more potash, and is also much richer in nitrogen, possessing, indeed, a high percentage of the latter constituent.

No. 3 has rather more potash than No. 1, but no great quantity, whereas it is well supplied with nitrogen.

No. 4 has plenty of potash and a fair quantity of nitrogen.

All four soils have abundance of lime.

I should consider No. 2 to be the richest and No. 1 the poorest soil.

For dairying purposes it would be an advantage to enrich the soils in phosphoric acid, while No. 1, at least, should have more nitrogen in the form of manure.

Drinking water.—The water used in the dairy, which was supplied from a well, was analysed by me on the 10th of June, and gave the following results, which show it to be pure and of excellent quality.

WATER FROM CHEESE SCHOOL, HASELBURY.

Per Imperial Gallon.	Grains.
Free (Saline) Ammonia	·001
Albuminoid (Organic) Ammonia... ...	·003
Absorbs Oxygen	·040
Total Solid Matter in Solution	30·100
Containing—	
Organic Matter	2·45
Calcium Carbonate	22·40
Calcium Chloride	1·13
Magnesium Sulphate	2·01
Magnesium Carbonate	·06
Sodium Chloride	·87
Alumina and Oxide of Iron	·14
Nitric Acid	none
Silicates	·64

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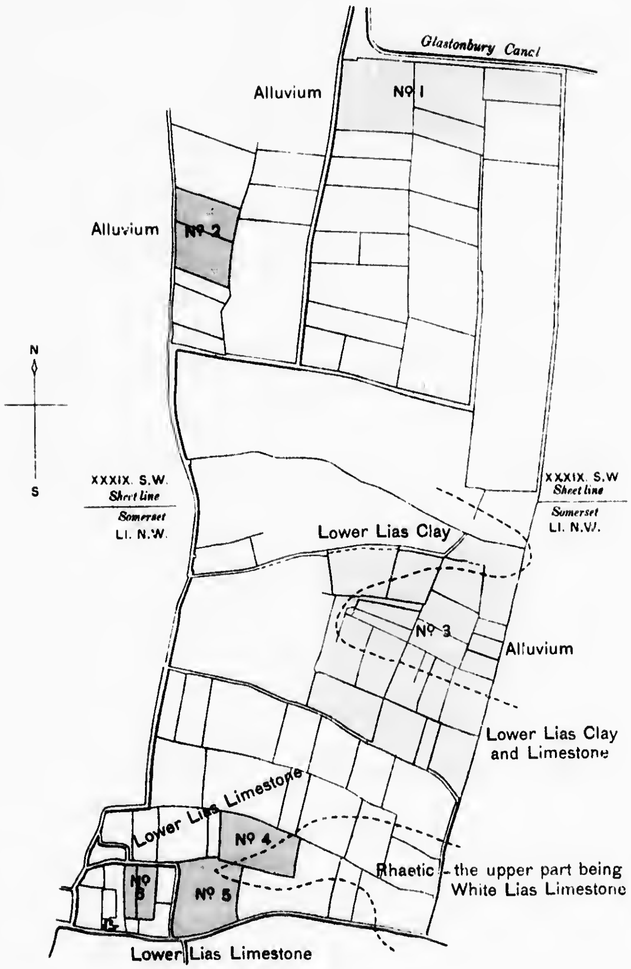
Site Nº 6 Cossington



Site No. 6.—Cossington, near Bridgwater, 1896.

The village of Cossington is situate upon comparatively high ground, on one of those outcrops of the blue Lias formation, which rise here and there from the flat valleys or moors of the north-west of Somerset.

Trivett's Farm, Cossington, in the occupation of Mr. Walter W. Tucker, was selected as the site of the School for 1896, because Cossington was said to be a place in which it was difficult to make good cheese.

The accompanying plan shows the portion of the farm on which the cows were fed.

Geologically, the land is composed partly of alluvium, partly of lower lias clay, and partly of limestone. The fields were mainly down on the moor, where the soil is clay, and where peat abounds, or is intermingled with the soil. The fields on the higher level are few, and comparatively small. The soil partakes of the blue Lias character, and the herbage is what is known as "teart," or "scouring."

The fields were not marked out as in former farms, the cattle being able to roam over many fields. Hence we must refer to these mainly as feeding grounds. In all, there were six.

No.	1.	Hatches	36	acres	Pasture.
,,	2.	Newlands	12	,,	Aftergrass.
,,	3.	Holywell	80	,,	Pasture.
,,	4.	Middle Moot Furlong			Aftergrass.
,,	5.	Stub close Furlong			do.
,,	6.	Home fields	11	,,	do.

Hatches was looked upon as the principal milking ground, because it afforded the best pasture. Half of Holywell was intended to be mown, but owing to the dry summer, and want of keep, the whole had to be fed.

No botanical examination of the herbage was made by Mr. Carruthers, nor were any samples of soil sent to Dr. Voelcker.

Water was supplied to the cattle by means of dykes or ditches running through the fields, the water in which came from a spring in the higher ground of Cossington. In spite of the drought, there was always sufficient water, though, as might be expected, it was not plentiful.

Site No. 7.—Long Ashton, near Bristol, 1897 and 1898.

Fenswood Farm, Long Ashton, about four miles from Bristol, is the property of Sir Greville Smythe, Bart., and was in the occupation of Mr. Richmond Harding. That portion of it which was used for feeding the dairy cows consisted of about 150 acres. The accompanying plan shows the fields on which the cattle fed in 1897 and 1898 respectively.

FIELDS AT LONG ASHTON.

—	Acres.	1897.	1898.
1. Wilmots and Bushey Ground.	26	Pasture ...	Pasture, limed.
2. Home Field and Orchard	9	" ...	" } " left unlimed.
3. Middle Rowens	7	Aftergrowth ...	"
4. Fishers	4	" ...	"
5. Hop and Mead	21	" ...	"
6. The Tips...	5	Pasture ...	Pasture.
7. Kings Craft	14	After-grass ...	"
8. Great Tining	9	Pasture ...	"
9. Little Tining	6	" ...	"
10. Goulstons Ground ...	8	" ...	"
11. Hivings Hill	10	" ...	"
12. Battens Sideland ...	11	" ...	"
13. Hill Top	12	Aftergrowth ...	Aftergrowth.
14. Costlands	8	" ...	"
15. The Mead	3	Pasture ...	Pasture.

BOTANICAL REPORT OF MR. CARRUTHERS, F.R.S.

I visited Fenswood Farm on the 20th of June last. Under the guidance of Mr. Lloyd, I examined all the fields on the farm in which the dairy cows had been feeding. The pasture was good and free from wild onions and other weeds which gave their odour to milk, and to the butter and cheese made from such milk. There was nothing in the herbage to account for the difficulties in cheese-making in 1897.

The soil is a sandy loam, mainly on the Keuper Marl, but partly upon the carboniferous limestone, and some of the fields are on the lower lias. No analyses were made of the soils.

During a portion of each season it was necessary to supply artificial foods to the cattle.

The Scouring Land of Somerset.

In 1893, when the Cheese School was situated at Butleigh, my attention was naturally drawn to these peculiar soils, which are well known and form one of the remarkable features of Somerset. The scouring land appears to crop up here and there only, and runs in tracts, mainly on the higher land, and far less frequently in the hollows, being confined to the outcrop of the lower or blue Lias. As the presence of these soils has an important bearing upon the cheese-making industry, for the feeding of cattle on scouring land is almost invariably associated with a taint in the curd, I have given some attention to the subject.

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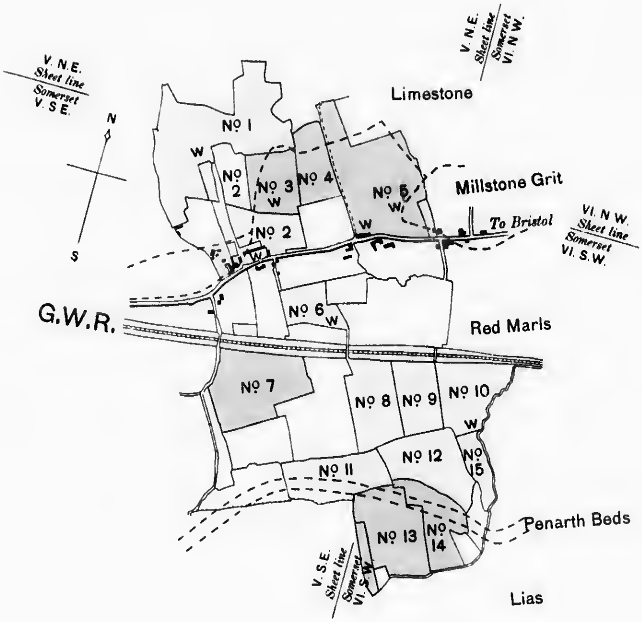
Site No. 7. Fenswood Farm Long Ashton



My first attempt was to see whether analyses would throw any light upon the cause. Two samples of soil were obtained from typical scouring land, and analysed with the following results.

ANALYSES OF SOILS (SCOURING LAND).

Soils dried at 212° F.	Hutchings.	Bludgeley.
*Organic matter and loss on heating	14·40	17·65
Oxide of Iron	10·02	9·55
Alumina	6·83	6·93
Lime	3·20	3·20
Magnesia	1·20	1·00
Potash	·60	·68
Soda	·90	·10
Phosphoric acid	·40	·42
Sulphuric acid	·15	·10
Carbonic acid, &c.	...	·42
Insoluble	62·30	59·95
	100·00	100·00
*Containing nitrogen	·55	·58
Equal to ammonia	·66	·69

My first thought was that the amount of magnesia in the land might account for the herbage grown thereon having a scouring effect. But if we compare these analyses with the analyses made by Dr. Voelcker of the soils at Axbridge we shall see that the amount of magnesia is not even so great as in the Axbridge soils. The scouring soils show, however, one peculiarity, an abnormally high percentage of nitrogen. Now, land containing a high proportion of nitrogen has a very rapid and forcing effect upon vegetation, and when conditions combine to promote a rapid growth of plant life upon a soil rich in magnesia, salts of magnesia enter the plant, and would have a scouring effect upon the cattle. Such appears to me to be the most probable cause of this scouring herbage.

It has been attributed also to the Purging Flax (*Linum catharticum*), which is frequently found growing in abundance on scouring land.

Be the cause what it may, the effect is marked. In 1891, I observed that a change of food —when the cows were first given cake— was productive of a taint in the milk. As is well-known, a change of diet is productive of a certain amount of scouring, though it may only last a day or two. A similar effect was noted at Axbridge, in 1892, and it is universally stated by cheese-makers, that it is impossible to make good cheese off "scouring" land.

We learn from these facts, that anything which causes cows to scour will spoil or deteriorate the cheese. It will introduce fæcal organisms into the milk, cause a fæcal smell in the curd, such as was present frequently at Butleigh, and only the very greatest care will enable the cheese-maker to produce good cheese under such circumstances.

The only remedy that can be suggested at present is scrupulous cleanliness, which, though necessary at all times, is indispensable upon soils of this nature.

An Experimental Cheese was made at Mark in 1894, to test the effect upon the cheese of land which had the reputation of being scouring and bad for cheese-making. The cows had been divided into two lots sometime previously, one lot, 21 in number, were on the scouring land (in all, 24 acres), and yielded 53 gallons of milk. The other lot, 33 cows, were on the old pastures, and yielded 51 gallons.

During the making, and even at the time of vatting, the two curds showed very little difference in quality; if anything, that from the scouring land being not quite so good as the other. The cheeses, when ripe, showed, however, far more difference in quality; that from the milk off the scouring land being of very poor quality, while the other cheese was much better, though not of good quality.

I had pointed out the great necessity of care to insure the cows being clean when on scouring land, and doubtless this care was observed, and so rendered the result less striking during the making of the cheese than it would otherwise have been. Moreover, the experiment was made in the Autumn, when the effect of the scouring land is far less marked than in the Spring.

The Effect of Liming Pastures.

It is generally considered in Somerset that land which has been heavily stocked with sheep is not suitable for cheese-making, and that sheep should not be allowed to roam or feed on the pastures during the cheese-making season. Whether there is any ground for this belief, I have not had time to investigate.

The difficulties in cheese-making which were met with at Long Ashton, in 1897, coupled with the fact that this farm had been heavily stocked with sheep previously, led to an assumption that perchance this might be the cause of the trouble, and as it is believed that such pasture can be materially improved by liming, it was determined in 1898 to apply lime to certain of the pastures, so as to ascertain the effect.

The Home fields, Wilmots, and Bushey Ground, having in the past been heavily stocked with sheep, it was decided to select these for the experiment on liming. The orchard also was limed, so that the cattle could be both kept and brought home to milk on land which had all been limed. The application of the lime was commenced about the middle of February, but was not finished until early in April, and it was not until some time after that there was sufficient rain to wash the lime into the soil. The quantity of lime used was two tons to the acre.

The method of experimenting was to keep the cattle for a certain length of time on the limed land, Fields 1 and 2, then for a similar period on the unlimed land, Fields 3, 4, and 5, and subsequently on the limed land.

The lime was considered by Mr. Harding to have produced a marked improvement in the herbage.

The effect of the lime was also noticeable in the cheese-tub, inasmuch as the curd seemed firmer and better than it was when the animals were on the unlimed land.

Neither chemical analysis nor bacteriological examination showed much difference in the curd.

The quantity of the milk was not appreciably affected, so far as one could judge; but it was difficult to determine this, as for each period the cows would normally be giving a larger yield of milk than in the preceding period.

The quality of the milk appears to have undergone but little change, as may be seen from the following figures:—

COMPOSITION OF MIXED MILK.

—	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.
Apr. 22, limed land	12·50	3·53	2·43	·41	5·45	·68
May 9, unlimed...	12·54	3·62	2·39	·39	5·48	·66
May 17, limed ...	12·56	3·60	2·60	·42	5·26	·68
May 25, unlimed...	12·46	3·44	2·56	·43	5·33	·70

There appears to have been some slight effect upon the acidity of the milk, for when upon the limed land the cows yielded milk of slightly higher acidity than they did when on the unlimed.

The following table shows the average acidity of milk during the periods named:—

1st period to 16th April on unlimed land	·175
2nd period to 1st May on limed land...	·190
3rd period to 14th May on unlimed land	·185
4th period to 20th May on limed land	·190
5th period to 30th May on unlimed land	·190

These results are the average of numerous observations, hence it may be that there was a slight improvement in the casein contents of the milk from limed land, and this is supported by the above analyses.

Analyses were made to determine whether there was more lime in the milk or curd from limed land than from unlimed land. The results showed such great variations from both the limed and unlimed land that no definite conclusion could be drawn therefrom.

Bacteriological examinations of the milks and curds were equally negative in their results, which was to be expected, as the curd showed no more liability to taints when on the unlimed land than when on the limed.

Hence, the only results actually obtained were a slightly increased acidity of the milk, probably accompanied with a slight improvement in its casein contents, and consequently a firmer and better curd.

Considering how important it is to have a firm curd, and in view of the improvement of the herbage on the limed land, there can be no doubt that the liming was beneficial and would have an effect lasting much longer than for the period of the experiments. Moreover, the exceptionally dry season was not calculated to produce the best results which ordinarily accrue from liming. It also necessitated the removal of the cows from pasture to pasture frequently, so that the experiment came to a close at the end of May, before the permanent effect of the lime could be determined.

On Soils said to be Unsuitable for Cheese-making.

There are certain soils or farms in England, especially in Somerset, upon which, if tradition can be believed, there are spectre sign-boards bearing the words, "Good cheese cannot be made here." Unfortunately, no one is able to see these signs except the tenant for the time being. But the belief in the inability to make good cheese on certain soils is so wide-spread, and the conviction that it is founded upon fact is so strong, that the subject received careful attention and inquiry. Some people said that the Society always selected a site for its Cheese School where it was possible to make not only good, but the best cheese, but that if a site were selected where good cheese had not been made before they would find out that it was impossible to make good cheese on such soil.

In 1892 a site was selected, where the milk was produced off alluvial land overlaying peat, and where it was difficult to make the best cheese.

In 1893, the Committee again determined to select a difficult site, and the school was fixed at Butleigh. Yet the prices fetched by the cheeses averaged from June to October, 68s. per cwt. and 66s. per cwt. for the season. It might be inferred that no difficulty was found in making cheese upon this site. Such supposition would be far from correct. The difficulties were great, and such as had not been met with during the two preceding years. Although these difficulties fluctuated from day to day, being at times very great, at others only slight, and this even when the cows were on the same pasture, yet as a matter of fact they were nearly always present. All the skill and experience, which Miss Cannon possesses in an exceptional degree, were needed to cope with them, and I can quite believe that an ordinary cheese-maker would find such difficulties insurmountable.

A site was selected in 1894, where, according to local tradition, it was not possible to make good cheese. To use the words of a local man who spoke to me on the subject, the common opinion was "that no good cheese had been made in Mark for thirty years." Nothing is more striking to an observer of local beliefs than the strong hold which they obtain upon the general inhabitants of a district. It would be difficult to account for them even were they founded on facts over which the inhabitants had no control, but when, as is generally discovered upon investigation, they are mainly founded upon superstition, one feels that no language can be too strong in which to denounce such folly.

What, then, is the cause of this tradition? So far as can be judged from hearsay, the people in certain parts of Somerset have to a certain extent lost the art of making good Cheddar Cheese. There may have been some special causes tending towards this end, included among them being, perhaps, certain difficulties intimately associated with the district, such as a bad water supply, or the dying out of those inhabitants who possessed special skill in the manufacture of cheese, and who were looked upon as guides in all cases of difficulty. From these, and perhaps other causes, the quality of cheese may materially decline in a particular district. After a few years the inhabitants begin to consider it a matter of course that the cheese which they produce will be of poor quality, and they do not seem to attempt to improve it, or to seek for the cause of its inferiority. If they do, then, with that perversity characteristic of human nature, they seek for a cause outside themselves, and, as a rule, partly, perhaps, from their inability to think of any other cause, they put the blame upon the land. Such a tradition had become firmly rooted in the parish of Mark. The land was universally declared to be unsuitable for making cheese, and it was held that no good cheese could be made there.

Thus, for three consecutive years the Cheese School had been located in a district where it was said good cheese could not be made, and always because of the nature of the land. On each of these occasions the soils were analysed by Dr. Voelcker, and in no single instance was he able to detect the presence of any chemical constituent which would be injurious to the milk or to the cheese made therefrom, or would in any way prevent good cheese being made off such land. The pastures were carefully examined by the Society's botanist, Mr. Carruthers, and he too in all cases reported that in these pastures he was unable to find any weed or plant which would cause the slightest taint in the milk, or which could in any way be considered as even remotely likely to injure the milk, or cause the pasture to be the source of any taint in the cheese. I shall hope to prove that, great as the difficulties undoubtedly are on some farms, the real cause of these difficulties is not the land. Thus, in 1892 I found that "taints appeared more frequent when the wind was in one quarter, than when in another," and this led me subsequently to discover that the earthenware drain-pipe which carried the whey to a receptacle in the farmyard and opened into the dairy, was a veritable bed of organisms, which were carried into the atmosphere of the dairy and so caused trouble. This same source of trouble I have known destroy a whole year's make of cheese in other dairies. It was remedied at Axbridge, and since then Miss Tilley has produced excellent cheese.

The trouble found at Butleigh in 1893 was undoubtedly due to the water supply, and that at Mark, in 1894, was, to a certain extent, due to the same cause. As at Butleigh so at Mark, there was one field noted for producing tainted milk, and Mr. Peters was most anxious I should discover the cause. But I was unable to then. My subsequent work, however, on the organisms of spongy curd at Haselbury led Mr. Peters to try the remedy suggested, and I subsequently received from him a letter containing the following: "The field which always produced the taint was the 12 acres (No. 11). I did not fence off the water, but dipped water from another pit and placed it in tubs for the cattle, which they drank, and we found the curd much better, with little or no taint. My opinion is that it would pay to dip water for cows at all times."

In view of this accumulated evidence, it is devoutly to be hoped that we shall hear less in the future of lands upon which, according to tradition, it is not possible to make good cheese. The sooner this superstition of the West is as dead and buried as is the belief in witches, once so prevalent in the same districts, the better. The belief that the cause of bad cheese lies in the soil is as pernicious as a belief in the evil influence of some supernatural presence; it is a veritable demon destroying all hope of improvement, and preventing all attempts to overcome the difficulties which undoubtedly exist, and it has already been the ruin of far too many people, and of the peace of far too many households.

Part IV.

The Conditions which affect the Quantity and the Quality of Milk.—The Stock and Yield of Milk at each Site of the Cheese School.—The Effect of Different Pastures on the Quality of Milk.—The Volume of Morning's and Evening's Milk.—The Decline in Milk Yield due to Time since Calving.—The Annual Milk Yield of Somerset Cows.—Tables: I. Average Composition of Milk, 1891–1898; II. Average Yield of Milk, Curd, and Cheese, 1891–1898; III. Curd from One Gallon of Milk.

The Conditions which Affect the Quantity and the Quality of Milk.

This subject will be best dealt with by studying seriatim the stock, the yield of milk, and the effect of season, at each site where the Cheese School has been held. It will then be found that on the same farm, from the same cows, and off the same pastures, both the quantity and quality of the milk yielded varies from year to year, and this variation can only be accounted for as due to changes in both the quantity and quality of the food which those pastures supply. It will further be seen that the effect of different farms and different seasons is even still more striking. Further, the breed of the cows, drought, rainfall, artificial feeding, and other minor causes affect the results which are obtained.

The influence of season will be found to be remarkable in many ways while a comparison between different seasons is possible by determining the date when the maximum yield of milk is obtained. Thus, in the years 1892, 1895, 1897, and 1898, the average maximum yield of milk was not obtained until the month of June, whilst in the years 1893, 1894, and 1896, the average maximum yield was obtained in May.

The Stock and Yield of Milk at Vallis in 1891.

The number of cows was about 50.

They were of somewhat varied character, being mainly crossbred animals with both Longhorn and Shorthorn blood in them. The size of their udders was, in my opinion, small, and consequently the animals were not calculated to give a large yield of milk.

In addition to the food which they obtained from the pastures, the younger animals, about one-third of herd, received from September 15th a mixture of 2 lbs. cotton-cake, and 2 lbs. linseed-cake each, per diem. The composition of the milk for

August, September, and October, is shown in Table I., and the yield of milk, curd, &c., in Table II.

The Stock and Yield of Milk at Axbridge in 1892.

On April 1st there were 30 cows in milk. These had increased to 48 by May 25th, leaving two more to calve. Ten were heifers with their first calf. The cows were ordinary Shorthorns of no precise character. No especial care appeared to have been taken to breed good milkers, and no register or record of the milk of individual cows had been kept.

The cows were on the pastures day and night during the whole period of cheese-making. They received a little cake in the early months, and also in the autumn.

Influence of Season.—The season was most unfavourable to the growth of grass, and the cows were, therefore, compelled to travel about and keep moving to get sufficient food. It is evident then that the conditions were such as to prohibit either the largest quantity or the best quality of milk being obtained. Though it is difficult to compare the milk of one herd with that of another, much less at a year's interval, and to say definitely what causes the difference, if any, between them, yet the following comparison, between the composition of the milk yielded at Frome in 1891, and at Axbridge in 1892, during the three months, August, September, and October, is interesting:—

—	AVERAGE COMPOSITION OF MILK.						
	Water	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.
Vallis Farm, Frome. Aug. 1891	87·39	12·61	3·87	2·76	·37	4·84	·77
Compton House Farm, Axbridge. Aug. 1892 ...	87·72	12·28	3·38	2·65	·37	5·20	·68
Vallis Farm, Frome. Sept. 1891	87·00	13·00	4·13	2·99	·41	4·69	·78
Compton House Farm, Axbridge. Sept. 1892 ...	87·44	12·56	3·57	2·87	·41	5·05	·66
Vallis Farm, Frome. Oct. 1891	86·19	13·81	4·75	3·21	·47	4·61	·77
Compton House Farm, Axbridge. Oct. 1892 ...	86·87	13·13	4·00	3·08	·51	4·84	·70

As it seemed probable that the difference first observed in August was due mainly to season, Mr. Armstrong, the occupier of Vallis Farm, was asked to send me samples of the mixed milk he was then obtaining, taken from his cheese-tub at the same time as the samples were being taken at Axbridge. This he did in September, and again in October, and the results of the analyses of these samples are given in the following table side by side with the results obtained on the same days in 1891 at Vallis, and in 1892 at Axbridge:—

Composition of Milk at Vallis and Axbridge Compared.

Date.	Vallis, 1891.			Vallis, 1892.			Axbridge, 1892.		
	Fat.	Casein, &c.	Solids.	Fat.	Casein, &c.	Solids.	Fat.	Casein, &c.	Solids.
Sept. 12 ...	4·03	8·75	12·78	3·66	8·69	12·35	3·65	8·99	12·64
,, 13 ...	4·07	8·73	12·80	4·02	8·70	12·72	3·55	8·97	12·52
,, 14 ...	3·85	8·75	12·60	3·88	8·56	12·14	3·69	8·93	12·62
,, 15 ...	3·98	8·86	12·84	3·96	8·76	12·72	3·57	8·87	12·44
,, 16 ...	3·75	9·13	12·88	3·84	8·66	12·50	3·65	8·97	12·62
,, 19 ...	4·06	9·00	13·06	3·85	8·71	12·56	3·45	9·07	12·52
Average ...	3·96	8·87	12·83	3·87	8·68	12·55	3·59	8·97	12·56
Oct. 20 ...	4·84	9·10	13·94	4·16	9·02	13·18	3·88	9·16	13·04
,, 21 ...	4·98	9·08	14·06	4·24	9·04	13·28	4·08	9·20	13·28
,, 24 ...	5·07	9·07	14·14	4·05	9·05	13·10	4·08	9·20	13.28
,, 25 ...	4·91	9·09	14·00	4·16	9·22	13·38	4·13	9·25	13·38
,, 26 ...	5·05	9·09	14·14	4·52	9·06	13·58	4·01	9·25	13·26
,, 27 ...	5·20	9·10	14·30	4·49	9·05	13·54	3·80	9·20	13·00
Average ...	5·01	9·09	14·10	4·27	9·07	13·36	4·00	9·21	13·21

It will be seen that the milk obtained at Vallis in 1892 was poorer than in 1891, which is probably the result of season, but it was richer than that given at Axbridge. So the poorer quality of the milk yielded at Axbridge is probably characteristic of the milk yielded by such pastures.

The Stock and Yield of Milk at Butleigh in 1893.

On the 1st April there were 38 cows in milk, 21 belonging to Mr. Bethell, and 17 to Mr. Hunt. They were then being stall fed, Mr. Bethell's cows receiving six pounds of cotton-cake per diem and mangels, and Mr. Hunt's a little less cake but additional hay. Soon after the cheese-making began, they were turned out to grass in the home fields, and on the 25th April went down on the moor, owing to the exceptionally warm season. They were, however, given some compound cake for some little time afterwards. On the 18th April there were 42 cows in milk, 24 of Mr. Bethell's, and 18 of Mr. Hunt's; and on the 29th, Mr. Bethell had 25, and Mr. Hunt 19 in milk. On the 11th May they were increased to 52, and on the 25th there were 55 in milk. The number remained about the same for the rest of the period. They were mostly Shorthorns; and the average yield from Mr. Bethell's cows was greater than that from Mr. Hunt's. This, Mr. Bethell attributed to the fact that he took great care in selecting the cows, and got rid of those which were found to yield less than he considered a fair amount of milk.

The effect of the Season.—The season was an exceptional one, and the result thereof was seen in many ways.

First. The effect of the warmth was already felt in April. Thus in 1892 the average time of vatting in that month was 6.58 p.m., while in 1893 the average time was 4.34 p.m., nearly $2\frac{1}{2}$ hours sooner. That this was due to the heat is shown by the fact that the average temperature of the dairy in 1892 was 54—60°, and in 1893 from 59—68°. It is also seen by comparing the average temperature of the curd when in vat, which in 1892 was 67° Fahr., while in 1893 it was 76° Fahr.

Secondly. If we compare the average results obtained at Butleigh in 1893 with those obtained at Vallis and Axbridge in 1891 and 1892, it will be seen that the yield of milk, owing to the shortness of keep, declined in June, and still further in July, while in each of the preceding years it rose in June very considerably, and even in July was in one case more than, and in the other nearly equal to, the yield in May.

Great as was the influence of the heat, as seen in the monthly average milk-yield, it was still greater when the yield is compared week by week. Indeed, the fluctuations were quite remarkable, the yield sometimes rising, and then again falling in a manner not easily to be accounted for.

Effect of Drought.—The following facts show the effect of the drought, and also indicate how very rapidly the cows felt the effect of any change produced in the food. The milk supply on the whole gradually decreased from the end of May. During the last week of May the cows were yielding about 160 gallons of milk. From that date scarcely any rain fell until the 22nd and 23rd June (see Rainfall, p. 47). The average yield of milk for the week preceding this fall was 131·7 gallons per day, but for the week after it rose to 137·1 per day. Then it began to diminish, until on the 11th July it amounted to only 126 gallons.

Effect of Rain.—A slight fall of rain on the 11th July, followed by others on 15th and 19th, had such an effect that whereas the average yield for the first ten days in the month was only 130·6 gallons per day, the average daily yield for the last ten days was 142·9 gallons.

Effect of Drought on Quality.—The effect on the quality of the milk was also most marked. Thus, while in April of each year the amount of cheese made from one gallon of milk has been practically identical, and in former years had increased every month, yet in 1893, after slightly increasing in May, it actually fell again in June, and in July and August was less than in either of the preceding years. We are justified therefore in concluding that, both in quality as well as in quantity, the milk was diminished by the prolonged drought.

Being anxious to discover what effect the drought was having upon the composition of the milk yielded at Vallis and Axbridge, where the Cheese School was held in 1891 and 1892, I wrote to Mr. Armstrong and Mr. Tilley asking for samples. These they very kindly forwarded. Unfortunately, the time taken in the transit of these samples was so long, and the heat so great, that sometimes when they reached me they were curdled, and a full and satisfactory analysis could not be made.

The following are the results obtained, and they are interesting:—

Average Composition of Milk from Vallis, Axbridge, and Butleigh, between 19th and 24th May, 1893.

Milk from—	Fat.	Casein, &c.	Solids.
Vallis	3·08	8·86	11·94
Axbridge	3·16	8·91	12·07
" in 1892...	3·25	8·95	12·20
Butleigh	3·18	8·98	12·16

It is noteworthy that the milk from Vallis, which in the autumn, as shown by the results in 1891, is richer than that yielded in 1892 at Axbridge, or than that yielded in 1893 at Butleigh, was, in May, 1893, poorer than the milk at either Axbridge or Butleigh. The reason of this is doubtless the fact that high ground like that at Vallis felt the drought and heat more than the moor lands at Axbridge and Butleigh. In the milk from these soils there was remarkable similarity.

We can also compare the milk yielded at Vallis, Axbridge, and Butleigh for the later portion of the season during the three years.

Composition of Milk at Vallis, Axbridge, and Butleigh compared.

———	Fat.	Casein, &c.	Solids.
1891. Vallis, 1st week in September, 4–9 ...	4·15	8·76	12·91
1892. Axbridge " " " ...	3·50	8·96	12·46
1893. Butleigh " " " ...	3·53	9·00	12·53
1891. Vallis, 1st week in October, 2–7 ...	4·39	9·08	13·47
1892. Axbridge " " " ...	3·87	9·08	12·95
1893. Butleigh " " " ...	4·30	9·19	13·49

It will be seen that the composition of the milk at Butleigh in September was again very similar to that yielded at Axbridge during the same month of 1892. The rapid rise in quality of the milk at Butleigh in October is due to the equally rapid and exceptional fall in the quantity yielded, and is therefore no criterion of the influence of the land or the pastures or the season.

The Stock and Yield of Milk at Mark in 1894.

The spring of 1894 was exceptionally warm and early, so that when the work of the School commenced on the 1st of April, the cows, then only twenty-two in number, were out on the pastures, and remained out during the whole seven months covered by the observations.

The herd was not a special one, the cows, including those subsequently bought by Mr. Peters, being ordinary dairy cows, mainly of shorthorn character. With these purchases the herd numbered fifty-three. From the 1st to the 21st of April they remained in the fields near the house; on the 22nd of April they were sent down on the moor.

If we consider the nature of the soil, as shown by Dr. Voelcker's Report, the nature of the herbage, as shown by Mr. Carruthers' Report, and the well-known fact that the year 1894 was exceptionally favourable to growth, we shall at once realise that upon this farm all the conditions were favourable to the production of a large yield of milk.

Table II. shows what this yield was, and that it was the highest yield which was obtained during the eight years, 1891 to 1898.

It is a somewhat remarkable fact, and well illustrates the desirability of care in the selection and breeding of dairy cattle, that the average daily yield of milk per cow at Butleigh, from 1st of May to the end of October in 1893, in spite of the exceptionally unfavourable season, was 27 lbs., and that exactly the same quantity, viz., 27 lbs., was the average daily yield at Mark from the 1st of May to the end of October, 1894, during a season when food was abundant.

Effect of Food on the Quality of Milk.—But, while the average quantity of milk yielded daily was exactly the same both at Butleigh and Mark, the composition of that milk was very different. The milk at Mark was of exceptionally good quality, so that the proportion of cheese made from each gallon of milk was far greater than at Butleigh. Indeed, it was as high as it had been during the three preceding years, and was almost identical with the yield obtained from the cows fed on the rich hill pastures of Vallis, and it has not been since equalled.

It is often asserted that the quality of the food has no influence upon the composition of a cow's milk. I do not believe in this theory which is utterly opposed to the universal experience of all practical men, and of all properly conducted experiments. The facts above stated afford striking evidence of the influence of food upon the quality of milk. The difference in the composition of the milk yielded at Mark as compared with that yielded at Butleigh in 1893, and at Axbridge in 1892, is well shown in Table I. on p. 80.

The Stock and Yield of Milk at Haselbury in 1895.

On account of the size of the farm the stock was divided into two portions, so separated from one another that each lot was milked by separate milkers, and the milk brought home in different carts and trunks. In all there were, during most of the time, seventy cows, of which thirty were on the pastures in the valley, and forty on the hill pastures. The former were, as is usual in Somerset, milked in the fields, and for the purpose of distinction, will be referred to as the field herd; the second lot were milked in a yard situated at and known as Rushy Wood, and will in future be referred to by this name.

The cows were well fed during the whole season, a liberal supply of artificial food being given during the time when the yield of the pastures was insufficient. The herd was made up, for the most part, of animals bred by Mr. Templeman from cows known to be good milkers.

Number of Cows.—At the beginning of the season forty-one cows were in milk. The weather being mild, they were out on the pastures, but as the food was scanty, each animal received daily, in addition, four pounds of decorticated cotton-cake, and two pounds of a mixture of bran, ground cotton seed (containing 23 per cent. oil), and barley meal. On the 16th of April some silage was given to the cows. The use of artificial food was continued up to the 13th of May, being slightly varied during that period for reasons which will be referred to subsequently. On the 13th of May the cows were placed upon the summer pasturage without additional food.

In the meantime the number of cows had increased. On the 9th of April five were added, making in all forty-six, and on the 23rd of April the number rose to fifty-three. No more were added until the 13th of May, when eleven, mostly heifers, were brought into the herd. Two were added on the 14th of May, two on the 21st, and finally two on the 29th, bringing the total number up to seventy. There was no variation in this number during the season up to the 22nd of September, after which a few cows were gradually withdrawn.

Towards the end of the season, on account of the drought, the cows also received artificial food.

Milk Yield.—The greatest quantity of milk was yielded on the 16th of May, and amounted to 198 gallons from sixty-six head of cattle, or exactly 3 gallons of milk per head. The average yield per head per day will be found in Table II., p. 83.

Influence of Food on the Quality of Milk.—The effect of the high feed with artificials was to produce milk exceedingly rich in fat, containing during the month of April on an average 12·65 per cent. of total solids, with no less than 3·70 per cent of fat. With the cessation of this supply of artificial food in May the composition of the milk changed, so that the average amount of total solids was only 12·58 per cent., containing 3·39 per cent. of fat. The influence of food upon the composition of a cow's milk is strikingly illustrated by these figures, for I cannot conceive how the high proportion of fat in the milk during the month of April can be explained except by the fact that the cows were then receiving a liberal allowance of artificial food. The subsequent falling off in quality was not entirely due to the influence of food, but partly to the increase in the number of cows, more especially of heifers. From the end of May the composition of the milk gradually improved, as it invariably does, and the milk at Haselbury was richer than that yielded at the Cheese School during the previous three years.

Casein in Milk.—There is one point about the composition of this milk which is of importance. While in April the milk contained no less than 3·70 per cent. of fat (see Table I.), due, I believe, to the high feed, yet this food appears to have had no effect upon the percentage of casein, which was almost exactly the same as had been found in previous years during April, when the percentage of fat was low. Each month, however, the percentage of casein rose as in former years. But the percentage of casein in the milk at Haselbury was as low as, and in most instances lower than, the percentage found in the milk at any of the Cheese Schools held during the preceding four years. As a rule the casein increases with an increase of the fat. But at Haselbury the percentage of casein had no definite relation to the amount of fat, for while in April the percentage of casein was only 2·43, in July it had risen to 2·67, although the milk contained less fat. In 1892, at the Axbridge School, the percentage of casein was also low. I then came to the conclusion that this deficiency of casein would appear to be due to locality or season, or to some especial peculiarity of the stock, rather than to any fixed relation between the constituents of the milk, and subsequent investigation proved this to be the case.*

The Stock and Yield of Milk at Cossington in 1896.

On the 1st of April there were fifty-one cows in-milk.

These were already out on the pastures, thirty in Newlands, receiving hay in addition, and twenty-one on Stubclose receiving, owing to the shortness of keep there, not only hay, but also cotton-cake (about 6 lbs. each per day).

The number of cows were increased by 14th of May to fifty-eight, and in the meantime had been changed into other fields. On the 9th of June there were sixty-two cows in-milk. This number continued in-milk up to 21st of September, when ten of the cows were milked only once a day; and on October 4th the number in-milk dropped to forty-nine.

On 27th of August there were ten feeding on "aftergrass" and receiving cake; and on 12th of September there were twenty cows cake-fed. Thus, owing to the drought, some of the cows had to be fed on cake during the greater portion of the season.

Milk Yield.—The greatest amount of milk yielded was on the 4th of May, when fifty-five cows gave 175 gallons, or an average of 3·18 gallons per cow. Even when the number of cows had risen to sixty-two on the 9th of June, the maximum volume of milk obtained was only 163 gallons. Comparing these figures with the 1895 results, it is interesting to note that in that year the maximum yield was given twelve days later, on 16th of May, and only reached 3 gallons per cow. We thus see how early was the season of 1896.

Quality of Milk.—Table I. appended hereto shows the average composition of the milk which was yielded at Cossington, from which it will be seen that the milk at Cossington was exceptionally rich in fat during the whole season.

Effect of Drought on Casein and Solids other than Fat.—The casein in the milk, while normal during April, May, and June, fell during the months of July, August, and September below the normal. A careful study of these results will show that the solids-other-than-fat in the milk also fell during these later months below the normal. I have found this to be a somewhat characteristic result of an exceptional drought and

* See further in 1896 and 1898.

scarcity of food, especially with individual cows, some appearing to be affected far more than others.*

The Stock and Yield of Milk at Long Ashton in 1897-98

The cattle were shorthorns, mostly bred on the farm, and were by a bull which was considered to have come from a good milking strain.

The Yield of Milk.—No record of the milk yield had been kept before the Cheese School commenced, but it was roughly estimated at about 2 gallons per head per day. Judging from the results obtained in 1897, this estimate is probably not far from correct; but I do not consider it very satisfactory for a well-bred and well-fed herd. Taking the average of the seven months it is only 2·21 gallons per day, while at Mark the yield was 2·39 gallons per day, and at Haselbury and Cossington 2·18 and 2·16 gallons respectively. On all dairy farms a record of the milk-yield of each cow should be kept, and the poor milkers gradually weeded out. This would probably greatly augment the average yield and well repay the little trouble involved.

The Quality of the Milk.—This, throughout the season, was inferior from a cheese-maker's point of view, owing to the deficiency of casein and consequent small return of curd. Only in the months of September and October was as much as 1 lb. of curd obtained from a gallon of milk. The average composition of the milk is shown in Table I. on p. 80. It is not possible to compare these figures quite closely with those of former years, because newly calved cows were brought into the herd from time to time, while in former years all the cows had calved in the spring of the year. So poor in solids other than fat was the milk found to be on the days on which the usual observations were made in April, 1897, that during the months of May, June, July, and August it was deemed necessary to analyse the milk daily. It is the average results of these daily tests which are recorded in the table showing the average composition of the milk.

In 1898 the stock at Long Ashton was practically the same as in 1897. Hence, any variation in the yield of milk must be attributed mainly to the season. In April the milk was exceptionally poor in casein, and contained much less fat than in 1897. In May there was a slight increase, which was partly lost in June, and not quite regained in July. But during

* Mr. A. W. Stokes has recently investigated the result of the dry season, 1898, and confirms these results. (Society of Public Analysts.)

August, September, and October, there was a slight improvement over the results obtained in 1897, both as regards fat and casein.

In spite, however, of this improvement, the milk yielded at Long Ashton is still conspicuous as having contained less casein during each of the seven months than has been present in the milk yielded at any previous Cheese School.

Hence the small return of curd per gallon of milk.

The Influence of Season.—This, in 1898, was exceptionally dry and warm, and was probably the main cause of a rapid decline in the milk yield as shown in the Table on p. 85. Whereas the average yield per head per day was almost the same during the month of June in 1897 and 1898, and by October, 1897, had only fallen to 1·68 gallons, yet in 1898 it fell by October to 1·23 gallons per head per day. The yield of milk in October, 1897, was thus 33 per cent. more than in October, 1898, from exactly the same number of cows, viz., 47, and from the same pastures.

The yield of curd per gallon of milk up to June was similar to that given in 1897, and small, considering that the cows were not all calved down in the spring. After June it improved, and though this improvement was marked, so far as the results of 1898 are compared with those of 1897, the results still compare unfavourably with those obtained in former years. At no former Cheese School, except at Butleigh and Axbridge, has the yield of curd taken from press been less than 1 lb. per gallon of milk used for its manufacture, during or after the month of July. Yet at Long Ashton, in 1897, only during September and October and in 1898 only during October, was the yield of curd more than 1 lb. to the gallon. This in 1898 is the more remarkable, inasmuch as we have already seen that the yield of milk was considerably smaller than in 1897, and, as a rule, a diminished yield is accompanied by an increase in the quality. It is even still more remarkable, considering the steps—to be referred to later on—which were taken to improve the quality of the milk. Probably the very dry season and shortness of keep had some effect in keeping low the proportion of solids other than fat, including the casein, as already drawn attention to.

Composition of Milk of Individual Cows.—In 1897, the milk was exceptionally deficient in casein, and one of the first objects of these experiments in 1898 was to try and discover the cause. There were two probable causes. Either it was peculiar to the cattle, or it was the result of some peculiarity in the food. If due to the cattle it would probably be much more marked in some than in others, but if due to the herbage or food it would be common to all. Hence, it was decided to completely analyse the milk of every cow in the dairy.

This was a tedious process, for only a few such analyses can be carried out at a time, and as the herd was not originally kept for cheese-making, but for the sale of milk, some cows were being continually drafted out of the herd, and fresh ones introduced.

The work proceeded gradually, and it became evident that the deficiency of casein in the milk was not general, but was peculiar to certain cows. This made it necessary that the milk of every cow, except those soon to be withdrawn from the herd, as being near the end of their milking time, should be fully analysed. The milk of fifty-three cows was examined, and the results of these analyses are given in the following table (see next page). Among these cows four were found to give milk of most exceptionally bad quality. These four were tested again and again to make quite sure that no mistake had been made in the analyses. The average results of these tests are given in the following table, as also the average composition of the milk of the remainder of the herd:—

Average Composition of Evening's Milk.

——	Solids.	Fat.	Casein.
Of four abnormal Cows	10·21	2·52	1·87
Of remainder of Herd	12·95	3·85	2·53

Cattle Yielding abnormal Milk.—In the table showing the composition of the milk of individual cows there will be found four animals, Cherry, Ayshire Horns, No. 8, and Eighteen, who gave milk of such poor quality that it may be called abnormal. It will be seen that others were also peculiar. Thus, assuming 2·4 per cent. of casein to be a fair minimum amount for milk during the month of April, and 2·5 for milk during the month of May, we find that eight cows tested in the former months, and six in the latter, fell below these standards. The first two were discovered on the 18th April, and the milk was again tested on the 21st and 22nd, to make sure that there had been no mistake in the analyses.

Influence of Abnormal Milk.—The next step taken was to try and make a cheese from the milk of these cows, and see what effect the milk would have. It was only possible to get the milk of three of the cows into the small vat which had been made for experimental purposes. The first thing noticeable was the effect of keeping the milk of the abnormal cows out of the ordinary milk. Thus, on the day preceding this experiment, the composition of the milk of all the cows was as follows, side by side with which I give the composition of the abnormal milk on the following day, and of the milk from which the abnormal milk had been kept out:—

ANALYSIS OF EVENING'S MILK OF INDIVIDUAL COWS AT FENSWOOD FARM, 1898.

Name or No. of Cow.	Date.	Total Solids.	Fat.	Casein.	Albumin.	Yield.
						galls.
Queen	April 12	12·92	4·05	2·56	·45	...
Thornbury	April 12	13·78	5·20	2·33	·35	...
Tunley	April 12	13·18	4·29	2·40	·41	...
No. 1	April 12	13·10	4·01	2·52	·30	...
Wedmore	April 13	14·18	4·99	2·34	·38	...
Bower Ashton	April 13	13·94	4·50	2·51	·36	...
Tucker	April 13	12·86	4·21	2·10	·34	...
No. 2	April 13	11·74	2·96	2·46	·35	...
Violet	April 14	12·34	3·92	2·40	...	...
No. 3	April 14	12·34	3·73	2·17	·33	...
Spot	April 15	14·64	5·37	2·10	·46	...
No. 4	April 15	13·90	4·62	2·65	·34	...
No. 5	April 18	11·91	3·66	2·28	·31	...
No. 6	April 18	12·06	2·76	2·68	·57	¾
*Cherry	April 18	10·86	2·76	2·00	·35	1½
*Ayrshire Horns	April 18	10·44	2·72	1·88	·42	1½
Lady	April 19	12·12	3·52	2·25	·50	2
Dundry	April 19	12·92	3·99	2·04	·33	1¾
No. 7	April 19	12·56	3·48	2·70	·33	2
Daisy 2nd	April 22	14·50	4·80	...	·47	2¼
Baby	April 22	12·06	3·43	2·44	·58	2
Double Teat	May 10	14·92	5·76	2·73	·61	1¾
Thornbury 2nd	May 10	11·64	2·68	2·48	·36	1¼
Wrington	May 10	12·46	3·63	1·27 (?)	1·86 (?)	2
*No. 8	May 10	8·66	1·97	1·70	·47	1
Cockhorn	May 12	12·82	4·07	2·47	·34	1¾
*Eighteen	May 12	9·54	2·26	1·70	·56	1
Little Red One	May 12	11·16	2·76	1·93	·54	1½
Queen 2nd	May 12	13·10	3·78	2·63	·44	2½
Guernsey	May 13	12·74	3·84	1·93	·40	1
"Oldest of Five"	May 13	12·84	3·48	2·77	·49	1
Show Cow	May 13	13·08	3·49	2·80	·41	1¼
Short Teats 2nd	May 13	13·34	3·30	3·06	·62	¾
Black Teat	May 16	12·60	3·78	2·50	·18	1
Cocktail	May 16	13·40	4·07	2·64	·44	1
Cowslip	May 18	14·52	4·96	3·38	·61	1¼
Farmer	May 18	13·02	3·73	2·67	·36	1½
Daisy	May 18	13·32	3·79	2·96	·54	1
Pretty	May 18	12·26	3·71	2·31	·46	1
Kicker	May 27	12·90	3·78	2·67	·35	3
Single Rump	May 27	12·78	3·61	2·67	·40	2
Sally	May 27	12·42	3·42	2·34	·42	1¾
Short Teats	May 27	13·38	4·32	2·62	·38	2
Big Star	June 21	12·86	3·58	1·83 (?)	·37	1¼
Granny	June 21	12·76	3·65	2·70	·67	1½
Star	June 21	14·50	4·68	3·27	·43	1
Young Lady	June 21	13·66	4·29	2·57	·45	1½
Brass Horn	June 23	12·12	3·15	1·32 (?)	·52	1
Broad Horn	June 23	12·96	3·64	2·66	·55	1½
Happy	June 23	11·98	3·44	1·34 (?)	·52	1½
Big Red Heifer	Aug. 16	12·68	3·60	1·74	·30	1
Long Neck	Aug. 16	12·28	3·14	1·12	·42	1½
Spider	Aug. 16	12·72	3·40	1·52	·39	1½

* Cows yielding abnormal milk.

NOTE.—The results marked (?) are due to the fact that owing to some peculiarity in the casein it could not be accurately estimated (see also p. 36).

——	Solids.	Fat.	Casein.
June 7.—Mixed Milk of all Cows	12·16	3·31	2·49
June 8.—Abnormal Milk ...	10·84	2·86	2·00
June 8.—Remainder of the Milk	12·44	3·33	2·57

The effect of keeping the abnormal milk out of the cheese-tub was marked. Miss Cannon reported—"the curd came much firmer and nicer; it was shotty and of a good texture throughout. The curd here has never before been so good." Great difficulty was found in making a cheese from the abnormal milk alone. In the first place, the rennet seemed to have no action upon the milk. It was more than two hours after renneting before the curd set, though with the remainder of the milk, the same proportion of rennet had not only set the curd, but this was fit to cut forty-five minutes after renneting. The curd remained soft, and much fat was lost in the whey. The acidity developed very slowly at first, but, when it had started, went rapidly, which had been a characteristic peculiarity of the cheese-making at Long Ashton. The yield was exceptionally small, being only 6 lbs. of curd from 9 gallons of milk.

On June 16th the experiment was repeated. The following is the composition of the two milks on that day:—

——	Solids.	Fat.	Casein.
Abnormal Milk	10·74	2·50	1·95
Remainder of the Milk	12·54	3·58	2·52

In order to give this abnormal milk every chance, one quart of stale whey was added to ripen it, and 50 per cent. more rennet than for the ordinary milk. The result was better, but the yield of curd was only 7½ lbs. from 9 gallons and 1 quart of milk.

The whey did not contain such an excess of fat as on the former occasion, so that the small yield of curd was not due to loss in the whey. But there is one striking peculiarity of the curds of these two cheeses; whereas the abnormal milk curd on the 8th June contained 44·90 per cent. moisture, and on the 16th June 44·80 per cent., the curd from the remainder of the milk contained on the 8th June only 40·90 per cent., and on the 16th, 42·30 per cent. moisture.

These experiments, coupled with the abnormal composition of the milk, convinced me that, to some extent, the disadvantages which had been met with at Fenswood Farm were due to this source. These four cows gave milk in which all the peculiarities of the Long Ashton milk were concentrated—milk of low acidity and a small percentage of casein, yielding curd which contained an excess of moisture, and a whey which contained an excess of fat unless special precautions were taken to prevent this fat passing into the whey. Hence, at my request, three of the cows were disposed of. The fourth was kept for rearing calves, and none of her milk was allowed to be sent into the dairy.

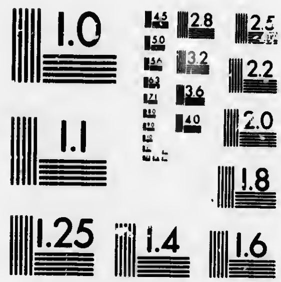
All four of these cows had been in the dairy during 1897, two having been bought that year for the purpose of obtaining the quantity of milk required for the School. The other two had been in the herd for some years past, having been bred by Mr. Harding. There was no sign of any disease or peculiarity in these cows. In fact, to all appearance they were as good cows as any in the herd, and their yield of milk, as shown in the table on p. 73, was up to the average. The one kept reared two calves well. The three cows which were disposed of had gone to a butter-maker.

Unchurnable Cream.—This butter-maker was surprised to find, after the introduction of these cows into the herd, considerable difficulty in churning the cream, which became so troublesome that the three newly acquired cows were suspected, and upon attempting to churn the cream from the milk of these cows separately, it was found almost impossible. The result was that the butter-making from this milk had to be given up, and the cows fattened for the butcher. I am of opinion that this abnormal milk is a peculiarity of certain strains of cattle, and I base this opinion not merely on the fact that no special cause could be found for the production of this milk, but because I have, from time to time, come across other cows in different parts of the country yielding similarly abnormal milk, and have not in a single instance been able to trace its origin to disease.

Practical Results.—The practical results are important. It is evident that if cheese-makers find exceptional difficulties in making cheese, they will have to consider how far these difficulties may be due perchance to one or more cows yielding abnormal milk. The way in which dairy farmers are in the habit of replenishing their herds with cows, the past history of which they know nothing whatever about is most indiscreet. In addition to the risk which farmers run of introducing disease into the herd by this system, it is now evident that they run a further risk of purchasing cows whose milk may materially deteriorate the produce of those which they previously possessed.*

* At no former Cheese School had the milk of each cow been analysed, so that it is not possible to say whether abnormal cows were present in other herds, nor how far other difficulties in cheese-making may be due to such source.

IMAGE EVALUATION TEST TARGET (MT-3)



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The Effect of Different Pastures on the Quality of Milk.

This subject of inquiry is one which presents considerable difficulties, and results obtained in any one year must not for one moment be expected to apply to all seasons, nor those obtained in one place to be applicable to others. Moreover, to satisfactorily investigate such a subject almost ideal conditions are requisite, and these have not existed at any site of the Cheese School. The conditions most suitable existed in 1891, at Vallis, where the fields were larger and the animals upon the same pasture longer than at any subsequent site of the Cheese School. But even at Vallis Farm keep was short, and the cows could not be left upon the same field or fields for any length of time. In order, however, to see whether any information upon this difficult question could be gathered, the following table was drawn up, showing the average percentage of the chief constituents of milk produced upon the various fields during each month, also stating the number of days' milk which these averages represent. The results are interesting, but they do not warrant any hard-and-fast conclusions being drawn therefrom.

1. It will at first sight be noticed that the milk improves in quality each month upon all the fields.

2. It will next be noticed that the milk produced in August on the Leaze and Stevens is superior in solids and fat, and inferior in casein, to that produced on the Summer Leaze and Leaze, and that the same result is obtained in September. This might have been accidental, but curiously enough the milk produced upon the Front and the Leaze is superior in both solids, fat, and casein, to that produced upon the Oxen Leaze and Leaze, or upon the Mixed Fields during August, while the same relative superiority is maintained throughout both September and October. This comparison might be carried further, but sufficient has been pointed out to show that in this instance there would appear to be a fluctuation in the constituents of the milk depending upon the pastures, which is independent of that fluctuation in quality due to season, or the prolongation of the time the cows have been in milk.

There are some minor subjects arising out of this table of averages, one of which is of considerable interest. There are few, if any, continuous series of analyses of milk in which the percentage of casein has been determined; the result is, that a somewhat new and important fact is revealed regarding the fluctuations of this constituent. It will be noticed that the casein is affected both by the time of the year and by the nature of the pasture, though it is only to a slight extent as compared with the variations in the fat.

TABLE showing the AVERAGE COMPOSITION of the MILK, arranged according to the FIELDS on which the Cows were feeding.

NAMES OF FIELDS.	August.					September.					October.				
	Days fed.	Composition of Milk.				Days fed.	Composition of Milk.				Days fed.	Composition of Milk.			
		Solids.	Fat.	Casein.	Ash.		Solids.	Fat.	Casein.	Ash.		Solids.	Fat.	Casein.	Ash.
The Leaze and Stevens.	3	12·92	4·09	2·78	·77	2	12·88	4·14	2·93	·79	...	...	...	...	...
Summer Leaze and The Leaze ...	6	12·82	4·02	2·36	·76	1	12·80	4·07	2·95	·80	...	...	...	...	...
The Front and The Leaze.	3	12·65	3·88	2·84	·75	3	13·22	4·27	3·07	·77	6	14·18	5·11	3·30	·76
Oxen Leaze and The Leaze.	3	12·46	3·79	2·76	·79	10	13·13	4·19	3·04	·78	16	13·74	4·68	3·21	·77
Mixed Fields ...	6	12·53	3·80	2·72	·77	11	12·93	4·07	2·94	·77	7	13·69	4·64	3·17	·77
The Leaze*	4	12·38	3·71	2·71	·78	2	12·86	4·08	2·93	·79	...	...	...	...	...

* The Leaze was fed by itself only on 6 days—on other days it was fed in conjunction with "Stevens," "Summer Leaze," "The Front," or "Oxen Leaze."

Summary of Results.

From the preceding facts it would appear that *quantity* of milk depends mainly upon succulent food. Thus, where the conditions are favourable to the production of abundant grass, be those conditions local or climatic, the maximum milk yield has been obtained.

The *quality* of milk appears to depend upon far more numerous factors. The cattle themselves, and the nutriment in their food, are the primary causes of fluctuation. But it will be seen that the nutriment in the food depends not only upon the character of the soil but also upon climatic conditions. Moreover, the milk will vary in quality not only in a general way, by at times containing more solid matters than at other times, but there is distinct evidence that the constituents of these solids also vary according to the food of the cows.

The Volume of Morning's and Evening's Milk.

During the whole period of these observations, the volume of morning's milk has always been greater than that of the evening's. The maximum variation is in the month of October, the smallest variation in the month of July. The volume of the morning's milk in April is one-fifth more than that of the evening's; in May it is one-sixth, in June one-eighth, in July one-twentieth, in August one-eight, in September one-fifth, and in October one-fourth. Hence the relative increase is greatest in October, and next in April and September.

These facts are not difficult to explain. In July the work of harvest keeps the farm hands busy until late in the evening and the evening's milk is brought into the dairy later in that month than during any other part of the year. Thus the time which elapses between the two milkings is more equal than during any other month. On the other hand, in October, the dark mornings make the milking later than usual, while the drawing in of the day causes the milking to be done earlier in the evening, so that the time which elapses between the two milkings is most uneven. Thus it would appear that the morning's milk is more than the evening's mainly owing to the longer time which has elapsed since the last milking, in other words, the animal has had a longer time in which to produce the milk.

Decline in the Milk Yield due to the time which has elapsed since Calving.

It appears from the results of these observations that cows which calve in the month of March and April come to the flush of their milk yield about one month or six weeks after calving, and maintain this flush for about four to six weeks. After this period there is a decline in the quantity of milk yielded.

Is there any definite proportion in this falling-off in the milk yield? Take the highest average daily yield (146 gallons in June) as the maximum from which the decline commences. The falling off during the month of July amounts to 19 gallons, in August to 14, in September to 18, and in October to 25. Thus the decline for each month is about one-eighth the maximum yield. The following table shows this very clearly.

FALLING OFF IN MILK YIELD DUE TO TIME SINCE CALVING.

Loss at the end of	Average falling off in Gallons.	Proportion approximately.	If Proportion exact, Gallons.
1 month	19	One-eighth = $\frac{1}{8}$	18
2 "	33	Two-eighths = $\frac{1}{4}$	36
3 "	51	Three-eighths = $\frac{3}{8}$	54
4 "	76	Four-eighths = $\frac{1}{2}$	72

The Annual Milk Yield of Somerset Cows.

As the observations were carried on each year for only seven months of the milking period it is not possible to state with certainty what is the actual yield of the cows at each farm. I have, however, attempted to estimate this yield in the following manner. In the tables, p. 81-85, the average yield per head per day is given; by multiplying this by the number of days in each month we obtain the total monthly yield, from which the total yield for seven months is easily obtained. The yield during the remaining three months must be estimated. I have done this by assuming that the loss each month would be only one-tenth of the maximum yield. The results thus obtained are as follows:—

Year.	Actual Yield, 7 months.	Estimated Yield, 10 months.
	Gallons.	Gallons.
1891	426	473
1892	443	501
1893	492	550
1894	511	568
1895	461	503
1896	464	500
1897	474	564
1898	453	507

If, as these results would justify one in assuming, the average yield of milk per cow is only about 500 gallons, it is evident that considerable improvement is not only possible, but highly desirable, and could probably be brought about at no very great expense by greater care in breeding.

Table I.

AVERAGE COMPOSITION OF MILK for each MONTH during the YEARS 1891–98.

Month.	Year.	Locality.	Total Solids.	Fat.	Casein.
			per cent.	per cent.	per cent.
	1892	Axbridge	11·75	3·06	2·35
	1893	Butleigh	11·89	3·09	2·43
	1894	Mark	12·31	3·29	2·42
April ...	1895	Haselbury*	12·65	3·70	2·43
	1896	Cossington	12·75	3·83	2·43
	1897	Long Ashton‡ ...	12·74	3·87	2·45
	1898	" " ...	12·28	3·48	2·29
	1892	Axbridge	12·04	3·12	2·55
	1893	Butleigh	12·01	3·05	2·59
	1894	Mark	12·51	3·35	2·73
May ...	1895	Haselbury*	12·58	3·39	2·60
	1896	Cossington	12·78	3·70	2·64
	1897	Long Ashton‡ ...	12·42	3·53	2·48
	1898	" " ...	12·52	3·55	2·51
	1892	Axbridge	12·20	3·17	2·65
	1893	Butleigh†	12·03	3·08	2·65
	1894	Mark	12·52	3·40	2·69
June ...	1895	Haselbury*	12·56	3·51	2·58
	1896	Cossington	12·59	3·57	2·64
	1897	Long Ashton‡ ...	12·28	3·42	2·43
	1898	" " ...	12·24	3·38	2·49
	1892	Axbridge	12·20	3·21	2·66
	1893	Butleigh†	12·14	3·20	2·49
	1894	Mark	12·52	3·47	2·64
July ...	1895	Haselbury*	12·68	3·60	2·67
	1896	Cossington	12·61	3·66	2·58
	1897	Long Ashton‡ ...	12·20	3·39	2·35
	1898	" " ...	12·47	3·52	2·50
	1891	Vallis	12·61	3·87	2·76
	1892	Axbridge	12·28	3·38	2·65
	1893	Butleigh†	12·14	3·19	2·77
ugust ...	1894	Mark	12·78	3·70	2·76
	1895	Haselbury†	12·[illegible]2	3·80	2·68
	1896	Cossington	12·73	3·83	2·66
	1897	Long Ashton‡ ...	12·45	3·63	2·38
	1898	" " ...	12·71	3·84	2·43

* For first and third weeks in month. † For first week in month only.
‡ Once in eight days.

Table I.—continued.

Month.	Year.	Locality.	Total Solids.	Fat.	Casein.
			per cent.	per cent.	per cent.
September...	1891	Vallis	13·00	4·13	2·99
	1892	Axbridge	12·56	3·57	2·87
	1893	Butleigh†	12·53	3·53	2·95
	1894	Mark	13·05	3·93	2·83
	1895	Haselbury*	13·03	3·94	2·91
	1896	Cossington	13·19	4·31	2·71
	1897	Long Ashton‡ ...	12·89	3·86	2·59
	1898	" " ...	12·76	3·91	2·59
October ...	1991	Vallis	13·81	4·75	3·21
	1892	Axbridge	13·13	4·00	3·08
	1893	Butleigh†	13·49	4·30	3·14
	1894	Mark	13·46	4·39	2·95
	1895	Haselbury*	13·70	4·55	2·92
	1896	Cossington	13·38	4·41	2·85
	1897	Long Ashton‡ ...	13·22	4·18	2·71
	1898	" " ...	13·24	4·20	2·75

* For first and third weeks in month. † For first week in month only.
‡ Once in eight days.

Table II.

AVERAGE YIELD OF MILK, CURD, AND CHEESE for each MONTH during the YEARS 1891–98.

MONTH.	VALLIS, 1891.						
	1	2	3	4	5	6	7
	Average No. of Cows.*	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	40	2·02	81	73	69	4	·85
May	46	2·59	119	117	111	6	·93
June	50	2·64	132	132	123	9	·93
July	50	2·24	112	114	107	7	·96
August ...	50	1·82	91	99	91	8	1·00
September ...	50	1·58	79	87½	82	5½	1·04
October ...	50	1·04	52	64	59½	4½	1·14
Average ...	48	1·99	95	98	92	6	·98

* No accurate record of the number of cows was kept during 1891, 1892, and 1893, so these figures are only approximate.

Table II.—continued.

Month.	AXBRIDGE, 1892.						
	1	2	3	4	5	6	7
	Average No. or Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	36	2·20	79	70	66	4	·83
May	42	2·60	109	102	94	8	·86
June	50	2·54	127	122	113	9	·90
July	50	2·32	116	115	108	7	·93
August	50	2·00	100	102½	94	8½	·94
September ...	50	1·68	84	91	85	6	1·01
October ...	50	1·16	58	68	62	6	1·07
Average ...	47	2·07	96	96	89	7	·93

Month.	BUTLEIGH, 1893.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	40	2·65	106	96	89	7	·84
May	51	2·92	149	142	132	10	·88
June	55	2·56	141	130	121½	8½	·85
July	55	2·43	134	129	122	7	·91
August ...	55	2·43	134	131½	124	7½	·92
September ...	55	1·86	102½	109½	104	5½	1·02
October ...	55	1·24	68	80	77	3	1·13
Average ...	52	2·30	119	117	110	7	·93

Table II.—continued.

Month.	MARK, 1894.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	33	3·12	102	101	96	5	·94
May	50	2·96	148	148	140	8	·94
June	51	2·74	140	141	132	9	·94
July	52	2·48	129	131	124	7	·96
August ...	52	2·15	113	118	112	6	1·00
September ...	53	1·89	100	112	106	6	1·06
October ...	53	1·40	74	87	82	5	1·11
Average ...	49	2·39	115	120	113	7	·99

Month.	HASELBURY, 1895.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	46	2·74	126	126	118	8	·94
May	61	2·87	175	167	159	8	·91
June	70	2·61	183	168	159	9	·87
July	70	2·09	146	148	138	10	·95
August ...	70	1·99	139	152	138	14	·99
September ...	69	1·64	113	124	119	5	1·05
October ...	65	1·17	76	90	87	3	1·14
Average ...	64	2·16	137	139	131	8	·98

Table II.—continued.

Month.	COSSINGTON, 1896.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	51	3·19	163	136	130	6	·80
May	56	2·96	166	164	157	7	·94
June	59	2·60	153	152	142	10	·93
July	60	2·28	137	139	131	8	·96
August ...	60	1·78	107	114	110	4	1·03
September ...	60	1·28	77	86	80	6	1·04
October ...	50	1·12	56	66	61½	4½	1·10
Average ...	57	2·17	123	122½	116	6½	·97

Month.	LONG ASHTON, 1897.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	36	2·55	92	90	85	5	·92
May	45	2·88	130	124	114	10	·88
June	48	2·70	130	123	113	10	·87
July	49	2·08	102	95	87	8	·85
August ...	49	1·83	90	85	78	7	·87
September ...	50	1·76	83	89	83	6	·94
October ...	47	1·68	79	81	77	4	·97
Average ...	46	2·21	101½	98	91	7	·90

Table II.—continued.

Month.	LONG ASHTON, 1898.						
	1.	2.	3.	4.	5.	6.	7.
	Average No. of Cows.	Average yield of Milk per head per day.	Vol. of Milk.	Curd taken from Press.	Cheese when Sold.	Shrinkage in Ripening.	Cheese from one gallon of Milk.
		galls.	galls.	lbs.	lbs.	lbs.	lbs.
April	34	2·47	84	79	74	5	·88
May	44	2·75	121	116	110	6	·91
June	47	2·79	131	124	119	5	·91
July	47	2·30	108	106	101	5	·93
August ...	49	1·72	84	82	77	5	·92
September ..	44	1·57	69	69	64	5	·93
October ...	47	1·23	58	63	59	4	1·02
Average ...	44	2·12	94	91	86	5	·93

Table III.

CURD OBTAINED FROM ONE GALLON OF MILK.—AVERAGE FOR EIGHT YEARS.

April	·92 lbs.
May	·97
June	·96
July	·99
August	1·03
September	1·08
October	1·15

Part V.

A Systematic Description of the Recorded Observations.

Concerning Acidity Determinations.—Straining Milk.—Rennet.—The Effect of a High Scald (Spring Cheeses.)—Temperature of the Curd when Vatted.—Moisture in Curd.—The Composition of Milk.—The Fat of Milk.—The Ultimate Distribution of the Constituents of the Milk.—The Time which is required to Make a Cheese.—The Ripening of Curd.—The Composition of Ripe Cheeses.—Tables: Monthly Averages of some Results of Observations.

Concerning Acidity Determinations.

The (apparent) Acidity of Fresh Drawn Milk.—It is a somewhat remarkable fact that milk, the moment that it is drawn from the cow, shows a high proportion of acid. This acidity certainly is not lactic acid, and I have proved, by experiment, that it is not carbonic acid. Milk is known to contain acid salts, and we must assume that these explain to a certain extent the results obtained.

This acidity of the milk as it came from the cow varied at different sites, i.e., each year, and I was therefore led to believe that it was associated with the soil or perhaps with the food, which is nearly the same thing, as the cattle would for the most part be feeding on the pastures during the cheese-making season. But what was more striking was the fact that at each site the acidity of the milk varied more or less from month to month. When we come to average the acidity for the seven years of the observations, it will be seen that the fluctuations almost disappear, and we obtain a nearly constant acidity for each month, equal to 0·19% of lactic acid. It seldom rises above 0·22, nor should it fall below 0·17 without inquiry into the cause, as will be explained hereafter. It was not until 1897 that any abnormal condition of the milk as regards acidity arose. Then the acidity of the milk was so low that it became necessary to investigate the cause.

Milk of Abnormal Acidity.—The cause of the abnormal acidity of the milk in 1897 was discovered in 1898. As previously pointed out on p. 72, certain cows were discovered at Long Ashton yielding abnormal milk. Upon testing the acidity of this milk, the results obtained were for Cherry, ·14 per cent., and for Ayrshire Horns ·13 per cent. These results, it will be seen, are quite exceptional—the average of the herd being ·19—and were equally unexpected. It was, therefore, determined to follow up this line of inquiry, and, side by side with the complete analyses of the milk, estimations were subsequently made of the acidity of each cow's milk. It was then discovered that the acidity of the milk varied generally in proportion to the casein in the milk. This is well shown by the following table, which gives not only the average acidity of the milk of the four exceptional cows, but also the acidity of the other milks, taking the averages according to the proportion of casein they contain.

Milk containing.—	Average acidity
Under 2 per cent. casein	·14
Over 2 and under 2·5 per cent. casein ...	·20
Over 2·5 and under 3 per cent. casein ...	·21
Over 3 per cent. casein	·23

As it is generally found that the proportion of solids in the milk is in direct relation to the proportion of casein, we may roughly express these results by saying that the greater the proportion of solids in the milk, the higher is the natural acidity of that milk. This probably accounts for the fact that the acidity of the milk is generally higher in the latter part of the year, when the milk is richer, than in the spring. It appears to me that these results justify the conclusion that the estimation of the acidity of each cow's milk would give the cheese-maker a rough (though not absolutely accurate) guide to the proportion of casein and solids in the milk, and as to its suitability for cheese-making. Any cow yielding milk of very low acidity should be regarded with suspicion by the cheese-maker.

The Effect of Milk of Abnormal Acidity.—The influence of the abnormal milk of the four cows upon the whole of the milk and the cheese produced therefrom was remarkable; but it can only be appreciated when studied in conjunction with the effect of keeping it out of the mixed milk.

In the first place, this milk, owing to its low acidity and small proportion of casein, diminished the percentage of both acid and casein in the mixed milk.

The Effect of the Low Acidity.—Diminishing the percentage of acid in the milk necessitates a lower percentage of acid being obtained in the curd before grinding, for the lower the percentage of acid in the milk as drawn from the cows the lower must be the acidity obtained in the liquid from press. It will subsequently be shown that the acidity of the liquid from press, for a fairly quick ripening cheese, should be five times that of the evening's milk when brought into the dairy, and with ordinary milk this can easily be obtained. But when dealing with abnormal milk a difficulty arises due to the want of casein.

The Effect of the Low Casein.—Owing to the deficiency of the milk in casein, the curd will be wanting in contractile power, so that by the time sufficient acid has been produced in the curd for it to be ground, it will not be sufficiently dry—in other words, it will not have expressed sufficient whey. The practical difficulty which the cheese-maker has to meet is to decide whether to put away the curd when sufficient acidity is developed, although it would not be properly dry, and the cheese would consequently ripen rapidly—for a wet curd always ripens more rapidly than a dry curd—or to obtain the requisite dryness with an excess of acidity, which would also make the cheeses ripen rapidly and further introduce the risk of producing an acid cheese. Miss Cannon decided to adopt the former system, and in my opinion was justified in doing so. Yet it necessarily resulted in certain peculiarities which will be referred to subsequently. (See *Moisture in Curd.*)

The Ripening of Milk.—Although the influence upon the milk of keeping it all night at a high temperature is undoubtedly marked, yet it is strange to see that the proportion of acid which is found in the evening's milk the following morning shows no very great advance upon that which was present in the evening when it came into the dairy. This is undoubtedly due to the fact that in Cannon's system of make no very great amount of acidity needs to be developed in the evening's milk, the necessary acidity generally being obtained by means of sour whey. Hence the evening's milk is well stirred, and allowed to fall in temperature during the night. But when, as has been sometimes the case, it was desired to ripen the evening's milk and, for this purpose, it has been kept warmer than usual, the acidity produced has been considerable, and I have known it rise during the night from ·20 to ·25 per cent. This, however, is exceptional; but it proves that the acidity test is capable of showing any exceptional rise in acidity. The average rise in the acidity of the evening's milk during the night will be 0·01 per cent., though, if the dairy is very warm during the night, it may rise ·02 per cent. Hence the average acidity of the night's milk in the morning is 0·20 per cent. It was with a view of trying to discover more accurately the exact amount of acid produced during the night, that in 1896 the acidity determinations were made with a soda solution only $\frac{1}{5}$th the strength of that ordinarily used. After special experiments had been made on the subject, this was found to be the best strength solution to use. By its use it was possible to estimate the acidity to $\frac{1}{50}$th part of 1 per cent. The results obtained showed very clearly the difference between the evening's milk when brought into the dairy and after standing through the night, and also confirmed those which had been previously obtained with the ordinary solution. As the use of this dilute solution is attended with difficulty, it had better not be employed by anyone except a trained chemist.

As it is of the utmost importance to the cheese-maker to know the acidity of the evening's milk in the morning, and as some difficulty has been found in obtaining sufficiently accurate results, it may be well to here describe a method of distinguishing the ripeness of milk by means of rennet, which is largely employed by cheese-makers and gives, with care, reliable results, though, in my opinion, it is quite as difficult to use as the acidimeter.

Testing Ripeness of Milk by Rennet.—This system of testing the ripeness of the milk is based upon the fact that the time which a given quantity of rennet takes to curdle a given quantity of milk at a definite temperature depends upon the acidity of the milk. To obtain accurate results, it is essential that the rennet should be from the same source for every test, and that the volume of milk and of rennet and the temperature of the milk should always be the same, and be most accurately determined.

The test is made as follows:—4 oz. of milk at 84° Fahr. are poured into a vessel, which can be placed in another vessel containing water at 84° Fahr. A few minute pieces of cork or straw-skin are floated on the milk; 3·55 c.c. (1 drachm) of rennet (some use 1 teaspoonful) are now accurately measured and delivered into the milk rapidly. The watch, which must have a second-hand, is held in the left hand, and the time the rennet is added must be accurately noticed. Stir the milk rapidly in a circular direction, and remove the stirring-rod at the end of 10 seconds. The straws or cork will revolve with the milk. But suddenly they will stop, which indicates that the milk has curdled. Time the moment they stop—to the second. The number of seconds which the rennet takes to curdle the milk shows the ripeness. Each maker knows by experience the standard he wishes to work up to. About 19 to 22 seconds is usually the time taken.

I have carried out a series of experiments with the rennet test, side by side with the acidimeter test, and the results obtained are almost identical. Hence the rennet test can be relied upon in careful hands, but great care is undoubtedly necessary in its use, if reliable results are to be obtained.

Ripening Evening's Milk.—Seeing how necessary it is to ripen the evening's milk properly, many experiments have been made to this end, one of which, by the addition of a little sour whey to the milk, may here be mentioned. The acidity of this whey was ·35 per cent. when added to the evening's milk at 6.15 p.m., the volume of milk being 52 gallons. The acidity of the remaining sour whey next morning was ·42 per cent. But the acidity of the milk which in the evening was only ·19, was in the morning ·66 per cent., hence the whole of it was a solid mass of curd. The main cause of this result was the high temperature of the milk, and, as a consequence, the rapid development of acidity. A number of experiments were subsequently made with small quantities of whey upon a definite quantity of milk kept at a constant temperature in the incubator. The results are tabulated below, being first calculated to 1,000 volumes of milk, so as to make them easier of comparison:—

RESULTS of EXPERIMENTS on the RIPENING of MILK by addition of WHEY taken from the tub after BREAKING the CURD.

Volume of Milk.	Volume of Whey.	Temp. at which kept.	Milk curdled.	Acidity of the curdled Milk.
				per cent.
1000	10·0	75–85	Before 13 hours	·64
"	5·0	"	"	·62
"	2·5	"	"	·57
"	10·0	67–77	After 15 and before 23 hours	·70
"	5·0	"	" "	·70
"	2·5	"	" "	·69
"	2·0	64–72	19 hours 20 minutes after	·65
"	1·0	65-72	22 hours after	·65
"	·5	65-72	22 hours 50 minutes after	·64

It is very evident that the action of sour whey upon the milk is both powerful and uncertain, and the rennet present in the whey may have contributed thereto. Therefore it is quite impracticable to use sour whey to raise the acidity of the evening's milk during the early and late months of the cheese-making season. But the influence of temperature in developing the acidity is well shown in the results obtained, which indicate the imperative necessity of keeping the milk and dairy warm at night, especially during cold weather, if we wish to ensure sufficient ripeness in the milk by the morning.

Whey Cream.—A second experiment was made to see whether more rapid development of acidity could be obtained, and the value of the cheese enhanced, by adding the whey cream from the previous day's make to the milk in the warmer, so as to get it well mixed with the milk before renneting. The quantity of whey cream was ½ gallon. Very little difference was manifested during the making of the cheese, except that the whey had on its surface an oily appearance, and had a slightly strong smell. The addition of the whey cream promoted the souring of the curd; while the fat did not come out again in the whey, but enriched the curd. Where whey butter has but little sale, or only at a low price, the practice of putting the whey cream back into the next day's milk may be advantageous, especially in the early months of the season, provided there be no taint in the whey.

The Influence of Rennet on Acidity.—In the act of setting, the acidity of the milk partly disappears. This is proved by the small amount of acid found in the first whey which separates from the curd after it is cut. It will be found on consulting the tables (Col. 25) that the acidity of the whey at this stage is only two-thirds that of the original milk. It is difficult to state what change has taken place. If the original acidity of the milk were due to acid salts alone, it would not be so difficult to explain, for the casein in milk is undoubtedly combined with lime, which, to a certain extent, is set free in the act of coagulation and would then combine with the acid salts and partly neutralise them. Two things, however, are certain: first, that all the lime which is combined with the casein is not liberated in the act of setting, for a large quantity subsequently separates from the curd; secondly, it is almost equally certain that some of the acidity of the milk is due to the acid nature of the casein itself. Whatever the changes may be they are evidently chemical changes, and follow the law of all chemical change in being exactly proportional.

The Development of Acidity in the Whey.—Alike one of the most important and at the same time one of the most difficult operations in the manufacture of a cheese, is to obtain the necessary amount of acidity in the whey before it is drawn. That condition of the curd when in the whey, which the practical cheese-maker calls "shotty," and judges by the feel of the curd, and by which he estimates whether the whey may be drawn or not, is a condition which may be brought about by a development of acidity, or by heat alone, though in practice it is the result of a combination of the two. In the Cannon system of cheese-making it is necessary that this condition should be brought about by the development of acidity. Under favourable circumstances, this condition of the curd is coincident with the development in the whey of an acidity slightly greater than the acidity of the milk before renneting. Thus, with normal milk of an acidity of 0·19, that of the whey should be 0·20. But it is only occasionally that this amount of acid can be obtained. Nevertheless the cheese-maker should aim at obtaining it. The greatest difficulty will arise during the months of April and May, and is probably due to the milk not being properly ripened, in fact it is always difficult to obtain when dealing with milk of low acidity. It is similarly difficult with milk of abnormal quality, whether this be due to excess of fat, or a deficiency of casein. When from whatever cause there is a difficulty in obtaining this amount of acidity in the whey, care must be taken not to stir too long, but to allow the curd to settle and rest in the whey until the requisite amount of acidity has been developed. Under such circumstances it will probably only be possible to obtain in the whey an acidity ·01 or ·02 per cent. below that of the mixed milk.

The Influence of the Scald on Acidity.—Up to the time of cutting the curd, the acidity present in the milk and whey, as already described, is due mainly to acid salts.

The subsequent production of acidity in the whey and curd will be due to the growth of a certain organism or bacterium, to be described more fully in a subsequent portion of this report, but which is known as the bacillus acidi lactici. This organism feeds upon the sugar of the milk, and in so doing converts it into lactic acid. Now both lactic acid and heat have the power of contracting the curd, rendering it firm, and expelling from it that liquid which is known as whey. When the milk sets the bacteria are caught in the curd, and only comparatively few escape in the whey. Thus it is that the formation of acidity, during cheese-making, is taking place mainly in the liquid within the curd, and not in the liquid surrounding the curd. This is well shown by comparing the acidity of the whey surrounding the curd (Col. 34) with the liquid which drains from within the curd when this is piled (Col. 35). This fact has many important bearings upon the manipulations of cheese-making, and is the one which more than any other gives rise to the various systems of cheese-making which exist.

If then the temperature of the scald be low, say, 94° F., the contraction of the curd due to heat is comparatively slight, and whatever contraction takes place is mainly due to the formation of acid within the curd, and the contracting power which it exerts. But if the temperature is higher, then the contracting power of heat comes into play side by side with that of acidity, and exerting more and more influence the higher the temperature until, with a scald temperature of 105° F., it is possible to obtain the curd in a sufficiently "shotty" condition to be fit for the whey to be drawn off without any material increase in the acidity. True, the greater heat of this scald is slightly more favourable to the rapid growth of the bacillus acidi lactici, but, on the other hand, the contraction of the curd withdraws from the curd the whey containing the sugar on which the bacilli feed, and it will always be found that the less whey there is in the curd the slower will be the production of acidity. For this reason, a wet curd is one which may become very rapidly acid, hence the origin of what will be found in the description of the Cannon system of cheese-making in a subsequent portion of this report as a soft acid curd.

The Development of Acidity in the Liquid in Curd.—From the time that the whey is drawn off the acidity developes within the curd only, and the quantity of acid has been estimated in the liquid which drains from the curd during each subsequent process to which it is subjected. The drainings from each stage were collected separately, and the results of the acidity determinations are given in the tables in Cols. 39-45. The development of acidity during these stages depends upon several factors, first and principally, on the number of bacteria present in the curd when taken from the tub, secondly, on the heat of the curd and whether this heat is maintained or not, thirdly, on the moisture in the curd, and lastly, on the amount of air which is allowed to get to the curd during the operations. Thus it is that, while on one day the curd is fit to be ground, there having been already developed sufficient acidity, after the first or second cutting, and quite early in the afternoon, on other days it is not fit to grind, owing to the absence of acidity, until it has been cut twice and turned four or five times at intervals of about one hour, so that it is not ready to be ground until late at night.

In the manufacture of a Cheddar Cheese the greatest difficulty which the maker had to contend with, before the introduction of the means of estimating acidity, was to determine when the curd was fit to grind. If the curd is ground before sufficient acidity is developed, then the cheese does not ripen properly, and often puffs up and is blown. On the other hand, if too much acidity is developed, the cheese ripens too rapidly, is too acid when it should be ripe, and will sometimes run wet in the cheese room or crack and afford a lodging for the cheese fly. Prior to the introduction of the acidimeter, the cheese-maker had to depend upon the taste, appearance, and texture of the curd to determine when it was fit to grind. My investigations soon convinced me that the amount of acid present in the whey which drains from the curd, when in the cooler, was an accurate indication of the fitness of the curd for grinding. In order to fix a standard for this acid, the average acidity of the liquid from the curd immediately preceding grinding has therefore been calculated, and the results are given in Col. 45a.

Now arises the most important question. What should this acidity be. As the acidity which will control the cheese is indicated by the liquid from press, the cheese-maker must first determine what the acidity of that liquid should be. Then, making allowance for the rise or fall in acidity which will take place during grinding, vatting, and pressing the curd, he will be able to estimate what acidity the liquid which drains from the curd when on cooler should show immediately before that curd is ground.

The Acidity of the Liquid from Press.—These figures (Col. 53) must be studied in conjunction with those of Col. 45a just referred to. They show that on an average the acidity rises in the whey or curd during the time of grinding and placing in the vat from ·92 to 1·02, per cent. Hence, if we can determine what amount of acidity is requisite in the liquid from the press, we shall have a standard for the liquid from the curd when this curd is fit to be ground. Our chief consideration in fixing this standard will be the time in which we desire the cheese to be ripe. If we wish a slow ripening cheese then the acidity must be lower, if a very quick ripening cheese, higher, than our ordinary standard

Another consideration of importance is the fact that an acidity in the liquid from press which, at one school, or at one time of the year, has given an excellent cheese, at another school or even at the same school, but at a different period of the season, has given either a too acid cheese or one showing a deficiency of acidity. This subject has been one of considerable difficulty to explain, but, after a very careful study of all the facts, it would seem to be due to the varying quality of the milk. Where the milk from which the cheese was made has shown a high proportion of acidity, there a cheese made with a high acidity in the liquid from press has been excellent. But if from a milk with a low acidity a cheese is made having a high proportion of acid in the liquid from the press, this cheese will, at the end of three months, which may be taken as the average time of ripening for cheese made on the Cannon system, be found to be too acid. I have carefully studied the results of the eight years' work as regards the acidity of the milk, and of the liquid from press, side by side with the opinions of the cheese-buyer upon the various cheeses, and it appears to me that the amount of acid required in the liquid from press must depend entirely upon the original acidity of the milk. For a cheese of fairly rapid ripening quality, the liquid from press must contain five times the acidity of the original milk. Thus, while on one farm, where the milk shows 0·18 per cent. of acid when brought into the dairy, the acidity of the liquid from press may be taken as ·90; on another, where the acidity of the milk is ·20, the acidity of the liquid from press should be 1·00 per cent., and in the autumn, or at farms such as Vallis, when the milk shows an acidity of ·22 per cent, the liquid from press may contain 1.10 per cent. of acid.

There are certain to be conditions on some farms which may necessitate some slight variation from this standard, apart from the variation which will be necessary for a slower ripening cheese. Those cheese-makers who are using the acidity apparatus as a guide in their cheese-making would do well to bear these facts in mind. This standard for the acidity of the liquid from press also presupposes that the curd is sufficiently dry. (See *Moisture in Curd.*) If the curd is moist, then the standard of acidity will be too high. Acid cheeses are nearly always the result of a moist curd and high acidity in liquid from press.

Acidity going Back.—Frequently during the months of August, September, and October the acidity of the liquid from the press is less than the acidity of the last drainings from the curd when on the cooler. It has been noticed on isolated occasions in most years, but never to such an extent as to affect the averages, until 1898. It is invariably associated with a fæcal taint in the curd, so that it is probably the result of bacterial changes. Its practical importance is this, that when such taint arises it is necessary to develop in the curd before vatting *more acidity than is desired in the liquid from the press*, otherwise the cheese will be tainted and inferior.

The Influence of Salt on Acidity.—It is a common belief among cheese-makers that the salting of the curd checks the formation of acidity. This supposition is entirely erroneous, so far as my experience goes. Indeed, so necessary is salt for the growth of bacteria, that it is one of the substances which must be placed in all artificial nutriment prepared for their growth.

A study of the tables shows that even during the addition of salt and the placing of the curd in the vat, the formation of acidity has been still going on, so that the liquid which comes away from the press is more acid than the last drainings from the curd before grinding.

Tests were made of the liquid from press immediately pressure was placed on the cheese, and the average acidity of the liquid was found to be 1·075 per cent., while the liquid coming away half an hour afterwards had an average acidity of 1.088 per cent.

However, with the idea that it would be of more practical value to make a distinct experiment upon this point, and record the result, the following course was adopted. On the 6th of June, 1895, the curd was salted and divided into two portions, one was vatted immediately after salting, the other spread out to cool, and left for three-quarters of an hour before vatting. The acidity of the drainings before grinding was ·91 per cent. The acidity of the liquid from the press of the portion vatted immediately after grinding was 1·08 per cent., while that of the portion which was allowed to stand for three-quarters of an hour was 1·22 per cent. The portion vatted immediately was at a temperature of 76° Fahr., that vatted after standing three-quarters of an hour was 72° Fahr. The acidity of the liquid from the press of the portion first vatted was again taken when the second portion was vatted, or three-quarters of an hour after it had been in the press. It was then found to be 1·14 per cent. It will thus be seen that the salt did not retard the formation of acid in either portion. The formation of acid was more rapid in the portion exposed to the air than in the portion placed in the press, even though the latter was 4° Fahr. higher in temperature.

This experiment proves beyond doubt that salt does not stop nor even retard the formation of acid in the curd. It also shows why, in those methods of cheese-making in which the curd is spread out to cool before being vatted, it is not necessary to produce so much acidity in the earlier stages as is essential when the curd is vatted immediately after being ground.

The Acidity of Curd.—Curd is one of those complex organic substances about which chemists know very little. In 1892, I found that, during the process of cheese-making, a large quantity of lime was extracted from the curd not only in the whey, and in each of the drainings from the curd on the cooler while it is developing acidity, but also from the curd when finally placed in the press. Now, this lime would exist in the milk, or more accurately in the curd when just set, either in solution or in combination with casein; if in solution, it would subsequently be present in the whey, but if in combination with casein, it would remain in the curd. The analyses of whey show that only about two-thirds of the mineral matter of the milk are present in it, so we must conclude that the remainder is in the curd. From a series of analyses made of the liquid from the press and of the curd, I find 0·5 per cent. of lime in the former, and nearly 1 per cent. in the latter. The only possible supposition is that it is combined with the casein. It would, therefore, appear that casein is an acid substance, that it is combined with lime in curd, and that as lactic acid is produced in the curd, it takes away this lime and leaves an acid casein behind. If this be the right explanation, then it is evident that curd, in addition to the acidity which it possesses from the lactic acid it contains, would have an acidity of its own partly proportionate to the amount of lime which had been taken away from the casein, but mainly in proportion to the quantity of pure casein present.

My first attempt to determine the acidity of curd was made in 1891. Considerable difficulty was experienced, and after frequent attempts, the only plan found practicable was to cut the curd into very fine pieces, to weigh out 1 gramme, place it in a glass tube, and boil with 25 c.c. of standard soda solution, until the whole of the curd was entirely dissolved. The solution was then washed into a glass vessel, and the quantity of free soda present estimated by standard sulphuric acid. This being deducted from the quantity originally taken, showed the amount of alkali neutralised by the curd.

Thus:—

	c.c.
Quantity of Alkali taken	25·0
Quantity present after boiling with curd	21·3
Neutralised by curd	3·7

which would represent 3·7 per cent. of lactic acid, only 1 gramme of curd having been taken.

Finding such a difficulty in the estimation of the acidity of the curd, I confined my estimations in 1891 to this one stage of the curd only. The results obtained were so high that they could not be due to lactic acid, and could only be accounted for by the fact that casein is itself an acid substance and evidently neutralised the soda.

In 1892 the estimations were continued, and again the fluctuations in the acidity of the curd when milled were very great, yet I was totally at a loss to explain the cause. On several occasions, in order to confirm the results, two tests were made in the curd of the same day; and the results obtained were so close as to preclude the supposition that the method was faulty; moreover many tests were made which gave absolutely concordant results. Why the curd should on some days show an acidity of 7·2 per cent, and on others only 3·6, I was utterly unable to discover in spite of many experiments.

The subject was left in abeyance until 1896, when the question once more arose in my mind—is there an acidity or acid condition of the curd, independent of and different to the acidity of the liquid by which that curd is impregnated? And, if so, is it of importance?

Experiments were made to determine the acidity of the curd by the following four methods:—

(*a*) Two grammes of curd were cut up into fine pieces, placed in a flask with distilled water, and allowed to stand in a warm place, or gently heated, and after standing for twelve hours the acidity of the liquid was determined.

(*b*) Thinking that the warmth employed in method "*a*" might cause the production of lactic acid, two grammes were treated similarly to the above, but the solution was immediately boiled so as to destroy the bacillus acidi lactici.

(*c*) Two grammes of curd were rubbed up in a mortar with distilled water into fine particles, and the acidity thereof immediately determined.

(*d*) Two grammes of curd were cut into fine pieces, placed in a flask with water, and an excess of caustic potash solution, and the liquid boiled. Subsequently the free potash was determined so that the amount of potash consumed showed the acidity of the curd, soluble in alkali.

The following table gives a few examples of the results obtained, and also the acidity of the liquid from press on the same dates.

DATE.	Acidity by "*a*."	Acidity by "*b*."	Acidity by "*c*."	Acidity of liquid from Press.	Acidity by "*d*."	Acidity due to Curd.
1896.						
June 6	·85	·87	·89	·88	6·05	5·16
" 24	...	·90	·97	·95	5·37	4·40
" 26	·94	·95	·99	·99	5·37	4·38
July 1	1·04	1·04	1·05	1·04	5·30	4·25

From these results, which have been confirmed by numerous other experiments, we learn that method "*a*" does not succeed in obtaining all the acid liquid out of the curd. That method "*b*," while it improves the results, owing probably to the contraction of the curd by heat expelling its acid contents more thoroughly, still fails to give quite so high results as method "*c*," which was consequently adopted in subsequent work. It is, fortunately, a more simple and more rapid method than either "*a*" or "*b*."

Comparing the results obtained by method "*c*" with the acidity of the liquid from the press, it will be seen that they are practically identical, so that this method of analysis appears to give us merely the same acidity as that of the liquid which is in the curd. As the curd contains only 50 per cent. of liquid at most, we might expect the figures to be one-half those of the liquid from the press. Why they are identical with the liquid from the press, I am unable to explain. It has been noticed that after estimating the acidity by method "*c*" there is a secondary reaction, which takes place slowly, and is more difficult to determine, but which gives almost constant results. So far as I am able to judge at present, this is due to the acid salts present in the curd.

Casein Acidity.—The result obtained by method "*d*" is very different. Here, in addition to the acidity soluble in water, we have an acidity which we must assume to be due to the solid substance of the curd insoluble in water, subsequently termed the "casein acidity." By deducting from this total acidity the acidity due to the soluble portion, we obtain the true acidity of the insoluble portion or casein.

The acidity of the casein, as determined by method "*d*" fluctuated from day to day in a most remarkable manner as in previous years.

The determinations with which the results obtained seemed mostly to accord, were those of the acidity of the liquid from the press. But, though up to 1896 very numerous experiments had been made to try and discover if there were any relation between these two determinations, no constant relation could be discovered.

Tabulating the figures obtained in 1896, and comparing them with results obtained in 1892—the only year for which the necessary data existed— the following results were obtained.

TABLE SHOWING AVERAGE "CASEIN ACIDITY" OF CURD DURING THE FIRST 10 DAYS OF EACH MONTH.

—	1892.	1896.
June	4·27	4·39
July	3·77	4·06
August	3·33	3·39
September...	3·62	3·43
October	3·16	3·47

These figures seem to prove beyond doubt that curd when vatted is an acid solid, surrounded by an acid pickle. Also, that the acidity of this solid varies not only from day to day, but in different months, decreasing during July and August, but increasing subsequently. These results were of sufficient interest to warrant further investigation. How far the acidity of the solid, as distinct from the liquid, might affect the ripening or quality of the cheese remained to be determined.

During 1897, the acidity of the curd was frequently estimated by at least two methods, and in addition many experiments were made.

It was now found that the quantity of acid which appears to be present in the curd depends very largely upon the way in which the method adopted for its estimation was carried out.

The results by any process depend primarily upon the quantity of water with which the curd is diluted before estimating the acidity. This is seen in the following experiments. Two grammes of curd were finely minced and 25 c.c. water added, the acidity indicated was ·75 per cent.: 2 grammes of the same finely minced curd when treated with 100 c.c. water showed only ·65 per cent. acidity.

A similar result is obtained if the curd is ground into a paste with water before the estimation of acidity. Thus 2 grammes of curd were ground up in a mortar with 50 c.c. water, and showed an acidity of 1·00 per cent., while 2 grammes of this curd when ground up with 100 c.c. water showed only ·85 per cent. of acidity. Numerous experiments were made upon this point, quantities of water varying from 25 c.c. to 150 c.c. being used, and always with the same varying results.

The most feasible explanation of these variations is that the alkaline solution of soda with which the estimation is made acts upon the casein itself when in a finely divided state, and that this action diminishes with the increasing dilution of the solution. The results also depend on the fineness of the curd. In order that there should be no doubt about this, three experiments were made with the same curd, 2 grammes being taken in each case. One portion was ground as finely as possible, the second not quite so finely, and the third roughly. The acidities obtained were 1·35 per cent., 1·15 per cent., and 1·00 per cent. respectively, which prove that the action of the soda depends on the fineness of the curd. Similar fluctuations were found when estimating the "casein acidity" by treatment with soda method "*d*," the results also varying with the quantity of soda taken, and with the temperature to which the solution was heated. Some experiments were also made to test the effect upon the estimation of using indicators other than phenol-phthalein. The results were rather remarkable. With methyl-orange as indicator, the curd, instead of showing an acid reaction, now showed an alkaline. It was very evident, in face of these results, that if the determination of the acidity of the curd had to be made or was likely to throw any light upon the problems of cheese-making, the acidities must be estimated daily in precisely the same way.

The following methods were therefore fixed upon in order to obtain uniform results, but as there is no standard by which to ensure their accuracy, they cannot be looked upon as being more accurate than any other methods. For the estimation of the acidity soluble in water, 2 grammes of curd were taken, rubbed up in a mortar with a small quantity of water, and made up to 30 c.c. For the estimation of casein acidity, 2 grammes were taken, minced very fine, transferred to a large test tube with 15 c.c. soda solution, each c.c. of which would neutralise 0·01 lactic acid, boiled, and the excess of unneutralised soda estimated: that which had been neutralised represented the "casein acidity."

All the figures given in the following tables were obtained in this way, and represent the acidities in terms of lactic acid (percentages).

Acidity of the Curd at Different Stages in the Manufacture of the Cheeses.—This has been estimated on three occasions, and the results are given in the following table:—

ACIDITIES OF CURD AT DIFFERENT STAGES.—PERCENTAGE, AS LACTIC ACID.

Stage in Manufacture.	Curd of May 13, 1897.			Curd of July 20, 1897.			Curd of Sept. 22, 1897.		
	In liquid draining from Curd.	In Curd soluble in water.	In Curd when treated with Soda (Casein acidity).	In liquid draining from Curd.	In Curd soluble in water.	In Curd when treated with Soda (Casein acidity).	In liquid draining from Curd.	In Curd soluble in water.	In Curd when treated with Soda (Casein acidity).
After taking to cooler	·39	...	...	·51	...	...	·38	...	...
After 1st cutting	·58	·75	3·60	·69	·75	3·40	·53	·75	3·40
" 2nd "	·78	1·10	3·76	·85	·90	3·50	·77	·90	3·35
" 1st turning	·93	1·25	3·70	·96	1·15	3·50	·86	1·00	3·50
" 2nd "	1·04	1·40	3·75	...	...	...	·98	1·05	3·45
" grinding ...	1·02	1·40	3·80	1·02	1·35	3·70	·90	·90	3·45

A careful study of these figures shows that both the acidity of the liquid draining from the curd, and the water soluble acidity of the curd itself, increase rapidly during the manufacture of the cheese, but there is no corresponding increase in the acidity of the curd.

The acidity soluble in water is due mainly to the lactic acid present in the curd. The casein acidity is remarkable for its constancy. One would expect it to rise simultaneously with the rise in acidity of the liquid from curd. But it does not.

There can be little doubt as to the important practical lesson to be learnt from these figures, namely, that the acidity of the curd affords no indication of the progress in manufacture, while the acidity of the liquid draining from the curd undoubtedly affords a very distinct guide to the condition of the curd itself.

Acidity of Curd when Ground.—This was estimated 103 times during the season 1897, both as regards solubility in water and solubility in soda. It is not necessary to quote these voluminous figures. It will be sufficient to give merely average results. The object of taking these averages has been to determine whether, when taking a large number of determinations into account, and so eliminating exceptional results, any relation could be found between the acidity of the curd and the acidity of the liquid from the press.

The following table gives the results obtained:—

AVERAGE ACIDITY OF CURD WHEN GROUND.

—	Average Acidity of liquid from Press.	Acidity of Curd in Water.	Acidity of Curd in Soda. (Casein acidity).
Of 8 samples where the liquid from press contained under ·80 per cent. acid	0·75	0·95	3·47
Of 28 samples where the liquid from press contained under ·90 per cent. acid	0·85	1·05	3·57
Of 38 samples where the liquid from press contained under 1·00 per cent. acid	0·94	1·17	3·68
Of 29 samples where the liquid from press contained over 1·00 per cent. acid	1·04	1·38	3·80

It is evident that the acidity of the curd, soluble either in water or in soda, rises on an average in the same proportion as the acidity of the liquid from press, indeed, appears to be dependent upon the acidity of the liquid which permeates the curd.

It would even appear that the acidity of the casein proper is almost unaltered. For if we deduct from the acidity of the curd in soda the acidity of the liquid from press, we obtain as the true acidity of the casein the following figures, 2·72, 2·72, 2·74, 2·76, which are remarkably similar. These figures indicate that for the practical cheese-maker the acidity of the liquid from the press is an amply sufficient guide to the acidity of the curd when it is placed in the cheese-room.

The last point of importance was whether the acidity of the curd would influence the ripe cheese. It has only been possible to make a few experiments upon this subject, the results of which are tabulated below.

DATE.		Acidity of Liquid from Press.	Acidity of Curd in Water.	Acidity of Curd in Soda.	Acidity of ripe Cheese in Water.
		Per cent.	Per cent.	Per cent.	Per cent.
April 13	... ...	...	1·90	5·05	2·65
" 21	... ...	1·00	1·60	4·60	2·35
" 27	... ...	·99	1·85	3·80	2·30
May 5	... ...	·95	1·00	3·60	2·80
" 7	... ...	·97	1·40	3·95	2·85
" 12	... ...	·90	1·20	3·80	2·75
" 21	... ...	1·07	1·35	3·80	3·00
June 8	... ...	1·03	1·25	4·00	3·10
" 24	... ...	·84	1·35	3·75	2·90
" 26	... ...	1·09	1·35	3·80	3·00
July 1	... ...	1·02	1·25	3·65	2·68
" 14	... ...	·90	1·20	3·65	2·80
" 24	... ...	·93	1·10	3·65	2·68
Aug. 10	... ...	1·00	1·20	3·55	2·16
" 17	... ...	·91	1·20	3·70	2·34
Sept. 8	... ...	·79	·90	3·40	2·16
" 14	... ...	·81	·90	3·70	2·16
" 22	... ...	·90	·90	3·45	2·16
" 23	... ...	·86	·90	3·45	2·34
" 28	... ...	·85	·90	3·55	2·34
Oct. 12	... ...	·81	·85	3·45	2·34
" 19	... ...	·89	·95	3·50	1·98

These results indicate that the acidity of the ripe cheese, as estimated by treatment with water follows most closely the acidity of the liquid from press.

It is evident that both as regards "casein acidities" in the curd, and the acidity of the ripe cheese, there are now and again exceptions to the rule which has been indicated above from the study of averages. These exceptions are, I find, sometimes due to the presence of a particular taint in the curd which invariably causes the liquid from press to show less acidity than was present in the liquid coming from the curd before grinding (*see* p. 94). Probably other variations are largely due to the proportion of liquid (whey) and of pure casein present in the curd when ground not being constant.

Summarising the results of these investigations into the acidity of curd, I consider first, that the estimation of the acidity in the liquid draining from the curd is an accurate guide to the acidity of that curd, and will enable the cheese-maker to judge with certainty when the curd is fit to grind; and secondly, that the estimation of the acidity of the liquid from the press affords a sufficient guide for all practical purposes to the keeping power of a cheese.

Straining Milk.

The milk when it is brought into the dairy is poured into a hoop temporarily fixed upon the sides of the tub and covered with a very fine muslin. This, whilst it ensures perfect straining from all large impurities, serves another purpose, in my opinion not less valuable than the mere straining out of these impurities. It is this, that from a careful examination of the residue left in the strainer some important information is often obtained. Thus, if the cows are not well cleaned before milking, the fact is soon shown by the presence of extraneous matter in the strainer. If the cows are suffering from sores it will be known at once by the presence in the strainer of scabs from the sores. Any soreness of the teats will also be shown by the presence of small clots of blood. After a little practice, the cheese-maker will find a few moments devoted to the inspection of the strainer well repaid as indicating whether or not the milking has been carefully and properly done. Far more cheeses are spoiled before the milk comes into the dairy than by careless manipulation in the dairy.

Whether it is advisable that the milk should be carried into the dairy by the milkers is, in my opinion, doubtful. They are liable to bring in on their boots more dirt than is desirable. I am inclined to think the old system of having a shoot leading from outside the dairy to the cheese-tub is preferable. This would not prohibit the milk being strained before it fell into the tub.

Rennet.

The rennet which has been used at the Bath and West School during the course of these investigations, was Hansen's extract.

The quantity which has been required has varied, not only at each cheese school, but frequently at the same school during the course of the cheese-making season. The reason for these fluctuations has been difficult to trace. It appears to depend particularly on the quality of the milk, thus in the autumn, when the milk is richer than in the earlier part of the year, the proportion of rennet required has at times, and as a rule, been smaller. Indeed when this has not been the case, I am of opinion that it has been due to some change in the rennet, which has caused it to lose its strength.

Although there can be no doubt that there is a close relation between the composition of the milk and the proportion of rennet required, yet it is difficult to find out what that relation is.

Results of experiments made at Long Ashton, in 1898, would point to the fact that the ordinary chemical analysis of a sample of milk is not sufficient to show this peculiarity of composition, though it evidently depends to some extent upon the proportion of casein.

Thus the abnormal milk yielded at Long Ashton, see p. 74, when treated with the same proportion of rennet as ordinary milk, took over two hours to set, whilst with ordinary milk the same proportion of rennet had not only set the curd, but this was ready to cut 45 minutes after renneting.

How to determine what proportion of rennet it is desirable to use would therefore appear to present some difficulty. It is generally believed that the milk of different farms requires different proportions of rennet. Reviewing the results obtained at the various cheese schools, it would appear that the quantity of rennet does not vary so much between different sites as it will actually on one and the same farm during the season.

The practical cheese-maker must therefore be guided as to the quantity of rennet to use by the time which it takes to set the curd, and must use such quantity only as will enable him to have a nicely firm curd, fit for cutting 45 minutes after the rennet is added to the milk. Once having found out by experience the proportion to use, the rennet measure should be employed subsequently.

If insufficient rennet be employed, the curd is soft, and unless sufficient time be given to the curd to properly set there will be a considerable loss of fat in the whey, as the curd will not be sufficiently firm to hold it. If an excess of rennet be employed, then, when the scald is applied, the curd is drawn together too rapidly and the whey is expressed before it has had time to perform its proper function, namely, to enable the bacteria feeding on it to bring about the desired acidity within the curd. An excess of rennet, by contracting the curd with too much force, may also cause some of the fat to be pressed out of it and lost in the whey. This contraction takes place more rapidly the greater the acidity of the milk before renneting. Hence, when the milk is very ripe, more than usual care should be taken not to employ an excess of rennet. On the other hand the use of too little rennet will cause the curd to retain too much moisture, to be soft, and therefore to subsequently develop acidity somewhat too rapidly, or in excess.

The influence of rennet on the time which the cheese takes to make is treated subsequently, p. 121.

A better cheese is made where there is a small proportion of rennet than where there is a large proportion. This conclusion has been arrived at after careful observation, and direct experiments. For example, a cheese made in August with the lowest proportion of rennet of any cheese made that month, was compared with one made three days previously, for which the highest proportion of rennet had been used. On December 31st following, the cheese made with least rennet was pronounced one of the best, if not the best cheese made in the month, and far superior to that made with a larger proportion of rennet. So also a cheese in September made with the lowest proportion of rennet employed that month was "excellent," while one made with the largest proportion of rennet was considered "not so good as the average make."

These opinions were expressed by competent judges, who were not aware of the difference in the make of the cheeses, nor of the reason for obtaining their opinions. There can be no question as to the accuracy of the conclusion to which these facts point, namely, that the use of an excess of rennet is detrimental to the production of a first-class cheese.

Unfortunately, manufacturers do not guarantee the strength of their rennet, so that it is difficult to say whether any sample has been tampered with or not. But I have good reason to believe that much of the rennet sold retail is first diluted, and is not of the same strength as when sent out by the manufacturer.

The quantity of rennet necessary depends more on the strength of the rennet than on the composition of the milk. Whenever and wherever it has been found necessary to materially alter the quantity of rennet used, it has not been possible to discover any corresponding difference in the milk to account for this necessary alteration, which therefore is most probably due to some change in the rennet, which causes it to lose its strength.

It must not be forgotten that the effect of the rennet will, to a certain extent, depend upon the acidity of the milk, for the greater the acidity the more rapid is the action of the rennet.

Founded upon this fact, the method of testing the ripeness of milk by means of rennet, adopted in Scotland, and explained on p. 89, has been introduced.

The purity of the rennet employed in cheese-making is of as great, if not of greater importance than its strength. Microscopical and bacteriological examination has shown that numerous bacteria, as also some yeasts, are present in the rennet, even when this is of good quality. If bacteria which are not injurious to cheese-making are capable of living in rennet, it is evident that others which would be injurious might also find in it sufficient nutriment for their existence. Hence it is necessary not only to insure that the rennet used is pure, but to keep it in a place where and in such a manner that it is not liable to become contaminated. I have found a bottle with patent stopper, similar to those used for sterilised milk an admirable receptacle for the rennet employed in the dairy.

The Effect of a High Scald.

In order to determine the effect of a higher temperature for scald than that adopted in the Cannon system, it has been necessary to make certain experiments.

In the first experiment the milk was treated exactly the same as usual up to the time of the first scald. For the second scald it was raised to a temperature of 95° F. The acidity of the mixed milk was ·23 per cent. The acidity of the whey after first scald was ·17, and at the commencement of the second scald ·175. It rose very slowly, and had not reached the desired amount until 12.6 p.m., having been in scald 2 hours 35 minutes. The quantity of fat in the whey was very great, due to the long stirring in scald. When the whey was first drawn it showed an acidity of ·25 per cent., but when the whole had been drawn it showed an acidity of ·27, proving that the formation of acid had been going on within the curd, and had not shown itself in the whey. This is confirmed by the acidity of the drainings from the piled curd and the rapid development of acidity afterwards. The curd was vatted at 4.49 p.m., was very dry (as shown by the small loss in press as well as by analysis), and lost considerably in the cheese-room.

Hence heat produces a contraction of the curd similar to that produced by acid.* Where a high temperature is used in the second scald, the development of acidity in the curd must take place after that curd has been removed from the whey, and not while in the whey as is permissible with a lower scald temperature. The above and other experiments have shown that when a high scald is employed, the curd is so contracted by heat that the acidity subsequently developed in the curd is not recognisable in the whey.

In the next experiment the curd was scalded to 100° F. in two scalds. When the second scald was on, the whey showed ·18 per cent. of acidity. The curd was stirred in scald for five minutes, and then allowed to rest for thirty minutes. The acidity of the whey standing on curd was ·20. The acidity of

* The following figures afford a striking proof of this fact :—

—	Temp. of Scald.	Time in Scald.	Acidity of Drainings. Piled Curd.	Moisture in Curd.
		h. m.		
August 14	90°	1 50	·38	47·45
„ 15	101°	0 40	·38	41·45

the whey when drawn was ·22. But the drainings from the piled curd showed a high acidity. The curd was broken up and spread on rack in cooler covered with a cloth, and no weight put on. The drainings came away pretty freely, and the curd held together well. There was rather a small weight of cheese, but it was a good cheese. It is thus evident that with a high scald it would be necessary to completely alter the system of manufacture. The analysis of the whey proved that there was no increase in the amount of fat due to the high scald, evidently because stirring in the whey had not been adopted.

The rise in acidity had been so rapid, and had gone so far, in previous experiments when a high scald was used, that to prevent it no sour whey was employed for the next experiment. The scald was raised to 100° F. as rapidly as possible, being first raised to 89° F., and then to 100° F. Stirring lasted for five minutes only, and the curd was then allowed to settle and remain in scald for twenty-five minutes. The whey, when stirring was finished, showed acidity ·17 per cent., and when drawn it was still ·17. So far, the object of making a cheese with high scald and low acidity had been attained. The curd was piled for thirty-seven minutes before the whey commenced to drop, was then cut into 6-inch cubes, taken to cooler and laid out thereon. The acidity of the first drainings was very slight. The curd was turned, allowed to remain one hour, and again turned, when the acidity of drainings was ·42. It was late in the evening before the acidity of the drainings was sufficient to justify vatting the curd, and a very poor cheese it made—"tough and with no flavour." So that keeping down the acidity proved worse than obtaining too much. This indicates how necessary the development of acidity is for the production of a good cheese, and that contracting the curd by heat is not alone sufficient.

Spring Cheeses.—Here we obtain an indication of the cause of the comparatively inferior quality of spring cheese, for it is frequently most difficult to obtain sufficient acidity in the whey and curd during the months of April and May. The result is that the curd is contracted by heat, and the acidity not properly developed in the curd before the whey is drawn, nor is sufficient attention paid to the subsequent development of acidity in the curd.

Following this line of argument, another Experimental Cheese was made to determine whether, if the subsequent development of acidity in the curd were ensured, the cheese would be of good quality.

The curd was scalded as quickly as possible to 101° F., stirred for five minutes, allowed to settle for twenty minutes, and the whey drawn. When taken from the tub, the curd was cut into blocks, spread out on the rack in cooler, covered with a cloth, and, while the drainings were still low in acidity, the curd was ground, salted, and spread out to cool. It took $2\frac{1}{2}$ hours to cool, during which time the acidity rose rapidly, so that the liquid from press was more acid than usual. This turned out to be an "excellent cheese." Thus it is evident that whether we obtain contraction of the curd in the whey by heat or by acidity, we can produce an excellent cheese provided care be taken to obtain subsequently the proper amount of acidity in the curd before it is vatted.

Temperature of the Curd when Vatted.

It is held by many cheese-makers that it is not advisable to vat the curd at a higher temperature than 70° F. In the Cannon system, however, temperature plays a secondary part to acidity, hence, as soon as sufficient acidity has been developed in the curd, this is vatted. The result is that the curd will vary greatly in temperature. So far as can be judged by a careful examination of the records of observations, putting the curd away at a high temperature has not had the effect of producing a bad cheese; some of the best cheeses have been the product of curd vatted at as high a temperature as 77°- 80° F.

Moisture in Curd.

The proportion of moisture which is left in the curd when this is vatted is of considerable importance, as it will materially affect the ripening of the cheese. If too much moisture be left in, the cheese will ripen too rapidly, while if there is not sufficient moisture, the cheese will not only be slow to ripen, but may become too dry and so deficient in quality. The average proportion of moisture left in the curd during the years 1891 to 1896 was 41·06 per cent., which may thus be taken as the standard for Cheddar Cheese. By studying the figures in the Appendix (Table 3), it will be seen how very nearly the average for each month and for each year approaches this standard.

The moisture in the curd when taken from the tub to the cooler was estimated daily from 29th July to 19th August, 1893, to determine what quantity of moisture was lost during the subsequent operations of cheese making.

These results show that the moisture at this stage varies somewhat considerably as compared with the very slight fluctuations found in the curd when ground. Thus the results were:—

Moisture in Curd when taken from Tub.

Minimum	41·45 per cent.
Maximum	50·20 ,,
Mean	46·72 ,,

The high proportion of moisture in the curd, which was characteristic of the cheese made in 1897 and again during the months of April, May, and June, or rather part of June, 1898 (*see* p. 139), was, in all probability, due to the influence of the abnormal milk, or of milk deficient in casein. Experimental cheeses were made with this milk, and on the same day the cheese was made as usual with the ordinary milk, from which all the abnormal milk was kept out. The following results conclusively prove the effect of the abnormal milk on the moisture in the curd:—

1st Exp.—Curd from the abnormal milk contained water...	44·90 per cent.
Curd from the remainder of the milk contained water...	40·90 „ „
2nd Exp.—Curd from abnormal milk contained water	44·80 „ „
Curd from the remainder of the milk contained water...	42·30 „ „

These results leave no doubt as to the effect of the abnormal milk upon the moisture of the curd, and the considerable fall in the average moisture in the curd in the months of July, August, September, and October, after the cows yielding the abnormal milk had been disposed of, confirm this opinion.* But, at the same time, the observations show that this abnormal milk was not the sole cause of the high proportion of moisture in the curd. Whenever there was present in the milk a particular taint—which if it was not the vinegar taint was very closely allied to it—which caused the acidity to rise with undue rapidity, and necessitated the curd being vatted much earlier than usual, then there was invariably a high proportion of moisture in that curd. It was, therefore, thought desirable to make some experiments to determine whether by adopting a higher temperature for the scald, the requisite dryness could be obtained in the cheese without injuriously affecting its quality. An experimental cheese was made, the temperature of the second scald being 100° F. Next day the cheese was made with an ordinary temperature for the second scald of 95° F., and the following day an experimental cheese was made, the temperature of the second scald being 105° F. The acidity of the liquid from press of these three cheeses was ·81 per cent., ·83 per cent., and ·80 per cent. The effect of the high scald upon the moisture of the curd was not so marked as I had expected, the moisture in the curd scalded to 100° F. being 41·40 per cent., in the curd scalded to 95° F., 40·80 per cent., and in the curd scalded to 105° F., 40·40 per cent. But the effect on the keeping quality of the cheese and on the texture was marked. These cheeses were specially

* In 1897 the average moisture in the curd during April, May and June was 42·18 per cent., and during July, August, September, and October 41·5. In 1898, during April, May, and June, it was 42·78, and during the remaining months, 40·91.

examined by Mr. Hill. In his opinion, that made with a scald temperature of 100° F. was the best of the three and excellent, though it was not quite ripe, and did not cut fat. That made with the scald temperature of 105° F. was more solid, very mild, and a good keeping cheese. These results are, in my opinion, most important. They show how largely the keeping quality of a cheese depends upon the amount of moisture in the curd, as well as upon the amount of acidity. I think, moreover, they justify the conclusion that on farms where the milk is either deficient in acidity, poor in casein, liable to yield a wet curd, or to produce a curd which developes acidity with greater rapidity than is desirable, in fact, from any cause whatever, produces a very rapid ripening cheese, a second scald temperature of 100° F. is desirable. It is, however, necessary to point out that when a high scald is employed the curd must subsequently be kept well open, so that by the time the proper degree of acidity is obtained, the temperature of the curd shall have fallen to nearly 70° F., in order that it may be fit to vat at once.

An experiment was also made to bring about the contraction of the curd by the use of a larger proportion of rennet, but the resulting cheese was inferior in quality. This confirmed the results obtained some years previously, as to the effect of an excess of rennet.

The Composition of Milk.

The composition of the milk with which the cheese-maker has to deal affects, as will have been seen in this report, the proportion of rennet to be used, the acidity which may be obtained in the whey before drawing off, and the acidity which should be present in the curd when this is taken to the cheese-room.

Its influence on the proportion of rennet, and on the acidity of the whey when drawn, was most marked at Haselbury in 1895, as may be seen by consulting the results for that year. The high percentage of fat in the milk, coupled with the comparatively low percentage of casein, necessitated a more careful handling of the curd than usual. Consequently, it was found necessary to draw off the whey, and take the curd from the tub from 22 to 36 minutes sooner than had been customary in former years. Hence the acidity of the whey when drawn was always less than the acidity of the mixed milk.

The influence of the composition of the milk on the acidity of the liquid from press is shown in the following table, which gives the average amount of fat in the milk, and the average amount of acid found in the liquid from press, for the three years 1893-4-5, and for three months of 1891:—

COMPARISON of ACIDITIES and FAT during the Years 1891 and 1893–5.

Month.	Year.	Locality.	Average Percentage of Fat in Milk.	Average Acidity of Liquid from Press.
April	1893	Butleigh	3·09	1·08
	1894	Mark	3·29	1·05
	1895	Haselbury ...	3·70	1·11
May	1893	Butleigh	3·05	1·02
	1894	Mark	3·35	1·08
	1895	Haselbury ...	3·39	1·12
June	1893	Butleigh* ...	3·08	1·01
	1894	Mark	3·40	·99
	1895	Haselbury† ...	3·51	1·09
July	1893	Butleigh* ...	3·20	·89
	1894	Mark	3.47	1·02
	1895	Haselbury* ...	3·60	1·12
August ...	1893	Butleigh* ...	3·19	·90
	1894	Mark	3·70	1·04
	1895	Haselbury† ...	3·80	1·09
	1891	Vallis	3·87	1·07
September ...	1893	Butleigh* ...	3·53	·94
	1894	Mark	3·93	1·02
	1895	Haselbury† ...	3·94	·98
	1891	Vallis	4·13	1·11
October ...	1893	Butleigh* ...	4·30	·95
	1894	Mark	4·39	1·04
	1895	Haselbury‡ ...	4·55	1·08
	1891	Vallis	4·75	1·22

* For first week in month only.
† For first and third weeks in month.
‡ For first week only ; during third week there was a taint in the milk which prevented proper acidity being developed.

It is perfectly evident from the preceding facts that the greater the knowledge which a cheese maker can obtain as to the composition of the milk with which he has to deal, the better.

Unfortunately, such knowledge is not easily obtained. The most simple guide to the richness of the milk is the weight of curd which is produced from one gallon of the milk. The amount of fat can be approximately estimated by the creamometer, though more accurately by the Babcock or Gerber tester. The determination of the acidity of the milk will also afford some indication of its quality.

The Fat of Milk.

In all the estimations of fat this substance is isolated and weighed in little glass flasks. Experiments were made, first by mixing it with hot water, to dissolve out any acid soluble in water that might be present; but only a trace could ever be found. Then the fat was treated with alcohol, to dissolve out any acid soluble in alcohol, and the acidity of the solution was estimated. In some years no soluble acids were obtained, but in 1896, both in the fat of whey and in that of curd, an appreciable amount of acid substance was found. I have calculated the acidity present as oleic acid, and the following table gives the average results obtained from about ten determinations made each month in both whey and curd:—

PERCENTAGE OF OLEIC ACID IN FAT FROM WHEY AND CURD.

—	Whey.	Curd.
May	...	4·10
June	30·74	8·84
July	31·20	6·94
August	16·18	3·10
September	17·79	3·55
October	19·08	3·94

The results vary with each cheese in a somewhat remarkable manner, for which fact an explanation has yet to be sought. One experiment was made by determining the acidity or oleic acid in the fat from a cheese when ripe to compare it with that found in the same curd at the time of vatting. The results were as follows:—

	Per cent. Oleic acid.
On Sept. 7th, 1896, in curd	1·98
On Nov. 25th, in cheese	2·23
On Jan. 28th, 1897, in ripe cheese	2·23

Practically no change seems to be produced in the fat by ripening.

I am unable to trace any relation between the acidities produced during cheese-making and these oleic acid determinations, so that it would appear that the fat in the original milk varied in nature from day to day.

In 1895, the fat which was coming from the press was found to be not ordinary butter-fat, but a fat of exceptional properties. It had the normal composition of butter-fat in most respects, but its melting point was as low as 54° F., the solidifying point being 51° F. In another instance a sample of this fat showed solidifying point 66° F., the fat in the whey butter from the same milk had a solidifying point of 79° F., while the average melting point of butter-fat is about 89° F. The question thus arises, does this fat form a regular constituent of milk-fat?

Unfortunately, we know really very little about the composition of milk-fat. Most of the work which has been done has been with butter. It does not appear that this butter was made with separated cream, probably it was not, so that the fat in the skim milk and butter-milk, which at a low estimate would represent at least one-sixth of the whole, has apparently been entirely neglected. Further, although it is evident that butter-fat contains several different fatty acids, and therefore different fats, yet how far these fats exist separately, or how far they exist as compounds, appears to be uncertain. The preceding results point to the possibility of their existing separately under certain conditions. Otherwise fats must at times be present in the milk which are not present at other times. The whole subject is one which requires further study.

The Ultimate Distribution of the Constituents of the Milk.

What becomes of the constituents of the milk during the manufacture of a cheese? Take the figures for July, 1895. The average volume of milk upon the days on which analyses were made amounted to 143 gallons, which would weigh 1,473 pounds. This milk contained 12·68 per cent. of solid matter, or an average daily amount of 186·77 pounds of solids. By a simple calculation, it will be found that of this only 90·21 pounds are recovered in the curd, while 93·08 pounds pass off in the whey, and 3·48 pounds are lost in the liquids from the cooler and press. Hence, in the process of cheese-making, less than half the total solids of the milk are recovered in the cheese. Perhaps it is not beside the mark to ask whether sufficient attention has yet been given to the other half?

The total weight of casein in the milk amounted to about 39 pounds per diem, while the solids in the curd, deducting the fat and mineral matter, amounted to about 40 pounds, showing that the curd contained about one pound of sugar. The remainder of the sugar and the albumin passed into the whey.

Composition of Whey.—The principal loss of constituents is in the whey, the average composition of which for each month of every year will be found in the Appendix (Table 3.)

The average composition for the whole period is solids 7·04, fat ·32, mineral matter ·50. The principal constituent of the solids is sugar. The results of 20 analyses show the average percentage of albumin in whey to be ·50, and to vary from ·38 to ·60.

The following analyses of the whey, taken during the various stages of the manufacture of a cheese, are interesting, as giving some idea of the chemical changes which are taking place. They indicate also the stages in the manufacture when fat is most likely to be lost:—

Percentage of	August 5th, 1892.				August 27th, 1892.			
	Solids.	Fat.	Sugar, Albumin, &c.	Ash.	Solids.	Fat.	Sugar, Albumin, &c.	Ash.
Whey before breaking...	6·87	·25	6·09	·53	6·74	·20	6·00	·54
Whey after breaking ...	7·10	·44*	6·08	·58	6·98	·35	6·12	·51
Whey when drawn ...	6·95	·29	6·12	·54	6·93	·27	6·13	·53
Drainings from piled Curd	6·66	·04	5·89	·73	6·65	·07	5·93	·65
Whey from Curd taken to cooler	7·73	1·13	5·58	1·02	7·67	1·07	5·64	·96
Whey after 1st cutting	8·22	1·30	5·56	1·36	7·78	1·12	5·51	1·15
Whey after 2nd cutting	8·60	1·32	5.64	1·64	7·81	·95	5·55	1·31
Whey after 1st turning	...	...	...	...	7·96	·94	5·55	1.47
Drainings from press ...	13·90	1·03	3·89	8·98†	13·46	·78	3·78	8·90†

* This result is probably too high, as the Curd was allowed to settle before the sample was taken, and probably a portion of the fat had risen to the surface during this time.

† Mainly salt.

The above figures show how, with the development of acidity, there is a constant abstraction of the mineral matter from the curd, and that the chief loss of fat is during the first and second cutting of the curd. Hence the necessity of care in performing this operation.

I am inclined to think the above results throw some light upon one or two questions of scientific and popular interest.

First, we cannot possibly account for the uniform proportion of sugar and albumin in these liquids, and the irregular amounts of ash, without coming to the conclusion that these bodies do not exist in the curd in a similar state.

There is no reason to suppose that the sugar and albumin, which are in solution in the milk, have been rendered insoluble by the processes of cheese-making. And there is good reason to believe that at least a portion of the lime in the milk, if no other ash constituent, is in an insoluble form combined with the casein. If this is so, the above results are easily explained. The acid, as it is formed, combines with this lime, and withdraws it from the casein, forming calcium lactate.

Loss of Fat in Cheese-making.—To what extent the fat originally present in the milk is ordinarily lost during the manufacture of a cheese is well shown by the following figures:—

Fat present in	Weight of Fat in pounds.		
	August 5th, 1892.	August 27th, 1892.	July, 1895.
Milk...	39·66	33·11	53·02
Curd	37·07	30·60	48·51
Whey	2·79	2·14	3·61
Drainings from cooler	·12	·15	·90
Total found	39·98	32·89	53·02
Error of Analysis	·32	·22	...
Fat in liquid from press	·11	·06	...

There are, however, times when an exceptional amount of fat is lost in the whey, and the cause of this has received my attention.

Loss of Fat in the Whey.—An abnormal loss of fat in the whey may be due to careless breaking of the curd. When not due to carelessness, it is generally due to the chemical composition of the milk.

Whenever the proportion of casein in the milk has been small in proportion to the fat there has been a loss of fat from the curd. Sometimes this loss is in the liquid from the press; sometimes in the whey, and in the latter case very little will be lost in the liquid from press. Why is this? If the acidity developes with a fair degree of rapidity, so that the acidity of the whey when drawn is high compared with the original acidity of the milk, contraction of the curd will have taken place while in the whey, and so the fat it was unable to retain would have been expelled in the whey. On the other hand, if the whey is drawn before this contraction of the curd has taken place, the fat will be expelled subsequently when the curd is submitted to pressure in the vat.

The loss of fat in the whey due to a soft condition of the curd, owing to deficiency of casein in the milk, was well illustrated in 1897 and 1898.

Throughout the season of 1898, the curd was soft, and, in spite of every precaution and the greatest care, the amount of fat in the whey remained higher than it had been in any previous year, except 1897.

American Curd Knives.—These results induced Miss Cannon to obtain some American curd knives, with which to cut the curd, and experiments were made to test the relative merits of the curd knives as against the breaker. The results of two consecutive tests were as follows:—

American knives used by a pupil, fat in whey	·27 per cent.
Breaker used by the same pupil, fat in whey	·44 „

From time to time the whey was analysed when the breaker had been used, and again when the American knives had been used, and always with the result that much less fat was present in the whey when the American knives were employed. If Miss Cannon had always used the breaker, less fat would, no doubt, have been present in the whey than was found on the average, but the pupils have to make the cheese, and in their first efforts at using the breaker they naturally cause more fat to pass into the whey than an experienced cheese-maker would, especially if the curd is soft and difficult to cut without loss of fat. These results evidently point to the fact that the American curd knives are instruments which might be introduced into Cheddar Cheese dairies with advantage.

They are mostly employed where oblong tubs are used for the cheese-making, but can be easily used in the circular tubs. Commencing at the side of the tub, the curd is cut once round in a spiral form to the centre with the vertical knives, and similarly once with the horizontal knives. No attempt is made to cut the curd into small cubes. The subsequent breaking of the curd is carried out with the breaker in the usual manner. These experiments conclusively prove, that to ensure the minimum loss of fat the breaker should be as sharp as possible, so as to cut the curd rather than break it.*

Loss of Fat in Liquid from Press.—There are times when a far larger amount of fat than usual comes from the curd when in the press. This fat rises to the surfaee of the liquid from the press in the form of an oily layer, and it is impossible to so incorporate it with the liquid as to enable a fair sample to be taken for analysis; the whole of the liquid must be analysed to obtain accurate results.

Such loss happened during the months of April and May, 1895, when there was a considerable amount of fat in the liquid from press. Considerable, that is to say, as compared with the small amount usually lost. But the total weight of fat lost was comparatively slight. Thus on the 9th of May, when the amount of fat present in the liquid from press was higher than usual, it was estimated and found to be $7\frac{1}{2}$ ozs. Half a pound of fat floating upon the whey looks very much more than it actually weighs. But in order to estimate its real im-

* Mr. George Gibbons informs me that Joseph Harding objected to a sharp breaker, considering that the curd should not be cut, but broken, as in that case it would break in the weakest part—which would also be the wettest part—and thus the whey would be got rid of.

portance we must consider how much fat was present in the milk from which that cheese was made. The quantity of milk used was 155 gallons, which would represent about 1,600 lbs. The milk of that particular day was not analysed, but judging from analyses made a few days before and a few days after, the milk would contain about 3·4 per cent. of fat. There would, therefore, have been present in the milk $54\frac{1}{2}$ lbs. of fat in all, of which $7\frac{1}{2}$ ozs. is only 0·86 per cent. Thus of the total fat present in the milk the quantity lost is very small, and would have no appreciable effect upon the quality of the cheese. What was of more importance was to discover the cause of this loss, for as it does not always take place there must have been some special cause for it during this period.

The two principal causes of fat coming out in the press are, first, too high a proportion of acid in the curd, and secondly, vatting at too high a temperature. With regard to the acidities, these undoubtedly were high, but it was found that the quantity of fat which came out of the cheese had no relation to the acidity of the liquid from press. Thus on the 15th of April the acidity of liquid from press was 1·09, and fat came out of press as usual; on the 17th, the acidity was only 1·03, and "more fat than usual came out"; on the 19th, the acidity was 1·24, and "much less fat came out." On examining the record of temperature, it was found that to a certain extent the amount of fat was influenced by this, for the higher the temperature at which the cheese was vatted the greater the amount of fat from the press. Some experiments were made in which the curd was allowed to cool before it was vatted. The result was satisfactory. Far less fat then came out. Hence it is evident that where there is a tendency for fat to come out in the press, it is necessary to allow the curd to cool to 70° Fahr. before vatting. It must not, however, be forgotten that by opening up the curd, and allowing it to cool after grinding, the acidity will increase considerably. This accounts for the high acidity on the 19th of April previously mentioned. But neither the acidity nor yet the temperature of the curd were the main causes of this loss of fat, for it had no fixed relation to either.

The artificial food of the cows was changed once or twice, but without any noticeable effect, the fat continuing to come out in the press as before. Hence it did not appear to be due in any way to the food on which the cows were fed.

Without any apparent cause it suddenly ceased on the 13th of May, after which date it never occurred, although both the acidity of the liquid from the press and the temperature of the curd when in vat were subsequently as high, in fact higher, than when the loss of fat occurred. On the same day, 13th May, the milk rose from 154 to 194 gallons, simultaneously with the introduction of eleven more cows into the herd. This caused me to study the effect which these cows had produced upon the milk. I found that during the period preceding this, the average composition of the milk was fat 3·66 per cent., casein 2·44 per cent., and that in the week immediately following the introduction of these cows the fat fell to 3·33 per cent., while the casein rose to 2·58 per cent. At first sight this does not appear to be a great difference, but the difference is better appreciated by calculating the amount of casein present for each pound of fat. It will then be seen that up to the 13th of May, for each pound of fat present in the milk, there was only ·66 pound of casein present, while, after that date, for each pound of fat there was present ·77 pound of casein, which therefore would be far better able to retain the fat in the cheese.

Mineral Matter.—The total mineral matter in the milk and all the products therefrom has been estimated, and the results obtained are given in the following table:—

MINERAL MATTER IN MILK AND ALL ITS PRODUCTS.

Substance	Weight.	Percentage of Ash.	Weight of Mineral Matter.
22nd September, 1897.	lbs.		lbs.
Milk	898	·68	6·106
Whey	792·0	·56	4·435
In liquid from curd	...	...	...
After taking to cooler	7·0	·80	·056
" 1st cutting	1·5	·98	·014
" 2nd "	1·5	1·24	·018
" 1st turning	1·0	1·42	·014
" 2nd "	1·0	1·58	·015
In curd	94·0	2·00	1·880
	898·0	...	6·432

That the total mineral matter found in all the products is greater than that present in the milk is probably due to the error of analysis, and the oxygen and carbonic acid combined with the constituents.

The Lime in Milk, Curd, &c.—The mineral constituent in milk which plays the most important part in the manufacture of a cheese is lime.

In the following table will be found the total quantity of lime present in the milk on three days, and how this lime was subsequently distributed over the various products of the cheese. It will be noticed that about one-half of the lime in the milk remains in the curd, the remainder being lost in the whey, and other liquids draining from the curd. The lime in the curd has been estimated on twenty-nine occasions, and the results show that the curd contains on an average 1·08 per cent. of lime (CaO).

LIME IN MILK AND ALL THE PRODUCTS THEREFROM.

Substance on	Weight.	Percentage of Lime. (CaO.)	Weight of Lime. (CaO.)
7th May, 1897	lbs.		lbs.
Milk	1,249	·224	2·79
Whey	1,110	·095	1·054
Curd	122	1·176	1·435
Drainings after taking to cooler	10½	·235	·025
" " 1st cutting ...	2½	·364	·009
" " 2nd " ...	2	·481	·009
" " 1st turning ...	1	·594	·006
" " 2nd " ...	1	·650	·006
	...	...	2·544
20th July, 1897.			
Milk	1,000	·2128	2·128
Whey	895	·101	·904
Curd	95	1·064	1·011
Drainings after taking to cooler	6½	·325	·021
" " 1st cutting ...	1½	·392	·006
" " 2nd " ...	1	·537	·005
" " 1st turning ...	1	·605	·006
	...	...	1·953
22nd September, 1897.			
Milk	898	·224	2·011
Whey	792	·129	1·021
Curd	94	1·064	1·000
Drainings after taking to cooler	7	·215	·015
" " 1st cutting ...	1½	·308	·004
" " 2nd " ...	1½	·408	·006
" " 1st turning ...	1	·526	·005
" " 2nd " ...	1	·604	·006
	...	...	2·057

The second fact illustrated by this table is that as the acidity of the liquid draining from the curd increases, from the whey onward, the percentage of lime present in the liquid also increases, proving that the increasing acidity is drawing this lime away from the curd. This view is supported by comparing the percentage of lime in the curd with the acidity of the liquid from press. Taking into account a number of examples, it is found that the higher the percentage of lactic acid developed in the curd, the smaller the proportion of lime which is left in that curd. These results, however, are complicated by the fact that the percentage of lime originally present in the milk is not a constant factor. It would thus appear that the lime is in some way connected with the curd, as chemists say, "combined" with it.

Hence the difference between freshly coagulated curd and curd when vatted must be very considerable; the former might be described as a compound of lime and casein, the latter will be deficient in lime, and so there may be in it free casein. But this change will not be limited to the time which elapses between the curdling of the milk and the vatting of the curd. It will also proceed during the ripening of the cheese; and may probably be the chief chemical change which takes place during ripening. The calcium lactate so formed in the cheese would supply an admirable food for bacteria, one which would more easily explain the formation of the chemical compounds upon which aroma and flavour depend than does the more complex substance casein.

There is another interesting and possible deduction. It is certain that the acid in the human stomach would be even more capable of withdrawing this lime from curd than the lactic acid produced during the manufacture and ripening of the cheese. But anything that tends to neutralise the acidity of the stomach tends to produce indigestion. May there not be then a good chemical explanation of the popular belief that new cheese is indigestible? I think this suggestion worthy consideration. Moreover, if it contain a truth, may it not account in some way for the diminished favour with which cheese is looked upon as a food by the working man, he being able to obtain only cheese which is almost new, and this opens up once more the economical question as to the advantages of the early ripening methods of cheese manufacture.

Liquid from Press.—Complete analyses were made of six samples of this liquid taken at different periods. The average of the six analyses is as follows:—

Water		82·23
Fat	3·48	
Lactic Acid	·99	
Albumin	·76	
Sugar	3·38	
Mineral matter (mainly salt)...	9·16	
		17·77
		100·00

The percentages of lactic acid, of albumin, and of mineral matter fluctuate but slightly. The percentage of fat is liable to greater fluctuation, while that of sugar is the most irregular.

Summary.—Summarising these results, we find that of the total solids present in milk one-half is lost in cheese-making. The curd retains the whole of the casein, most of the fat, about one-third of the mineral matter and a very small quantity of sugar.

The remainder of the sugar and mineral matter, as also the albumin, pass off in the whey and other drainings from the curd.

The Time which is Required to Make a Cheese.

The principal fault to be found with the method of manufacture adopted at the School is the uncertainty, and sometimes great length, of the time required to make the cheese. Practical cheese-makers appear to be totally unable to explain why the time before the curd is fit for vatting varies so greatly.

It is evident that it would be a great advantage if the curd could be vatted by 4 p.m., which frequently happens without any loss of quality; for some of the best cheeses made have been vatted earlier than this, but at times the curd has not been vatted until 10.17 p.m., and even then the acidity of the last drainings has only reached ·87 per cent. of lactic acid. I have therefore paid considerable attention to this question, and find many causes which undoubtedly operate to this end.

1. The time will depend partly upon the number of bacteria originally present in the milk, especially the evening's milk (see p. 159). This, at present, the cheese-maker cannot altogether control though he can do so to a large extent by proper treatment, *i.e.*, keeping the evening's milk warm. The use of stale whey is mainly to increase the number of bacteria, and consequently we find that when no stale whey is used, owing to a taint in the previous day's cheese, the cheeses take longer in making. Frequently, although no stale whey was used, the curd was vatted early. The explanation is that the acidity of the evening's milk had sufficiently risen by the morning because it had been kept warm. In other words, the growth of the bacteria present in the evening's milk had been promoted and kept up during the night, so that the number present in the morning in the mixed milk was probably greater than when, under ordinary conditions, stale whey was employed.

2. The quantity, or rather the proportion of rennet used, will, for reasons already mentioned, considerably affect the time of vatting. This is well shown in the following table:—

Influence of Rennet on time of Vatting.

High Proportion of Rennet.		Low Proportion of Rennet.	
Date.	Time of Vatting.	Date.	Time of Vatting.
	P.M.		P.M.
August 11	5.55	August 14	4.10
„ 4	6.15	„ 19	3.30
„ 8	8.30	„ 18	3.15
September 26	5.45	September 12	3.35
„ 1	3.5	„ 11	2.58
„ 23	5.15	„ 13	3.25
October 24	7.5	October 16	5.50
„ 7	7.0	„ 15	5.45
„ 8	6.30	„ 22	7.20
Average time ...	6.9	Average time ...	4.39

It will thus be seen that the average daily gain in time by using the smaller proportion of rennet was 1 hour 30 minutes.

3. The development of sufficient acidity in the whey during the second scald, prior to drawing the whey off, exercises considerable effect upon the time when the curd will be fit to grind.

If the acidity of the whey when drawn is less than that of the mixed milk before renneting, the subsequent development of acidity in the curd will be slow, so that the curd will not be vatted until late, while if the acidity developed in the whey before drawing off be high, compared with that of the mixed milk, the time of vatting will be early.

The following instances will illustrate these facts:—

Date.	Acid in Milk.	Acid in Whey.	Time of Vatting.
	per cent.	per cent.	P.M.
August 23	·24	·26	2.50
" 21	·25	·22	5.30
September 20	·22	·25	3.38
" 19	·23	·19	7.55
October 20...	·21	·24	6.20
" 26...	·21	·20	8.55

As these results were obtained solely in the autumn it was deemed desirable to see whether the same principle was true in the early months of the year. The following table shows the results in the month of May of six early and six late vatted cheeses.

INFLUENCE OF ACIDITY OF WHEY ON TIME OF VATTING.

Date.	Acidity in Milk.	Acidity in Whey.	Time of Vatting.	Date.	Acidity in Milk.	Acidity in Whey.	Time of Vatting.
			P.M.				P.M.
May 6 ...	·21	·25	4.10	May 17 ...	·23	·17	10.0
" 18 ...	·22	·20	4.40	" 10 ...	·22	·19	9.57
" 21 ...	·22	·21	5.0	" 13 ...	·23	·18	9.50
" 19 ...	·21	·20	5.15	" 5 ...	·21	·18	9.50
" 15 ...	·22	·19	5.25	" 24 ...	·24	·19	9.45
" 12 ...	·22	·22	5.30	" 22 ...	·24	·20	9.35
Average ...	·21	·21	5.0	Average ...	·23	·19	9.50

Besides the saving in time and trouble, there is a distinct advantage gained by so working as to ensure a fairly rapid development of acidity in the curd.

During the early part of the cheese-making season there is frequently considerable difficulty in obtaining this acidity in the whey before drawing off. In such cases it is not desirable to keep the curd stirred during the whole period, but when it has been brought to a sufficient state of division, and is fairly solid, it should be allowed to settle and left in the whey for such period as may be necessary.

In the month of May, 1892, there was much difficulty in getting the curd sufficiently ripe for vatting before a late hour in the evening, and an experiment was made to determine whether it were possible to develop sufficient acidity in the whey during second scald prior to drawing off the whey to ensure an early cheese. The acidity of the mixed milk was ·23; after cutting, ·15; before breaking, ·16; after first scald, ·17; at commencement of second scald, ·175. The scald commenced at 9.40 a.m., and the second scald was in at 10.20, and then a most tedious operation was gone through in order to fulfil the conditions of the experiment, and obtain in the whey, before drawn, sufficient acidity. The acidity of the whey rose most slowly, taking about twenty minutes for a rise of ·01 per cent., so that it was not until 12 o'clock that the whey showed the desired acidity of ·24 per cent.; then the curd was allowed to settle, the time in scald having occupied 2 hours and 35 minutes. Nevertheless, from that moment the acidity progressed rapidly, and consequently, in spite of this long and tedious process in the morning, the curd was fit to grind at 5.35 p.m. Only six cheeses during the month had been vatted at an earlier hour.

There are occasionally instances in which the curd has been slow to develop the necessary acidity, even though the whey has been slightly more acid than the milk. These exceptions are, I think, explained partly by the first cause mentioned—namely, a want of bacteria in the milk to start with—and partly by the second cause—the quantity of rennet used.

Should, by accident, the whey be drawn before sufficient acidity is developed, the curd should be allowed to remain piled longer than usual, for now, when it is warmer than it will be at any subsequent stage, the formation of lactic acid will take place most rapidly.

The rapidity with which the formation of acid takes place at this stage is well shown by the following figures, though the curd only remained piled 17 minutes:—

Acidity of whey when first drawn	·23	per cent.
Towards the end of drawing (just before piling)	·29	,,
Liquid from curd when first piled	·36	,,
After a short time	·37	,,
Final droppings	·41	,,

During the early years of these observations, Miss Cannon always tasted the whey which first came from the piled curd, and determined in this manner how long the curd should remain piled. But very few makers possess sufficient delicacy of taste to form an accurate opinion on such basis. The use of the acidimeter now obviates this trust to taste.

The addition of sour whey to the second scald would fail to bring about the desired end; the development of acidity is needed *within* the curd, while such addition would promote the development in the whey and tend to harden the outside of the curd.

4. The temperature of the second scald has considerable influence on the time which it takes to obtain the requisite acidity, and hence on the time required to make the cheese. (See p. 106, *The Effect of High Scald.*)

The Ripening of Curd.

One of the original objects of the experiments was to discover, if possible, what changes take place during the ripening of curd and its conversion into cheese. Everyone knows how very different in texture and flavour newly-made curd is from ripe cheese. There is every reason to suppose that the ripening of cheese depends on the growth and chemical changes produced by bacteria. For it is well known that if a cheese is kept at a low temperature, such as retards the growth of bacteria, ripening takes place slowly. On the other hand, when a cheese is kept at a higher temperature, more favourable to the growth of bacteria, ripening takes place rapidly. Hence the investigation divides itself into two parts—first, what bacteria are at work in the ripening of a cheese, and secondly, what chemical changes are brought about by their growth?

It is the second subject, namely, what chemical changes take place in the ripening of curd, which must now receive atteniton.

Only those who have studied chemistry can at all appreciate the difficulties of such an investigation, and it is far from an easy task to clearly explain the work which has been done. Curd, when taken to the cheese-room, consists of water, fat, a small amount of milk sugar, lactic acid, albumin, and mineral matter (including the salt added to the curd), and lastly, "curd" itself, or the "casein" of the milk in a solid and insoluble form.

That all cheese when ripe has lost moisture and become dry was evident. Some workers said that the fat was increased, others denied this, while the changes which had taken place in the casein were but little understood.

My first object was to devise a method of analysis which might throw some light on the changes that had taken place. The primary question was, did the ripening of the cheese render the casein or any other substance soluble in water?

The Composition of Ripe Cheese.

The difference in appearance between the white solid interior and the yellow semi-liquid exterior of a half-ripe Camembert Cheese, affords a striking example of change due to ripeness, and my first experiments were made therewith. As difficulties were met with and overcome, the system of analysis was extended, and at last a definite system of examination was drawn up. Owing to the small sample of cheese which can be obtained from a boring, and the minute amount of substances to be estimated, it was not always possible to carry out the complete scheme, nor yet to check figures which seemed doubtful. In spite of these drawbacks and the incompleteness of the results, they throw some light upon the subject of ripening.

The analytical data are given in the table on page 126. For the information of those who may wish to apply this method of investigation to other cheeses, I will briefly describe the process adopted. In order to obtain accurate results, the various determinations must be made with the utmost rapidity compatible with accuracy. The solutions undergo rapid change, after which the results would be useless and misleading. All the chemical solutions and apparatus must be scrupulously accurate and tested specially before commencing work.

The sample of cheese is cut up on a porcelain slab into minute fragments; these must be well mixed together and portions taken for each determination. As regards the first six estimations, the methods by which these are made are well known. No. 7 is obtained by rubbing up 1 gramme in a mortar with water, and the acidity is estimated as previously described for curd.

The soluble constituents are estimated as follows: 5 grammes of the sample are taken, rubbed to a thin paste with a little water in a porcelain mortar, and then transferred to a graduated glass cylinder (stoppered), and the mixture made up to 104 cubic centimeters. This will yield 100 cubic centimeters of solution. After repeated shakings, the mixture is allowed to stand until next morning, when it is filtered, and the determinations are immediately made in the filtered liquid. In these determinations the acidity is first estimated as usual, the portion taken for this estimation being then evaporated to dryness for the solids. I find that unless precaution is taken to first neutralise the solution there is a loss during evaporation.

No. 13 is estimated by Kjeldahl's method.

No. 14 by distillation, after making slightly alkaline.

No. 15 by titrating with standard sulphuric acid, using methyl orange as indicator.

No. 16 by distilling the solution used for No. 15 estimation.

After repeated investigations no fat has been found in the soluble constituents.

Some of the nitrogenous constituents are soluble in ether after the sample has been dried. Thus an attempt to estimate the fat in the cheese by drying with gypsum and then extracting with ether in a Soxhlet apparatus, has yielded abnormally high fat results, while the estimation of the nitrogen in the extracted residue gives abnormally low casein (nitrogen) results.

TABLE SHOWING THE COMPOSITION OF CHEESE AT VARIOUS STAGES OF RIPENESS.

No.	—	CAMEMBERT CHEESE.		CHEDDAR CHEESE OF APRIL 22, 1896.*			CHEDDAR CHEESE OF JUNE 4, 1896.†			CHEDDAR CHEESE OF SEPT. 7, 1896.			CHEESE OF APRIL 24, 1897.
		Unripe.	Ripe.	On April 22.	On July 7.	On Aug. 17.	On June 4.	On Aug. 5.	On Aug. 31.	On Sept. 16.	On Jan. 25, 1897.	On Nov. 18, 1897.	On June 14, 1897.
1	Water	52·70	51·15	39·95	36·55	35·45	39·90	34·40	36·15	37·75	34·65	27·60	38·55
2	Solids	47·30	48·85	60·05	63·45	64·55	60·10	65·60	63·85	62·25	65·35	72·40	61·45
	Containing :—												
3	Fat	21·87	22·52	30·78	31·20	31·75	30·80	30·60	30·75	33·16	34·54	37·40	25·84
4	(a) Casein, &c., by difference	21·93	22·88	26·57	29·30	29·15	27·30	30·95	29·15	24·14	26·76	30·15	31·61
5	(b) Mineral matter	3·50	3·45	2·70	2·95	3·65	2·00	4·05	3·95	3·95	4·05	4·85	4·00
6	In (a) Casein by estimation of $N \times 6\frac{1}{4}$	...	...	24·06	26·31	26·35	25·81	28·06	27·74	23·56	25·11	33·93	28·68
7	Total acidity calculated as Lactic Acid	...	...	·95	3·78	3·15	1·03	2·50	3·24	1·53	2·07	2·70	2·97
8	In (b) Lime	...	...	1·00	...	1·00	1·03	...	...	...	1·04	·90	·84
	Soluble constituents—												
9	Total solids	...	...	7·65	15·27	14·40	7·96	13·43	14·80	8·80	13·60	20·10	10·80
10	Acidity calculated as Lactic Acid	·72	1·08	1·44	2·16	2·16	1·80	2·34	2·52	·81	·85	2·16	1·62
11	Mineral matter...	...	...	2·26	2·27	...	·96	...	...	...	3·40	4·30	3·80
12	Containing Lime	...	...	·67	...	...	·45	...	...	...	·89	...	·56
13	Casein, by estimation of $N \times 6\frac{1}{4}$	15·44	23·00	4·18	8·69	8·81	4·21	9·61	14·25	4·00	9·30	9·59	...
14	Ammonia Volatile	·54	·65	...	...	...	·14	·24	...	·09	...	...	...
15	Neutralising power estimated as Ammonia...	·17	·44	·27	·41	·60	·34	·47	·60	·30	·34	·37	·34
16	Volatile acids estimated as Butyric Acid...	·61	·72	...	·53	...	...	...	...	...	...	1·20	...

* This Cheese was tainted, and subsequently became unfit for food.

† Very good Cheese, in perfect condition on August 31st.

Let us now turn to the results obtained. It is evident that, during ripening, practically no change takes place in the fat. It is not increased in quantity, and it is not rendered soluble. The most marked change is the gradual increase in the amount of solids rendered soluble (No 9), while this soluble matter is seen to consist mainly of nitrogenous substances (No. 13). Side by side with this change, we have a constant increase in both the acidity of the cheese and in the soluble acids, and it is highly probable that this increase in acidity is the primary cause of the increase in solubility of the nitrogenous matter. In other words, the principal factors in the ripening of cheese are the continued production of lactic acid, side by side with an increase in the solubility of the casein, or nitrogenous compounds. But this is not all. As the casein is rendered soluble, we find an increase in the amount of ammonia (No. 14), and also of substances like ammonia, having a basic action (No. 15). There can be little doubt but that these substances are products of the decomposition of casein, and, so far as my experiments go at present, the main portion of the casein appears to have been converted into peptones. I have not been able to find any soluble albumin.

Now, if we examine the figures relating to the cheese of 22nd April, we shall find on 17th August, when the cheese had commenced to go off, that, while the soluble acidity (No. 10) had not increased since July, the actual acidity of the cheese (No. 7) had decreased. The formation of lactic acid had ceased, and fermentation of the soluble constituents—in other words, decomposition—had set in. The germs of taint not yet destroyed in the curd, but apparently kept in check by the activity of the lactic acid bacillus, so long as that organism was at work, now, having the field clear, commenced anew their evil influence.

One other point in connection with the ripening of cheese was investigated, namely, the effect of keeping a cheese for twelve months. The cheese of September 7th, 1896, was analysed for the third time on November 18th, 1897, and the results of the three analyses, are given in the preceding table. It will be seen that the acidity of the cheese has increased, comparatively speaking, but slightly. But the soluble constituents have very greatly increased, as also the soluble acidity. Also there has been a considerable amount of butyric acid formed.

The very small quantities of butyric acid found in the other cheeses show that the conclusion at which I have arrived from a microscopical examination of the cheeses is correct, and that the butyric ferment plays practically no part in the ripening of Cheddar Cheese.

On the other hand, the very considerable increase in the percentage of lactic acid in the cheese lends additional proof to my conclusion that it is the development of this acid which plays the most important part in the process of ripening.

On Excessively Rapid Ripening Cheese.—The investigation into the ripening of Cheddar Cheese which had been commenced in 1896, was continued in 1897, a sample of the cheese made at Long Ashton on 24th April being submitted to analysis on the 14th of June. It will be seen that there has been a rapid development of acidity, and nearly 11 per cent. of the curd has become soluble in water, so that it already showed signs of being nearly ripe, though not two months had elapsed since it was made. These figures greatly surprised me, and led to inquiries which subsequently resulted in my discovering that Fenswood Farm had been noted for making quickly-ripening cheese. This result was confirmed on the 20th December, 1897, I then carefully tasted the cheeses of August, September, and October, and was surprised to find that the October cheeses were in ripe condition, and of good flavour. The September cheeses were in my opinion slightly overripe, and not of such good flavour, and the August cheeses had gone off considerably. Thus the experience of 1897 convinced me that the cheese made at Long Ashton was of exceptionally rapid ripening quality. This was due to the presence in the curd when vatted of a high percentage of moisture, and the presence in the milk of taints which promoted both the ripening of the cheese, and its subsequent deterioration.

One of the most striking peculiarities of this taint (the vinegar taint) was that it did not show itself in the curd during the early stages of ripening, so that anyone tasting the cheese might reasonably think it would improve upon keeping. The Committee, however, had paid dearly for the lesson in 1897, and were not going to repeat it in 1898. Unfortunately the season of 1898 was greatly against the cheese made at Long Ashton, the great and continued heat caused the cheese to ripen even more rapidly than in an ordinary season, though every possible means was taken to keep the cheese-room cool and well ventilated, an outlet for air being made in the roof, and an inlet in the door.*

The question, however, arose—if the cheese does not show the taint until it is fully ripe, how can we determine when this ripeness has taken place? Here the results of my past experiments came to my help, and I considered that it was possible to determine the ripeness of the cheese with sufficient accuracy for practical purposes by means of the solubility of the curd and the percentage of soluble acid. Some of the members of the Committee were not prepared to accept this as a test of ripeness, but, after fully discussing the subject, it was decided that this

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* A simple method was adopted which might be followed in most cheese dairies. Six two-inch holes were bored in the bottom of the cheese-room door, and a sliding shutter containing similar holes placed inside, by means of which the holes could either be left completely open, or partly or completely closed at will.

chemical test should be adopted in 1898, and that the cheeses should be sold when, in my opinion, they were fit for sale.

The Chemical Test of Ripeness.—As previously pointed out, if a sample (5 grammes) of curd, taken immediately before being vatted, be ground up in a mortar with 50 c.c. water, and made up to 104 c.c., and the solution, after standing for 24 hours, be filtered, it will be found that a certain amount of curd is soluble and has passed into the water solution, as also a certain amount of acid. As the curd ripens, the proportion of solid which is soluble in water increases and also the proportion of acid. Hence, the amount of soluble matter, and of soluble acid may be looked upon as a test of the progress of ripening, in other words, of the ripeness of the cheese.

It was deemed necessary in the first place to determine what results would be obtained by examining in this way curd as vatted. Twenty-two samples of curd, immediately after it was ground, were examined so as to give me a standard for the future, and the average results of these analyses were as follows:

Solids in newly made curd soluble in water ... 4·74 per cent.
Acidity of newly made curd soluble in water ... 1·00 „

The percentage of soluble solids in curd when ground varies from 3·80 to 6 per cent., though this large amount is rarely found. The soluble acidity is more constant, varying only from ·80 to 1·20 per cent. It will be necessary to bear these facts in mind when considering the following table. This table gives the results of the soluble solids and acid which were determined in a number of cheeses at different periods of ripening in 1898.

ANALYSES OF CHEESE TO SHOW SOLUBLE CONSTITUENTS.

Date when made	Number of Weeks after when Tested.	Soluble Solids per cent.	Soluble Acid per cent. (as lactic).	Date when made.	Number of Weeks after when Tested.	Soluble Solids per cent.	Soluble Acid per cent. (as lactic).
April 1	12	14·00	1·80	June 16	11	15·60	2·00
„ 9	11	14·80	1·80	„ 16	16	17·00	2·40
„ 15	8	12·60	2·00	„ 25	10	16·00	2·20
„ 26	7	12·60	1·60	July 9	13	15·20	2·40
„ 30	8	14·40	1·60	„ 10	13	15·20	2·00
May 5	10	15·00	1·60	„ 11	13	15·80	2·00
„ 5	15	16·60	2·00	„ 13	12	14·60	2·20
„ 17	10	15·20	1·60	„ 17	14	13·80	2·00
„ 17	11	15·60	2·00	„ 27	12	13·20	1·80
„ 17	15	17·50	2·40	Aug. 6	10	14·00	2·00
„ 18	15	16·00	2·40	„ 16	9	13·80	2·20
„ 19	15	16·60	2·40	„ 26	8	12·90	1·40
„ 25	8	14·00	1·60	Sept. 4	6	12·90	1·20
„ 25	13	15·00	2·00	„ 14	5	13·10	1·40
June 7	12	15·20	2·20	„ 24	4	10·60	1.00
„ 7	17	17·60	2·60				

It will be seen from these figures, first, that the proportion of soluble constituents and of soluble acid increases with the age of the cheese. The cheeses of May 5th and 17th, and of June 7th and 16th, show this well.

Secondly, that this increase is not always the same for an equal period of ripening, which is probably due to the fact that the temperature at which the cheeses are kept is not constant throughout the season. This variation is well seen by comparing the cheeses of April 9th, May 5th and 17th, June 25th, and August 6th. Each of these was analysed at the end of ten weeks, and it will be seen that the August cheese ripened most slowly, the April cheese next, then the May cheese, and lastly the June cheese, which ripened most rapidly. The rapid ripening of the June cheese was mainly due to the great heat of August.

There is one other point about these analyses which must be noticed, namely, that the soluble solids at times increase more rapidly than the soluble acid. This is very probably due to the initial solubility of the curd varying as already pointed out. The figures which have been obtained are not perhaps sufficiently numerous to justify taking the average results as a permanent standard; the following, however, may be quoted:—

—	Average Soluble Solids.	Average Soluble Acid.
Cheeses 8 weeks old or younger ...	13·2	1·57
Cheeses from 9 to 12 weeks old ...	14·7	1·95
Cheeses from 13 to 16 weeks old ...	15·8	2·20

In 1896 the soluble constituents in a cheese thirteen weeks old, which was of a very good quality and in perfect condition, amounted to 14·80 per cent. I therefore decided to take this as my standard for the April cheeses, and to determine as the season proceeded whether the standard required to be altered or not.

How this worked out in practice now remains to be related.

On the 15th day of June analyses were made of two of the April cheeses, and the results were so high that, in my opinion, it was desirable to at once take steps to sell them, for such arrangements necessarily take time. The cheeses were sold on the 12th day of July for 50s. a cwt. In Mr. Hill's opinion the cheese was fully ripe, there was a slightly unpleasant flavour in several, but as a whole they were better than those made in 1897. Thus the April cheeses, though sold when only from ten to fourteen weeks old, were considered fully ripe. Now, if we examine the analytical data in the preceding table, we shall find that the cheeses of the 4th and 9th April, when only eleven and twelve weeks old respectively, showed nearly as much soluble matter as I had taken as my standard. Hence I felt no reason to alter this standard.

On the 19th of July, the cheeses of 5th, 17th, and 25th of May were tested, and yielded the results seen in the table, p. 129. In my opinion they were fit for sale, and the Secretary was informed thereof.

As some of the Committee thought that the cheeses were being placed on the market too soon, two of the May cheeses, viz., 18th and 19th, were kept back in order to determine whether by further keeping they would improve or deteriorate. The rest of the May cheeses were not sold until the 30th day of August, and fetched 58s. per cwt. The cheeses had not been sold so promptly as I could have wished, and had already, in my opinion, commenced to deteriorate. On the 6th October, the buyer, when visiting the purchasers of these cheeses, was asked to try them. He informed me subsequently that he found them "hot and stingy," and not worth nearly so much as he had given for them in August. The two May cheeses which were kept back were subsequently tested, and were not considered so good as when the remainder were sold. One had kept fairly well, but not the other.

Further proof of the deterioration of the cheeses by keeping is found in the prices which the first half of the June cheeses fetched. On the 1st September, three of the June cheeses were analysed, and found to be fit for sale; but, from some cause or other, they were not sold until the 6th of October. The result was that they were over-ripe, and only fetched 50s. per cwt.

After this date, owing mainly to the elimination from the dairy of the abnormal milk of the four cows previously referred to in this Report, the cheeses were of a different character altogether, and fetched for the remainder of June and the first half of July, 60s. per cwt. The analyses of the four July cheeses, 9 to 13, were started the day they were sold, and the results again show that the standard of about 14·8 per cent. of soluble solids was a fairly accurate indication of a ripe Cheddar Cheese.

The second half of the July cheeses and those of August, September, and October, were sold on the 14th December, and fetched 60s. per cwt. On 17th November, the cheeses were tasted; not one of them was hot or stingy, and, though some were not of the finest flavour, yet they were a very considerable improvement on all the cheeses made prior to the 15th June.

From the results of these investigations, I am inclined to think that the determination of the solid matter soluble in water and the acidity thereof afford a very fair indication of the ripeness of a Cheddar Cheese. And so far as can be judged from the results at present obtained, not more than 15 per cent. should be soluble, and the soluble acidity should amount to under 2·5 per cent.

Summary of Results. — From the preceding investigations we get some slight idea as to the processes which are taking place during ripening, and their practical bearing is both interesting and important. So long as lactic acid is being developed in the curd, so long is the cheese ripening. When the maximum acidity has been attained, it then begins to gradually diminish, decomposition sets in, and the taints, or rather the bacteria of taints, which up to this period seem to have been compelled to lie dormant, now re-assert their sway.

The process of ripening is followed by that of decay, the rapidity of which will depend mainly upon the impurity of the original milk and curd. We also understand why it is that cheeses which, if examined during the period of ripening, are found of fair quality, when kept over that period "go off," diminish materially in value; and become in time absolutely valueless.

It cannot be too strongly impressed upon cheese-makers that a cheese, when ripe, is at its best, and from that time it begins to deteriorate. The warmer the room in which the cheese is kept, the more rapid is both the ripening and the subsequent falling off. Thus it is that cheese made late in the season keeps better and longer than that made early. The early made cheese is ripening in a continually rising temperature; the process of ripening is therefore continually increasing in rapidity. The late made cheese ripens in a continually falling temperature, and therefore the process of ripening is week by week more and more checked. Hence it is that a cheese-room requires to be artificially heated in the autumn or the cheeses will not properly ripen. The temperature of a cheese-ripening room should be about 65° F.

The only possible means of checking the ripening of a cheese beyond a desirable point is to at once place it in a low temperature. I am informed by Messrs. Douglas, who have had exceptional opportunities of judging what temperature is best, that, as the result of their experience, they recommend 40° F., and this temperature is one which would agree with the dictates of science, so far as we are at present able to judge. Still I have reason to think that even at this temperature certain changes will take place, though the subject is one which has not yet been thoroughly investigated. I merely mention it to warn cheese-makers that cheese could not be kept indefinitely even at this temperature.

If a cheese has been made from exceptionally pure milk, the changes which proceed in the cheese, after what may be termed complete ripeness has been reached, are such as will not materially injure the cheese, and they will proceed comparatively slowly. But if any taint was in the milk when the cheese was made, then the changes which take place after complete ripeness has been reached are more rapid and more destructive to the quality of the cheese.

It is impossible to study these results without feeling that the question of the rapid ripening of cheese and its consequent results needs, indeed demands, serious consideration. Has not rapid ripening been carried too far? While, on the one hand, it is not imperative to make a cheese that requires a twelvemonth in which to ripen, is it desirable to make one which is ripe three months after it is made, and commences to show signs of decomposition a month later, unless made under exceptional conditions or kept at a temperature which few cheese-makers can ensure.

Composition of Ripe Cheeses.—A large number of the cheeses made each year have been analysed, and the average results obtained are collected in the following table:—

AVERAGE COMPOSITION OF CHEDDAR CHEESE DURING 1891–97.

Made in	Number Analysed.	Water.	Fat.	Casein, &c.	Mineral Matter.
April	21	35·75	31·51	28·71	4·03
May	19	35·71	30·89	29·30	4·10
June	25	35·10	30·81	30·12	3·97
July	29	34·63	31·23	30·18	3·96
August	25	35·51	31·51	29·05	3·93
September	29	35·74	31·47	28·86	3·93
October	27	36·59	31·87	27·66	3·88
Average ...	175	35·58	31·33	29·12	3·97

It thus appears that the average composition of ripe Cheddar Cheese is as follows:—

Water.	Fat.	Casein.	Mineral Matter.
35·58	31·33	29·12	3·97

It was for long maintained that in the ripening of cheese, fat was formed out of the curd. The analyses of many ripe cheeses have been compared from time to time with the analyses of the curd from which those cheeses have been produced, with the result that they afford no evidence that fat has been produced in the ripening of Cheddar Cheese.

The amount of salt present in the cheeses varies, but as the mean of some analyses it appears to be about 2·70 per cent.

The prices obtained for the cheeses which have been made during the course of these observations are shown in the following table:—

PRICES OBTAINED FOR THE CHEESES MADE DURING 1891–98.

Month.	Shillings per Cwt. of 112 lbs.							
	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.
April	54	58	60	60	51	54		50
May	65	65	66	63	58	66		58
June	66	68	68	64	58	66		50 60
July	66	68	68	64	58	71	60 & 41/6	60 50
August	66	70	68	65	58	71		60
September	66	70	68	65	58	72		60
October	66	70	68	60	58	72		60

MONTHLY AVERAGES OF RESULTS OF OBSERVATIONS, 1894.

	3	5	6	7	9	9	10	11	13	14	15	19	20	23	25	27	34	34a	35	45a	51	53	54	55	60
	Relating to Evening's Milk.								Morning's Milk.				Mixed Milk, &c.												
		At night.			In morning.																				
Month.	Volume of Milk.	Temp. of Dairy.	Temp. of Milk.	Acidity.	Temp. of Dairy.		Temp. of Milk.	Acidity.	Volume.	Acidity.	Total volume of milk.	Acidity of Stale Whey.	Acidity.	Proportion of Rennet added.	Acidity of Whey before breaking.	Acidity of Whey put aside.	Acidity of Whey when drawn.	Volume of Whey.	Acidity of drainings from piled curd.	Acidity of drainings from Curd before grinding.	Weight of Curd when vatted.	Acidity of Liquid from Press.	Weight of Cheese taken to cheese room.	Loss in Press.	Weight of cheese when sold.
	galls.	° F.	° F.	Per cent.	° F. min.	° F. max.	° F.	Per cent.	galls.	Per cent.	galls.	Per cent.	Per cent.	1 of Rennet to	Per cent.	Per cent.	Per cent.	galls	Per cent.	Per cent.	lbs.	Per cent.	lbs.	lbs.	lbs.
April ...	51	58	83	·21	56	59	68	·22	55	·21	103	·40	·22	9006	·15	·16	·19	88	·25	·82	109	1·05	101	8	96
May	70	60	81	·22	58	60	68	·23	78	·22	148	·39	·22	9011	·15	·16	·20	142	·28	1·00	162	1·08	148	14	140
June	67	64	82	·21	62	64	69	·22	72	·21	140	·37	·22	8939	·14	·15	·18	135	·27	·92	153	·99	141	12	132
July	63	66	84	·21	64	67	70	·22	65	·20	129	·39	·22	8940	·15	·15	·18	124	·27	·93	141	1·02	131	10	124
August ...	55	65	82	·22	64	66	70	·22	58	·20	112	·36	·22	8821	·14	·15	·17	108	·23	·90	128	1·04	118	10	112
September ...	48	63	83	·22	62	64	69	·23	52	·22	100	·31	·23	8024	·15	·16	·19	97	·23	·90	120	1·02	112	8	106
October ...	34	64	79	·22	61	66	70	·22	40	·22	74	·36	·22	6880	·14	·15	·18	67	·24	·94	94	1·04	87	7	81

MONTHLY AVERAGES OF RESULTS OF ANALYSES.

Month.	Composition of Mixed Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April	87·69	12·31	3·29	2·42	·41	5·52	·67	7·08	·24	·44	40·03	59·97	28·28	2·45
May	87·49	12·51	3·35	2·73	·40	5·33	·70	7·05	·17	·46	40·28	59·72	27·53	2·59
June	87·48	12·52	3·40	2·69	·40	5·31	·72	7·28	·21	·52	40·12	59.88	29·62	2·41
July	87·48	12·52	3·47	2·64	·39	5·30	·72	7·15	·23	·49	40·38	59·62	31·45	2·28
August	87·22	12·78	3·70	2·76	·40	5·17	·75	7·13	·22	·46	40·33	59·67	30·06	2.26
September ...	86·95	13·05	3·93	2·83	·42	5·07	·80	7·21	·23	·47	40·94	59·06	29·81	2·20
October	86·54	13·46	4·39	2·95	·44	4·85	·83	7·27	·21	·45	40·58	59·42	30·19	2·25

MONTHLY AVERAGES OF RESULTS OF OBSERVATIONS, DURING 1ST AND 3RD WEEKS, 1895.

	3	5	6	7	9		10	11	13	14	15	20	23	25	27	34	35	45a	51	53	54	55	60
MONTH.	RELATING TO EVENING'S MILK.								MORNING'S MILK.		Total Volume of Milk.	MIXED MILK, &C.		Acidity of Whey before breaking.	Acidity of Whey put aside.	Acidity of Whey when drawn.	Acidity of drainings from piled Curd.	Acidity of drainings from Curd before grinding.	Weight of Curd when vatted.	Acidity of Liquid from Press.	Weight of Cheese taken to cheese room.	Lo[illegible]n Press.	Weight of Cheese when sold.
	Volume of Milk.	At night.			In morning																		
		Temp. of Dairy.	Temp. of Milk.	Acidity.	Temp. of Dairy.		Temp. of Milk.	Acidity.	Volume.	Acidity.		Acidity.	Proportion of Rennet added.										
	galls.	° F.	° F.	Per cent.	° F. min.	° F. max.	° F.	Per cent.	galls.	Per cent.	galls.	Per cent.	1 of Rennet to	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	lbs.	Per cent.	lbs.	lbs.	lbs.
April ...	54	58	88	·17	56	59	69	·18	70	·18	124	·18	7483	·13	·14	·16	·22	·94	132	1·11	124	8	116
May	74	6[illegible]	89	·19	60	63	70	·20	91	·19	165	·20	6194	·13	·14	·17	·23	·92	183	1·12	171	12	160
June	80	67	89	·20	65	67	72	·21	89	·19	169	·20	6339	·13	·14	·16	·23	·90	176	1·09	164	12	152
July	66	66	88	·20	65	67	73	·21	77	·19	143	·20	6010	·13	·13	·17	·25	·95	156	1·12	145	11	135
August ...	56	65	88	·20	63	65	73	·22	78	·20	134	·21	6007	·14	—	·18	·27	·89	151	1·09	141	10	133
September ...	52	65	89	·20	64	66	74	·22	64	·20	116	·21	6006	·14	·14	·20	·30	·92	136	·98	128	8	122
October ...	36	64	84	·19	61	65	73	·20	45	·19	81	·20	6002	·13	·13	·18	·26	·93	104	1·01	97	7	92

MONTHLY AVERAGES OF RESULTS OF ANALYSES.

MONTH.	COMPOSITION OF MIXED MILK.							COMPOSITION OF WHEY.			COMPOSITION OF CURD.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April	87·35	12·65	3·70	2·43	·41	5·37	·74	7·40	·34	·48	41·40	58·60	32·27	2·13
May	87·42	12·58	3·39	2·60	·41	5·45	·73	7·24	·25	·44	41·14	58·86	29·78	2·15
June	87·44	12·56	3·51	2·58	·41	5·34	·72	7·20	·31	·42	40·95	59·05	29·70	2·14
July	87·32	12·68	3·60	2·67	·40	5·29	·72	7·16	·28	·43	41·04	58·96	31·10	2·03
August	87·18	12·82	3·80	2·68	·41	5·18	·75	7·13	·23	·43	41·14	58·86	31·17	2·13
September ...	86·97	13·03	3·91	2·91	·42	5·00	·76	7·18	·27	·42	41·28	58.72	29·91	2·05
October	86·30	13·70	4·55	2[illegible]	·44	5·01	·77	7·21	·20	·43	41·05	58·95	31·05	2·12

MONTHLY AVERAGES OF RESULTS OF OBSERVATIONS, DURING FIRST 10 DAYS OF EACH MONTH, 1896.

Month.	3	5	6	7	9		10	11	13	14	15	20	23	25	27	34	35	45a	51	53	54	55	60
	Relating to Evening's Milk.								Morning's Milk.			Mixed Milk.											
		At night.			In morning.																		
	Volume of Milk.	Temp. of Dairy.	Temp. of Milk.	Acidity.	Temp. of Dairy.		Temp. of Milk.	Acidity.	Volume.	Acidity.	Total Volume of Milk.	Acidity.	Proportion of Rennet added.	Acidity of Whey before breaking.	Acidity of Whey put aside.	Acidity of Whey when drawn.	Acidity of drainings from piled Curd.	Acidity of drainings from Curd before grinding.	Weight of Curd when vatted.	Acidity of Liquid from Press.*	Weight of Curd taken to Cheese Room.	Loss in Press.	Weight of Cheese when sold.
	galls.	° F.	° F.	Per cent.	° F. min.	° F. max.	° F.	Per cent.	galls.	Per cent.	galls.	Per cent.	1 of Rennet to	Per cent.		Per cent.	Per cent.	Per cent.	lbs.	Per cent.	lbs.	lbs.	lbs.
April... ...	62	62	81	·184	61	69	75	·194	69	·181	131	·190	8000	·132	—	169	·247	·90	134	1·01	126	8	118
May	77	66	87	·186	63	66	71	·199	89	·177	166	·189	8000	·137	—	·207	·301	·92	175	1·01	164	11	157
June	72	68	88	·172	66	69	73	·185	85	·166	157	·175	8000	·140	—	·223	·329	·85	167	·96	155	12	145
July	73	68	87	·196	67	69	72	·208	69	·190	142	·198	8000	·146	—	·203	·304	·93	153	1·00	142	11	137
August ...	62	68	86	·182	66	68	72	·196	57	·177	119	·185	8000	·138	—	·178	·228	·99	134	·96	124	10	119
September ...	36	67	83	·180	66	67	74	·192	46	·177	82	·185	8000	·134	—	·201	·318	·93	97	1·01	90	7	83
October ...	27	65	80	·185	63	66	71	·200	37	·181	64	·189	8000	·139	—	·199	·271	·99	79	·90	74	5	70

* This determination was made every day, and the average given is that of the whole month.

MONTHLY AVERAGES OF RESULTS OF ANALYSES.

Month.	Composition of Mixed Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April	87·25	12·75	3·83	2·43	·39	5·46	·64	7·48	·32	·45	40·66	59·34	32·05	1·78
May	87·22	12·78	3·70	2·64	·36	5·41	·67	7·21	·25	·48	40·72	59·28	30·64	2·05
June	87·41	12·59	3·57	2·64	·35	5·36	·67	7·12	·21	·44	41·33	58·67	29·88	1·83
July	87·39	12·61	3·66	2·58	·34	5·34	·69	7·17	·25	·49	42·07	57·93	30·87	2·01
August	87·27	12·73	3·83	2·66	·36	5·17	·71	7·00	·34	·50	41·65	58·35	31·09	1·93
September ...	86·81	13·19	4·31	2·71	·38	5·06	·73	7·03	·34	·54	40·57	59·43	32·85	1·88
October	86·62	13·38	4·41	2·85	·40	5·02	·70	7·13	·33	·51	41·40	58·60	31·69	2·05

RECORD OF OBSERVATIONS, LONG ASHTON, 1897.

	3	5	6	7	9		10	11	13	14	15	20	23	25	27	34	35	45a	51	53	54	55	60
	Relating to Evening's Milk.								Morning's Milk.			Mixed Milk.											
		At night.			In morning.																		
Month.	Volume of Milk.	Temp. of Dairy.	Temp. of Milk.	Acidity.	Temp. of Dairy.		Temp. of Milk.	Acidity.	Volume.	Acidity.	Total Volume of Milk.	Acidity.	Proportion of Rennet added.	Acidity of Whey before breaking.	Acidity of Whey put aside.	Acidity of Whey when drawn.	Acidity of drainings from piled Curd.	Acidity of drainings from Curd before grinding.	Weight of Curd when vatted.	Acidity of Liquid from Press.	Weight of Curd taken to Cheese Room.	Loss in Press.	Weight of Cheese when sold.
	galls.	° F.	° F.	Per cent.	° F. min.	° F. max.	° F.	Per cent.	galls.	Per cent.	galls.	Per cent.	1 of Rennet to	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	lbs.	Per cent.	lbs.	lbs.	lbs.
April... ...	39	63	87	·198	62	67	73	·207	46	·198	85	·213	8000	·140	·152	·183	·27	·93	89	1·08	84	5	78
May	59	63	88	·185	60	63	73	·189	70	·184	129	·187	7185	·122	·132	·164	·24	·92	132	·98	123	9	112
June	62	66	89	·170	65	67	71	·178	69	·168	131	·175	6005	·121	·150	·173	·26	·92	133	·98	124	9	113
July	51	68	87	·146	66	68	71	·157	52	·144	103	·156	6005	·106	·110	·169	·28	·92	104	·93	98	6	90
August ...	47	68	89	·149	66	70	74	·154	44	·149	91	·158	5993	·105	·100	·164	·26	·91	91	·89	85	6	77
September ...	38	65	89	·162	62	65	74	·171	51	·159	89	·169	6003	·110	·122	·178	·27	·93	94	·83	90	4	84
October ...	34	62	87	·167	60	62	71	·176	48	·164	82	·172	6004	·116	·125	·197	·28	·93	90	·81	87	3	82

MONTHLY AVERAGES OF RESULTS OF ANALYSES, LONG ASHTON, 1897.

Month.	Composition of Mixed Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April	87·26	12·74	3·87	2·45	·42	5·29	·71	7·23	·42	·46	42·01	57·99	30·00	2·08
May	87·45	12·55	3·65	2·48	·38	5·33	·71	7·19	·44	·43	41·95	58·05	28·57	2·25
June	87·63	12·37	3·50	2·43	·38	5·35	·71	7·08	·45	·52	42·58	57·42	28·12	2·26
July	87·54	12·46	3·61	2·35	·37	5·41	·72	7·02	·51	·54	41·40	58·60	30·53	2·17
August	87·46	12·54	3·66	2·38	·35	5·42	·73	7·05	·53	·54	41·42	58·58	30·57	2·17
September ...	87·11	12·89	3·86	2·59	·38	5·34	·72	7·08	·43	·54	41·90	58·10	29·39	2·12
October	86·78	13·22	4·18	2·71	·44	5·14	·75	7·13	·44	·51	41·30	58·70	29·41	2·10

RECORD OF OBSERVATIONS, LONG ASHTON, 1898.

	3	5	6	7	9		10	11	13	14	15	20	23	25	27	34	35	45a	51	53	54	55	60
	RELATING TO EVENING'S MILK.								MORNING'S MILK.			MIXED MILK.											
		At night.			In morning.																		
MONTH.	Volume of Milk.	Temp. of Dairy.	Temp. of Milk.	Acidity.	Temp. of Dairy.		Temp. of Milk.	Acidity.	Volume.	Acidity.	Total Volume of Milk.	Acidity.	Proportion of Rennet added.	Acidity of Whey before breaking.	Acidity of Whey put aside.	Acidity of Whey when drawn.	Acidity of drainings from piled Curd.	Acidity of drainings from Curd before grinding.	Weight of Curd when vatted.	Acidity of Liquid from Press	Weight of Curd taken to Cheese Room.	Loss in Press.	Weight of Cheese when sold.
	galls.	° F.	° F.	Per cent.	° F. min.	° F. max.	° F.	Per cent.	galls.	Per cent.	galls.	Per cent.		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	lbs.	Per cent.	lbs.	lbs.	lbs.
April... ...	34	56	87	·177	53	58	63	·191	46	·177	80	·186	6000	·126	·14	·158	·20	·84	79	·90	75	4	68
May	55	63	87	·190	60	63	69	·198	70	·185	125	·198	6000	·133	·14	·186	·25	·86	128	·94	122	6	117
June	61	63	87	·200	61	63	69	·213	70	·196	131	·206	6000	·140	...	·193	·28	·88	131	·94	124	7	119
July	51	69	88	·200	66	70	70	·227	56	·202	107	·212	6000	·145	...	·200	·25	·89	112	·83	105	7	100
August ...	39	69	88	·193	65	70	71	·215	42	·203	81	·203	6000	·140	...	·185	·22	·92	86	·88	81	5	76
September ...	28	68	89	·197	65	68	73	·217	39	·190	67	·202	6000	·137	...	·200	·28	·92	71	·81	67	4	62
October ...	23	63	85	·200	60	63	71	·226	36	·206	59	·213	6000	·140	...	·186	·25	·96	68	·82	64	4	59

MONTHLY AVERAGES OF RESULTS OF ANALYSES, LONG ASHTON, 1898.

MONTH.	COMPOSITION OF MIXED MILK.							COMPOSITION OF WHEY.			COMPOSITION OF CURD.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April	87·72	12·28	3·48	2·29	·41	5·43	·67	7·09	·60	·44	43·35	56·65	27·92	2·20
May	87·48	12·52	3·55	2·51	·41	5·37	·68	7·02	·43	·48	42·80	57·20	27·40	2·40
June	87·76	12·24	3·38	2·49	·39	5·27	·71	6·96	·40	·44	42·20	57·80	26·55	2·30
July	87·53	12.47	3·52	2·50	·44	5·33	·68	6·99	·38	·53	40·77	59·23	28·70	2·25
August	87·29	12·71	3·84	2·43	·50	5·25	·69	6·93	·41	·55	41·50	58·50	28·94	2·27
September ...	87·24	12·76	3·91	2·59	·52	5·07	·67	6·90	·44	·51	40·72	59·28	29·75	2·12
October	86·76	13·24	4·20	2·75	·52	5·00	·77	7·01	·41	·55	40·66	59·34	30·03	2·15

Part VI.

The Bacteriological Observations.

Introduction.—Bacteria: Their shape, size, weight, food, &c.—Microscopical Examination of Milk, &c.—Isolation and Cultivation.—Counting Bacteria.—The Importance of Bacteria.—The Bacillus Acidi Lactici.—The Bacteriological Examination of Cheese.—Pure Cultures as Starters.—The Organisms Injurious to Cheddar Cheese.—The Vinegar Taint.—Spongy or Holey Curd.—The Fæcal Taint.—Puffing of Cheese.—Ropey Milk Bacteria.—Mould in Cheese.—Oidium Lactis.—Yeasts.—Rennet.—The Variations in the kind of Bacteria found at Different Periods of the Year and at Different Sites.

Introductory.

It is well known that the changes which take place in milk during its conversion into cheese are brought about by the action of what are usually called "ferments." The term ferment is now restricted to a chemical substance, such as "diastase," which is the active principle in malt, or to rennet, and should not be applied to those living organisms or minute plants which are known as bacteria or organised ferments.

These organised ferments probably do, in many instances, secrete a true ferment, but there is no evidence to show that those with which the cheese-maker is concerned act in this manner. The principal organised ferments which the cheese-maker has to consider are "yeasts" and "bacteria," and sometimes "moulds." These organised ferments are present everywhere; they have various shapes, are only capable of growing under certain conditions, which vary with different individuals, while each seems to have a special power of inducing chemical change.

Moulds.—These play so small a part in the manufacture of Cheddar Cheese that no discussion of them is necessary.

The Yeasts are characterised by their method of growth as they multiply by budding. They are mostly round or oval.

Bacteria.

The Bacteria are much smaller than the yeasts and of very different shapes, as shown in the following illustration (Fig. 7). They are all characterised by the fact that they multiply by splitting in two. Each half then grows to a full size

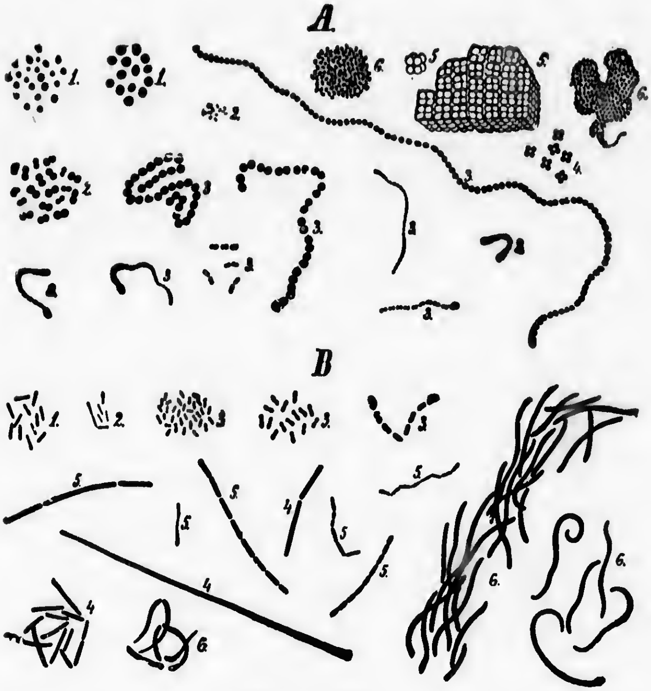


FIG. 7.—Bacteria.

Except A, all the other illustrations are representations of equally magnified bacteria. Mag. 950. Those in A are all symmetrical cells, those in B are elongated.

A.—1. Cocci of various sizes.
2. Diplococci of various sizes.
3. Streptococci of various sizes.
4. Tetrads.
5. Sarcina. Mag. 700.
6. Staphylococci.

B.—1, 2, 4. Bacilli of various lengths and breadths.
3. Short rods, partly of biscuit form.
5. Chains, composed of either short or long rods.
6. Long threads, or Leptothrix.

organism, and proceeds itself to split in two, and so produce two new organisms.

Those bacteria which are in the shape of globes are termed cocci or micrococci; when they grow almost invariably in pairs they are termed diplococci; if four cocci grow together in the form of a square they are termed tetrads; while if these four are superimposed upon another similar four, so as to form a bundle of eight, they are termed sarcina. When several grow in a chain or necklet form they are termed streptococci, or if they grow in clusters like a bunch of grapes they are termed staphylococci.

The second series of bacteria are those which take the form of a small rod or lead pencil. These are the bacteria proper, frequently also called bacilli. These are the names given to them collectively, and hence are in the plural. One organism would be called a bacterium or bacillus.

The bacilli vary greatly in length. Some are so short that it is difficult to see whether the organism is a coccus or bacillus.

The bacilli, like the cocci, sometimes form chains like the streptococci, but no special name is given to this form, the division, however, between the individual bacilli remain visible. But when the division does not remain visible and the bacilli grow into long threads, the distinctive name of leptothrix is given to these threads. The bacilli vary greatly in thickness, some being very fine, others stout as compared with their length.

Sometimes bacteria are surrounded with a jelly-like substance in which they are imbedded. This material is called a capsule, and the bacteria are said to be capsuled.

Lastly, there are a variety of organisms somewhat like the bacilli, short rods curved instead of being straight, these are termed comma bacilli.

Such are the principal forms of bacteria met with in connection with the investigation of Cheddar Cheese.

Size. — These organisms are infinitely minute. Thus 3,000 bacteria of average length, if placed end to end would form a line about one-eighth of an inch long. Hence, for measuring them it has been necessary to adopt a special standard. This standard is the one-thousandth part of a millimetre, and is termed a micron. It is designated by the Greek sign for the letter "m," namely, "μ."

Weight. — One of the characteristic peculiarities of bacteria is that although so minute they are comparatively heavy, and consequently sink to the bottom of a liquid. Some carry on their peculiar chemical action there far more rapidly than at the top of the liquid. Just as a house is built more rapidly the greater the number of men at work, so the chemical action of the bacteria is the more rapid the greater the number of organisms present. This peculiarity of sinking to the bottom I have proved by placing some lactic acid organisms in a test-tube containing milk, and, after thorough mixing, keeping the tube at a temperature suitable for their growth, and free from disturbance; the result was that the milk at the bottom of the tube curdled into a solid mass, while the milk at the top of the tube remained quite liquid. Hence the practice of keeping the evening's milk well stirred has probably an important bearing on the thorough ripening of the evening's milk, in addition to its well-known action of keeping the fat from rising.

Food.—Bacteria are vegetables, and like all vegetables, require both mineral and carbonaceous food. For their growth they require not only suitable food, but also sufficient heat and moisture. If sufficient moisture be not provided, they dry up, but do not always lose their vitality, and may remain for a considerable time in this dried up condition, capable at any moment of starting into active growth when moisture is again provided. The want of sufficient heat has a similar effect: with a decrease in temperature activity decreases, while as the heat approaches to that of the blood activity increases. This is why milk is kept cold to prevent its getting sour, and kept warm to promote the development of acidity.

In taking their food from any substance which they feed upon bacteria do not as a rule consume this substance, but only a very small portion thereof. In taking away this small portion, they materially alter the substance and leave a residual material which is quite distinct from the original substance. Thus, in feeding upon the sugar of milk, they leave behind a substance which is known as lactic acid, other compounds being formed at the same time. The old idea, still frequently met with in text-books, that they split up the molecule of milk sugar into two of lactic acid was a very pretty theory, but quite erroneous.

Some bacteria require air, or more precisely, oxygen, to enable them to live actively, and are termed "aerobic," others are only active when no air is present (anaerobic) while some are capable of growing under either condition, and are termed "facultative." All these varieties are supposed to take an active part in the manufacture of Cheddar Cheese.

Growth.—The rapidity of the growth of different bacteria varies greatly. Thus, if several varieties be kept on the same food and at the same temperature, some will increase in numbers far more rapidly than others. This is well seen in a plate culture (see p. 146), as each of the colonies formed is the result of the growth of one organism, and as all have been growing for the same time, it is very evident that those producing the large colonies grow far more rapidly than those producing the small colonies. Now, the smaller circular or oval colonies are those of the lactic acid bacillus, while the larger colonies are produced by bacteria which are impurities, and ought not to be present. And these investigations have proved beyond question what this plate culture admirably illustrates, that nearly all the bacteria which are injurious to Cheddar Cheese grow more rapidly than the lactic acid organism.

Light, especially direct sunlight, is most detrimental, in fact destructive to many varieties of bacteria.

Microscopical Examination

It will be evident that to study organisms so minute as the bacteria special apparatus is necessary. They can only be seen under the highest powers of the microscope when magnified at least 600 times, but for systematic study it is necessary to be able to study them magnified 1,000 times. This requires a good one-twelfth inch objective, and a high power eye-piece. Into the method of using the microscope for this work, I do not purpose to enter here.

If it is desired to study the bacteria alive under the microscope so as to determine whether they have the power of moving or not, this is done in what is termed the "hanging drop," a minute quantity of liquid in which the bacteria are living or have been placed for the purpose of examination, being suspended from the under side of a cover-glass and then examined. But for the most part bacteria before being examined under the microscope are first destroyed by heat so as to prevent any motion and facilitate the examination, and then stained with an aniline dye which enables them to be far more easily seen. A brief description of this method of examination may not be out of place. Take, for example, a drop of milk. A minute portion of this milk is placed on a cover-glass, spread out as much as it can be by means of a platinum needle, and dried. It is then passed through the flame of a spirit-lamp three times, by which it is raised to such a temperature as will solidify all the albumen in the liquid or rather in the dried layer. The cover-glass is next floated for two minutes on the surface of some aniline stain contained in a watch glass. The bacteria will now absorb the stain, as will also to a certain extent the casein of the milk. The cover-glass is taken out of the stain, and slightly washed in water, then dipped once or twice into alcohol, and again washed in distilled water until no colour comes away. If now examined under the microscope it will be found that the bacteria are deeply stained, while most of the stain has been washed out of the casein and albumen of the milk. Such is the most simple method of staining bacteria whether from a pure culture or in milk or whey.

The microscopical examination of the bacteria in cheese is somewhat more difficult, owing first to the presence of so much fat, and secondly to the ease with which the curd takes up any stain used, and thereby hides the bacteria.

A method which I have found to give admirable results is the following:—

A small portion from the interior of a cheese is taken up with a sterile platinum rod and rubbed down into a very fine layer on a cover glass. This is well dried, passed twice through the flame of a Bunsen burner or spirit-lamp, washed in a watch-glass, film downward, with ether, dried, and again passed through the Bunsen flame twice. The ether removes the fat without affecting the bacteria. Next insert the cover-glass in the staining solution and stain very deeply. An alkaline solution of methylene blue gives good results. Wash off the excess of stain, then insert the glass in a 2 per cent. solution of acetic acid B.P. until *just discolorised*, and *immediately* afterwards in a 3 per cent. solution of ammonia for a few seconds. Subsequently wash in distilled water. If successful, the bacteria will now be deeply stained on a colourless ground. If they are not sufficiently stained, again place the glass in the stain for a minute or two. They will now take up sufficient stain, and as the casein has been partly removed by this treatment, if properly conducted, the ground will be only slightly coloured. The best results are, however, obtained when this further treatment is not necessary. The same method may be adopted for the examination of milk, and has been found invaluable in these investigations.

Stains. — The stains which I have found of most value are:—

(a.) Ziehl's carbol fuchsine solution.
(b.) Gentian or methylene violet.
(c.) Methylene blue.
(d.) Brunswick brown, and water solutions of fuchsine, methylene violet and blue for contrast staining.

Gram's Method.—This method of staining bacteria is so valuable as a means of distinguishing between different varieties that it is necessary to describe it as it will be frequently mentioned hereafter. Most of the aniline dyes are dissolved by alcohol. But certain bacteria have the power of absorbing some of these dyes and presumably of altering them into compounds which, when treated with iodine, are rendered insoluble in alcohol. But these bacteria are only capable of doing this with certain dyes, such as, methylene or gentian violet. The cover-glass preparation of the bacteria is deeply stained with one of these two dyes. This is best done if the stain be kept warm, by standing it on a water bath for 10 to 15 minutes. The excess of stain is just washed off in water which must be allowed to drain from the cover-glass, and this is next placed in a solution of iodine (1 part iodine, 2 parts potassium iodide in 250 water) for two minutes. The cover-glass is now transferred to some absolute alcohol, and kept in this until all the stain has been washed out. The cover-glass is next transferred to a water solution of fuchsine, and this will stain the casein slightly red. The bacteria will now be stained deep violet, and the milk bright red. Only certain bacteria are capable of retaining the stain when subjected to this treatment, and if a liquid is being examined containing both bacteria which retain the stain and others which do not, then the former will be stained deep violet, while the latter will be stained bright red by the fuchsine.

Isolation and Cultivation.

Plate Culture.—When it is desired to isolate all the varieties of bacteria in a sample of milk, whey, or curd, the following method has to be adopted: a drop of the sample, if a liquid, or a small piece, if a solid, is taken with the greatest care on a sterile needle, and placed in some sterile salt solution, about 10 c.c. in a test-tube, to dilute it. Subsequently, a drop of this dilute solution is taken upon a sterile needle and placed in 10 c.c. beef broth gelatine, which for the time is kept at a temperature of 90° F., so that it is liquid. The inoculated liquid gelatine is then poured into a sterile flat dish (Petri dish), placed on a level surface, and allowed to cool to the temperature of the atmosphere. When cool, the gelatine becomes solid, and the micro-organisms which were contained in the substance placed in this gelatine are now fixed, so that they cannot move about. This "plate culture" is placed in an incubator, and kept at a uniform temperature of 70° F. Most micro-organisms are capable of living and multiplying in this gelatine, and each one rapidly increases in number until it has produced so many that a little "colony" of these bacteria is formed which may be seen with the naked eye. The following is a reproduced photograph of such a plate (Fig. 8), showing the colonies and their different

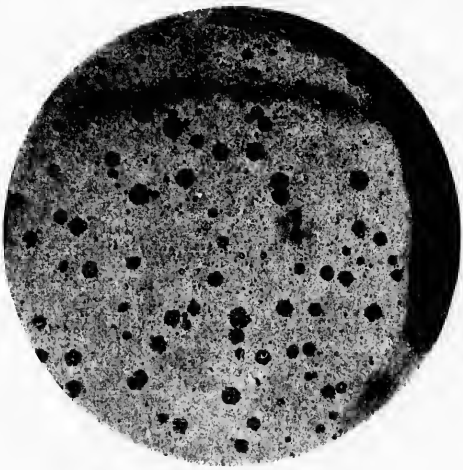
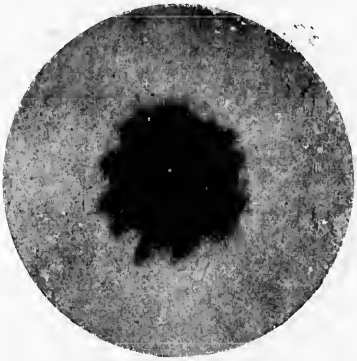
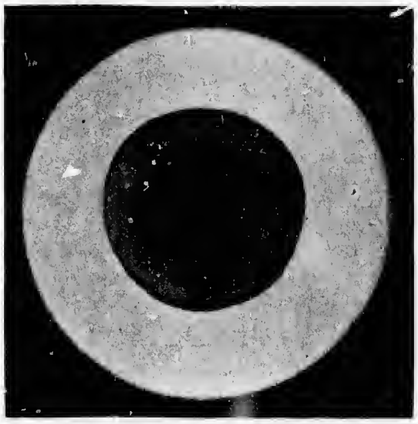


Fig. 8.—Plate Culture of Bacteria.

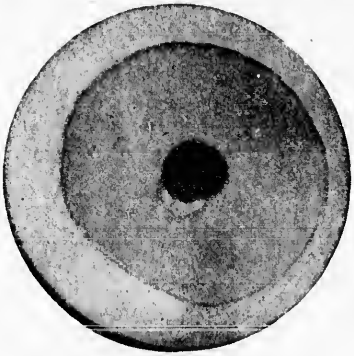
appearance. When the plate has been kept in the incubator for about seven or ten days, the colonies will be sufficiently large, and when examined under the microscope so characteristic—which may be seen from the following illustration of four different colonies (Fig 9)—as to enable the next step in their study to be taken.



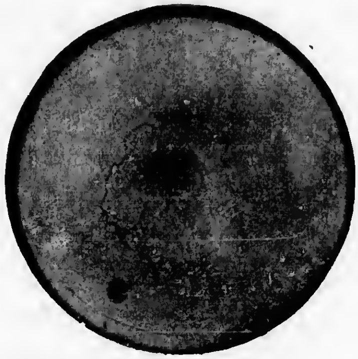
Yeast.



Liquefying Colony.



Streptococcus.



Large colony, Taint-producing Bacillus. Small colony, Lactic Acid Bacillus.

Fig. 9.—Colonies on a Plate under Microscope.

Streak and Stab Cultures.—By means of a sterile needle, a minute quantity is removed from one of these colonies, and the needle drawn along the surface (streak-culture) or thrust into (stab-culture) some nutritive gelatine contained in a test-tube. Here the bacteria will in the course of from seven to ten days have grown so considerably as to form a more or less definite streak of growth on or in the gelatine. Should the plate have several colonies, which from their appearance may be considered the growth of different organisms, then as many cultures in test-tubes are made as there are different colonies on the plate. With due care each of these test-tube cultures will contain only one variety of bacteria, and in such case will be what is called a "pure culture." The reproduced photograph opposite, Fig. 10, shows how differently various organisms grow in these test-tubes. A small portion is taken from a pure culture and a slide made, so that the organisms may be examined under the microscope. Subsequently, pure cultures are started from this first one in or upon other substances, more especially milk, beef broth, agar, &c. By carefully noting the aspect of the colony on the plate, and of the growth in or on various substances, one is able to compare the results with the work of other observers, and so find out whether the organism has been found before, and, if so, when and where. Meantime, each organism has to be indicated by a number in default of a name.

Liquefying Organisms.—The bacteria which are found on the plate will be of two distinct classes, some will grow in or on the gelatine without having any visible effect upon it, while others will liquefy the gelatine. Those which liquefy the gelatine when transplanted to some gelatine in a test-tube are always made into "stab cultures," *i.e.*, the platinum rod on which the bacteria have been removed from the plate is thrust into the gelatine. But those which do not liquefy the gelatine are always grown on the surface and these are termed "streak

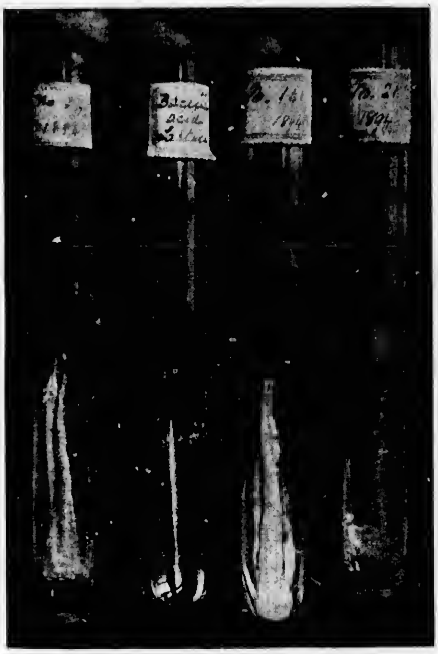


Fig. 10.—Pure Cultures.

cultures." The method of growth of the "stab cultures" varies greatly, and distinctive names are given to the various growths.

Shake Cultures.—These are made by inoculating 10 c.c. of gelatine in a test-tube at a temperature of 90°, so that the gelatine is liquid, shaking it well, so that the substance becomes spread throughout the gelatine, and cooling rapidly. The chief object of these shake cultures is to determine whether any gas is produced by the bacteria.

Milk Cultures.—For studying the effect of bacteria on milk, in the first instance, they are grown in 10 c.c. of sterile milk contained in a test-tube. I have found that separated milk is the best material for this purpose owing to the very small amount of fat which it contains. But as the process of separation causes most of the bacteria to pass into the separated milk, and as this separated milk is generally at a high temperature when separation takes place, it is most desirable that it should be cooled immediately, and that it should be most thorougly sterilised before being used for pure cultures.

Litmus Tinted Culture Media.—An attempt was made to differentiate between various bacteria by cultivating them on gelatine which had been coloured blue with litmus. They were also grown in milk tinted with litmus. The sub-cultures on gelatine containing litmus did not grow so well as those on ordinary gelatine, and I could discover no advantage in the use of litmus gelatine for distinguishing between the various kinds of bacteria. Prof. Conn, however, tells me that he has found litmus gelatine, when used for plate cultures, of great value as an aid to distinguishing the acid-producing bacteria. If, however, it is desired to photograph the cultures, better photographs can in most cases be obtained when they are grown on litmus gelatine than when grown upon the ordinary gelatine. There are a few exceptions to this, for some of the cultures absorb the blue colouring matter of the litmus, and are less distinct than ordinarily.

The cultivation of the bacteria in milk which has been slightly tinted blue with litmus is of far more value as a means of distinguishing between different varieties.

Anærobic Organisms.—For the study of the anærobic organisms, two methods have been adopted. The first was to inoculate 10 c.c. of sterile milk, heat the milk gently so as to exclude all the air, and then cover with a layer of vaseline, which has been first sterilised, and then just melted and poured on the top of the milk. The second method has been to grow the bacteria in gelatine containing 10 per cent. grape sugar.

Agar, Potato, and other Materials.—Some of the organisms found have been cultivated upon these substances, for the method of preparing which the text-books on bacteriology must be consulted. Sometimes it has also been found necessary to place certain chemical substances in the various media to determine the effect of these, or to supply special nutriment, which was not present in the ordinary gelatine or milk tubes.

Other Methods of Investigation.—These depend partly upon special processes of staining, such as the staining of the flagella in the bacillus coli communis, also upon the production of definite chemical compounds, which are easily tested for, such as the formation of indol also by the bacillus coli communis. These and other methods will be found fully described in the most recent works on bacteriology.

Counting the Bacteria.—In order to count the bacteria present in a sample of milk, whey, or curd, the following methods have been adopted. A definite quantity or weight of the milk, &c., has been diluted to a given bulk with sterile water or salt solution, and from a definite quantity of this solution a plate culture has been made. It is seldom that all the cultures on a plate can be counted. It is then necessary to divide the plate up into segments and count the number in 3 or 4 of these segments and take the average. At times, so numerous will be the bacteria that even this method cannot be adopted, and in such case I have covered the plate at various parts with a piece of paper having holes cut in it of exact dimensions, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$-inch square. By counting the colonies visible over these holes at several parts of the plate, and by knowing the area of the plate, the average number present can be approximately estimated.

The Importance of Bacteria.

The importance of bacteria to the cheese-maker cannot be over-estimated. They produce the lactic acid without which no cheese could be made, they bring about those changes in the curd which are termed ripening, and they are the cause of most of the troubles which the cheese-maker has to contend against, commonly termed "taints." Thus, of the inferior cheeses made at the Society's cheese school, a careful estimate shows that seventy-five per cent. were due to taints produced by bacteria. Hence, there are some which are desirable and others which are undesirable, and our first consideration must be to ask whence come these bacteria? So far as we can judge at present they are universal. They are present in the air we breathe, in the atmosphere, floating about with the particles of dust which may be seen floating in the atmosphere with every sunbeam. How numerous they are in the atmosphere, even in the dairy, may be seen from the following fact:—

On the 24th of October, 1891, at a time when the dairy had not been previously entered by the students for about ten or fifteen minutes, but during the manufacture of a cheese, I exposed a prepared surface of gelatine for two minutes. No less than forty-eight organisms fell upon that surface of under nine square inches in the two minutes. Of these six were moulds, and the remainder were bacteria.

But it is not only the atmosphere which is so thickly populated with bacteria, they are present in the food of the cows, in the water they drink, and in the soil. Nowhere are they to be found in greater numbers than in dirt of every description.

Hence the milk with which cheese is made is literally swarming with bacteria; in fact, I have occasionally found nearly 100,000,000 bacteria per cubic inch in milk just before the rennet was added. Most of these organisms will have come from the atmosphere.

The question will at once arise in the minds of my readers, how is it that with so many organisms present in the milk, it is possible to make good cheese? It will be as well to at once explain. Many of these air organisms have, I find, little or no action on milk. Moreover, the lactic acid formed in the manufacture of the cheese destroys most of them, and thus prevents them doing any harm.

A striking illustration of this fact is shown by the following experiment. A characteristic organism is found in hay, known as the hay bacillus (bacillus subtilis). As it was frequently present in the milk, at the time when the hay was being carted home, or when the wind was blowing from the direction of the hay rick, an experimental cheese was made with milk inoculated with this organism, but the lactic acid produced in the manufacture of the curd proved so destructive that in the curd when ground I could not find a single hay bacillus.

Method of Experimenting with Bacteria.—Experimental Cheeses.—To determine the effect of bacteria in the process of cheese making, it was necessary to inoculate the milk with a pure culture of a definite organism, and see the effect it would produce on a large scale. The organism was first isolated in a pure state, a culture was then made on gelatine, and after three days—which would allow of considerable growth—the whole or part of this culture, containing millions of the organism, was transferred either direct to a flask of sterile milk, or first to a tube, and subsequently to a flask of milk, and kept in the incubator at a warm temperature for a day or two. The contents of this flask were then poured into the evening's milk as soon as it was in the tub, and well stirred in, the milk being subsequently stirred occasionally during the evening. On the following day the cheese was made as usual, and as if nothing had happened, Miss Cannon, however, taking special care to notice if any difference in the curd or any taint could be observed. The results of these experiments were frequently most disappointing. Sometimes I wanted to make bad cheeses, and could not. The effect during the manufacture of the cheese was at times nil, and upon examining the cheeses when sold, some would contain only a few, whilst others would not contain a single living specimen of the organisms with which the milk had been inoculated. They had been destroyed either in the process of manufacture, or during the ripening of the cheese.

In other experiments the evening's milk was divided into two portions; one-half being placed in a tub for Miss Cannon's use, and the other half in a tub for the experimental cheese. As soon as the milk was in this tub, the contents of the flask were poured into it, and the milk was well stirred, the stirring being repeated two or three times during the evening. The morning's milk as it came in, was divided equally between the two tubs. The cheeses were then made simultaneously, and, so far as possible, in every respect similarly. Thus the special effect of the organism which had been placed in the evening's milk could be distinctly noticed, provided that the milk was originally free from taint. But when, as unfortunately happened too frequently, the cheese made by Miss Cannon proved to contain a taint, it was impossible for me to determine what particular effect the organism being experimented with had produced. In other experiments the results were more satisfactory. The cheeses made possessed a characteristic taint, thus proving that the organism with which the milk had been inoculated was the true source of the taint. In this way the origin of some of the taints has been discovered, though many yet remain for future investigations.

Having briefly explained the methods of investigation adopted I shall now proceed to describe the results obtained, and shall commence with that organism which is of most importance to the Cheddar Cheese-maker.

The Bacillus Acidi Lactici.

Bacillus Acidi Lactici.—It is only necessary to have a mere smattering of bacteriology to know that many organisms are capable of producing lactic acid by the fermentation of milk sugar. Those in which this power is most marked have been described by various writers as lactic acid organisms.

Of these the organisms most frequently referred to are as follows:—

1. Bacillus acidi lactici. Hueppe.
2. Bacterium acidi lactici. Grotenfeldt.
3. Bacterium limbatum acidi lactici. Marpmann.
4. Micrococcus acidi lactici. Marpmann.
5. Sphaerococcus acidi lactici. Marpmann.
6. Micrococcus acidi lactis liquefaciens. Krueger.
7. Pediococcus acidi lactici. Lindner.
8. Streptococcus acidi lactici. Grotenfeldt.

Putting aside, for the moment, No. 6, which has the characteristic property of liquifying gelatine, let us examine the information available concerning the others. They do not liquefy gelatine. They, one and all, are described as forming on gelatine plate-cultures, small circular colonies, white, porcelain white, grey, or tinged with yellow, while all are described as colonies having a smooth glittering appearance.

I can only find a statement of the time which they take to curdle milk for Nos. 3, 4, and 5, and these all require twenty-four hours. Here let me state that, according to Krueger, his micrococcus acidi lactis liquefaciens takes no less than five days to curdle milk, so that it cannot be compared with any of the other organisms, and does not need our further attention.

For eight years I have been constantly seeking to find these various lactic acid organisms, and have failed to do so. During that time hundreds of cultures have been started, and every possible attempt has been made to obtain these organisms. At times I have thought that I had secured two or more varieties of lactic acid bacteria. But when cultures of these were made simultaneously in or on the same media and kept under similar conditions as to temperature, &c., I have invariably found that my assumed varieties were in every respect identical. I am, therefore, forced to the conclusion that there is only one true lactic acid producing organism, ordinarily met with in the manufacture of Cheddar Cheese, and this may be termed the bacillus acidi lactici.

In shape it is slightly pointed at either end, and being only about one and a-half times as long as it is broad, it does not really appear to be a bacillus, nor yet a coccus, which should be perfectly spherical. There ought to be some word to designate an organism so shaped; but at present there is not, hence it is termed a bacillus.

This small, stumpy, or egg-shaped bacillus (Fig. 11) varies greatly in size, according, so far as I can judge, to the food which

Fig. 11.—The Bacillus Acidi Lactici.

it is growing in or on, the age of the culture, and probably the number of bacteria present. Thus, in a young and vigorous growth it is quite large and distinctly bacillus shaped. With increasing age it diminishes in size, and in an old growth can scarcely be distinguished from a coccus. This is the form it mostly assumes in milk cultures, especially after they have curdled, also in cheese. Indeed, so very varied is it both in size and form that I have frequently felt certain of having obtained two distinct organisms, only, however, to be disappointed on further investigation. Frequently in the same culture there will be present organisms of very different sizes, and in old cultures I have noticed some remarkably large ones, probably in a resting stage, as the organism does not appear to form spores. As a rule, two organisms grow together in the form of a dumb-bell. This is very characteristic of the bacillus, and is best seen when it is growing in milk or curd. Occasionally, small chains of four are met with, but never longer chains.

In recently-made cultures it takes all the ordinary stains readily; but in old cultures it is more difficult to stain, and the stain is readily washed out. It will not retain the stain when subjected to Gram's method.

Not only does the organism itself vary in size, as above described, but a similar variation is noticeable in colonies of the bacillus acidi lactici when growing on gelatine plate cultures. Two plates were inoculated from a pure culture of the bacillus, similar nutrient gelatine being used for each plate, and both being kept at the same temperature. The only difference was in the number of bacteria with which each plate was inoculated; in one case there were but few, in the other many, organisms. During the whole period of their growth the colonies on these plates were but slightly similar. Those few in number grew rapidly and attained considerable size, while the numerous colonies grew slowly, were minute, and never attained one-fifth the size of the other colonies. It would seem that in their growth, even on the solid gelatine, they either exhaust the material around them of its nutriment, or else poison it. While in milk, the influence of the lactic acid produced might account for their less vigorous growth, yet why this should take place on a solid nutriment is difficult to understand.

It has, indeed, always been a puzzle to me how the bacteria in a colony on a plate obtain their nutriment at all. I have seen colonies of bacteria rising one millimetre* above the surface of the gelatine, so that the food which supplies the organisms on the top of such a colony is one thousand times their own length away from them. How does it reach them?

However, putting aside these interesting problems, let us return to the bacillus acidi lactici.

A colony on the plate is identical in appearance with the description given by other observers of several of the previously mentioned varieties. It is a small, porcelain white, circular smooth growth, very rarely larger than a pin's head, though occasionally it will spread over the surface, forming a thin circular disc, about one-tenth of an inch in diameter. When growing in the gelatine, the colonies are spheres, or at times lemon-shaped, both forms being present. The colonies, sometimes mere specks, sometimes nearly as large as a pin's head, are rarely one millimetre in diameter. When examined with a 2-inch objective they appear yellowish-brown, brown, or even

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* A millimetre is about 1-25th of an inch.

black, and have a sharply defined outline. The colonies growin on the surface are much larger and lighter in colour than those growing in the depth.

A surface or streak culture on gelatine produces a delicate growth, under one-eighth of an inch wide, made up of numerous minute, isolated colonies. These subsequently run together, producing a fairly uniform, thin, transparent streak, the edges being composed of semi-circular projections. On agar and on potato the culture is similar to that on gelatine, but not so vigorous, except at a higher temperature than 70° F.

When milk is inoculated with the organism it is coagulated into a solid mass in forty-eight hours at a temperature of 70° F.

This is due to the fact that the bacillus produces lactic acid out of the sugar of the milk. The time which elapses before the milk curdles depends partly on the number of organisms present, but mainly on the temperature which has a most marked influence upon the growth of the organism.

The rate of formation of lactic acid in a series of milk tubes, to which had been added, so far as possible, a similar number of organisms, was determined and the following results were obtained:—

PRODUCTION OF LACTIC ACID IN MILK BY A PURE CULTURE OF THE BACILLUS ACIDI LACTICI AT TEMP. OF 65° FAHR.

Interval.	Acidity of Sterile Tubes of Milk.	Acidity of Inoculated Tubes.			Acid formed in 12 hours over average of Sterile Tubes.	
		1st.	2nd.	Mean.	Total.	Increase.
hrs.						
12	·23	·40	·40	·40	·20	·20
12	·19	·47	·48	·475	·275	·075
12	·18	·48	·53	·505	·305	·030
12	·19	·55	·56	·555	·355	·050
12	...	·64	...	·640	·440	·085
12	...	·66	...	·660	·460	·020
12	...	·68	...	·680	·480	·020
12	...	·70	...	·700	·500	·020

Such is a description of the only lactic acid-producing organism, in any way similar to the eight previously mentioned, that I have been able to find.

In 1897 an opportunity arose of studying simultaneously the lactic acid bacillus present in the curd made at the seven sites of the cheese school on the same day. No difference could be found between the seven organisms, either when growing upon the plates, or in pure cultures on gelatine or in milk. In each case the milk was curdled in forty-eight hours, and the lactic acid produced in seven days was as follows: B.A.L. from Vallis, ·95 per cent.; from Axbridge, ·96 per cent; from Butleigh, ·95 per cent.; from Mark, ·92 per cent.; from Haselbury, 1·00 per cent.; from Cossington, ·94 per cent.; and from Ashton, ·96 per cent.

The evidence appears to me conclusive that only one variety of lactic acid organism plays any important part in the manufacture of Cheddar Cheese.

Strepto-Bacillus Acidi Lactici.—There is, however, one lactic acid-producing and milk-curdling organism which has occurred from time to time among the bacteria in milk, and which I have sometimes found in cream; a bacillus which grows together in long chains, *i.e.*, a strepto-bacillus.

I am even inclined to think that there are two varieties of this strepto-bacillus, one taking only twenty-four to thirty hours to curdle milk, the other taking three to four days at a temperature of 70° F.

The individual bacilli are about one and a-half to two μ long, with pointed ends, which give them an oval appearance (Fig. 12).

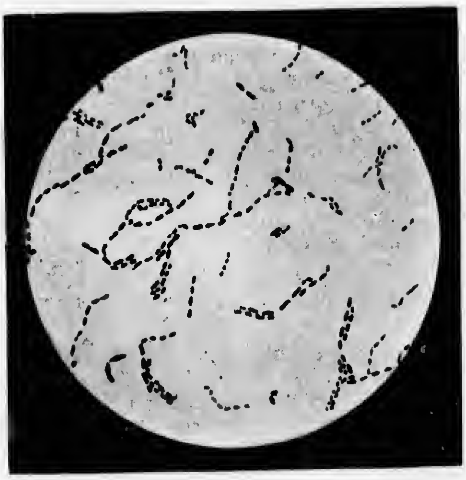

Fig. 12.—Strepto-bacillus Acidi Lactici.

Growing on a plate (gelatine) culture, the colonies cannot be distinguished from those of the ordinary bacillus acidi lactici, being round on the surface, spherical or lemon-shaped when growing in the interior, white and small.

The streak culture on gelatine shows more marked difference, It is slower of growth, and forms a very thin streak, seldom one thirty-second of an inch wide, and it is made up of numerous, for the most part disconnected, colonies, whereas in cultures of the bacillus acidi lactici, as a rule, the colonies coalesce to form a uniform surface growth.

This strepto-bacillus appears to have a remarkable power of producing lactic acid, for in several instances milk was coagulated by it in from twenty-four to thirty hours. Here it may be well to explain the word "coagulated." When the milk sets in a solid mass, in which the whole of the water of the milk is contained, I term it coagulated. The true lactic acid-forming bacteria always produce this effect. There are other organisms which have the power of "curdling" milk, but they separate or precipitate the curd from a more or less clear whey. This distinction between the bacillus acidi lactici and other organisms is very marked.

Cheeses were made from milk inoculated with this organism, and in these cheeses, when ripe, I was able to find the strepto-bacillus, as well as the ordinary bacillus acidi lactici.

Importance of the Lactic Acid Bacillus.—It will be evident that so far as the manufacture of Cheddar Cheese up to the time of vatting the curd is dependent on the growth and chemical action of bacteria, any organism essential to these changes must be invariably present at all stages, and that any organism which is only occasionally found must be considered as accidental and a contamination.

Thus one fact was soon conclusively proved, namely, that in the manufacture of Cheddar Cheese one and only one organism played an important part up to the time the curd was put into the vat, and that organism was the bacillus acidi lactici. What part this organism played up to this stage has already been considered, inasmuch as all those chemical changes due to acidity, which have previously been described, are due to its growth.

There are, however, one or two considerations which deserve further attention.

The milk has been examined frequently, both as it came into the dairy and when it had stood in the dairy over-night, and the bacillus acidi lactici has invariably been present in large numbers. But the numbers vary considerably. And this explains why it is at times necessary to use so much sour whey in the manufacture of the cheese, while at other times less whey is required.

The importance of these bacteria does not depend upon their size, but upon their number, and upon the rapidity of their increase. This increase results in a simultaneous production of lactic acid. Hence the acidity determinations are indirectly estimations of the number of bacteria present. The milk of the 2nd of May, 1896, about three to four hours after it was drawn from the cow, that is soon after it came into the dairy, contained over 750,000 bacteria in one cubic inch. The number of bacteria in the evening's milk is of the utmost importance, for it is mainly upon the increase in the number of these bacteria during the night that the next day's cheese-making will depend. If the cheese-room and milk are kept warm this increase will be considerable, but if not kept warm it may not be sufficient. This is shown by the following figures:—

On the Night of	Temp. of Dairy.	Temp. of Milk in Morning.	No. of Bacteria in one cubic inch of Milk
1st to 2nd September	65–66	72	11 million.
9th to 10th September	67–68	74	57 ,,
9th to 10th April	65–73	74	87 ,,

How greatly the number of bacteria varies in the mixed morning's and evening's milk just before the rennet is added, can be seen from the following table, in which, to indicate the importance and influence of these bacteria on the manufacture of the cheese, a few of the ordinary observations as to times and acidities are also given.

Date.	Bacteria in one cubic inch of Mixed Milk.	Acidity of Whey.	Acidity of Liquid from Piled Curd.	Increase in Acidity while Curd Piled.	Time Curd remained Piled.	Acidity of Liquid from Press.	Time Curd Vatted. (P.M.)
		per cent.	per cent.	per cent.	min.	per cent.	h. m
Sept. 2, 1896 ...	11,500,000	·205	·270	·065	25	·96	7 10
Sept. 10, 1896 ...	57,700,000	·205	·300	·095	10	·91*	2 10
April 10, 1896 ...	87,000,000	·185	·325	·140	5	1·02	1 4

* This curd, if it had been left some time longer before grinding, say 30 minutes, would probably have had about the same acidity as the other two.

It is clearly evident that the time of vatting and the development of acidity in the piled curd are dependent upon the number of bacteria originally present in the milk.

In face of these figures, it is scarcely necessary to point out how important it is to keep the evening's milk at a moderate temperature, in order to prevent the cheese-making on the following day being unnecessarily protracted. They also indicate why the cheese-maker uses "stale whey."

They also enable us to understand why it is that the Cheddar Cheese-makers in Scotland, who ripen the milk up to a fixed standard before renneting, succeed, as a rule, in finishing cheese-making early in the afternoon. If only a fixed standard of acidity could be obtained in the mixed milk before renneting, cheese-making would be more regular than it is.

Sour Whey or the Whey put aside.—This liquid has been examined from time to time, and in every case found freer from extraneous bacteria than any other liquid examined. It has seldom contained more than two or three varieties of organisms other than the bacillus acidi lactici, hence it is admirably suited for the purpose to which it is applied, namely, to increase the number of the lactic acid bacilli in the mixed milk. Thus science explains the true foundation of this practice. I understand that it is not universal in Cheddar Cheese-making to take the whey which is to be put aside the moment after cutting when sufficient has risen on the curd to permit of its being removed. But this undoubtedly should be done wherever stale whey is used, for the whey at no other stage of the manufacture possesses the same purity.

The Bacteriological Examination of Cheese.

When, in 1891, these experiments were first started, it was almost universally believed that the ripening of cheese was due to the growth of the bacillus amylobacter or butyric acid bacillus.

To quote the words of no less an authority than De Barry, "the butyric acid fermentation is essential to the ripening of cheese."

Duclaux* had found in Cantal cheese ten varieties of bacteria, to which he gave the name of Tyrothrix, the most prominent among these being certain forms known as leptothrix or long thread bacilli.

My surprise then was great when in the examination of the cheese made in 1891 I was unable to find a single instance of a leptothrix organism, and very few of the bacillus amylobacter. As I then wrote in my report:—"The examination of the cheeses shows that when ripe only two or three organisms are present in any number. Those in most abundance are the bacilli acidi lactici. The others are a long and very thin bacillus, and a shorter and thicker bacillus. Comparatively few of these are present in the later made cheeses. After having examined several of the cheeses made in August last, 1891, and upon finding now, in January, 1892, that the organism present in infinitely largest numbers is the bacillus acidi lactici, it would appear that as in the making, so in the ripening of Cheddar Cheese, this organism plays the chief rôle. Hitherto, it has been supposed that the ripening of cheese was due to

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* Le Lait. Paris, 1887.

the action of the bacillus amylobacter, but these observations do not support that view."

Analyses were therefore made of a few of the cheeses to determine whether the acidity had increased in the process of ripening. The following are the results obtained:—

Curd Vatted on	Acidity.	Acidity of Cheese on Jan. 4th 1892.	Increase.
		per cent.	
August 23	2·90	9·8	6·9
September 23	3·50	9·6	6·1
October 23	2·90	6·0	3·1

"Thus it appears that the ripening of Cheddar Cheese is during the first few months dependent mainly on the continued action of the bacillus acidi lactici.

Such was the result of my first year's observations. It was scarcely to be expected that so novel and revolutionary a result should be at once accepted. But the result of all my subsequent work and of the work of others who have studied this subject goes to prove the accuracy of these deductions.

In the meantime many cheeses have been examined bacteriologically.

In cheese we have to deal with a substance from which the air is excluded, and consequently should expect to find present those organisms which hitherto have had no opportunity of growing, namely, the anaerobic organisms, such as the bacillus amylobacter or butyric acid organism. These large thick rod bacteria are, however, very seldom found, and even when present there are very few.

That there should be so few varieties of organisms in the cheese would be somewhat surprising were it not for the investigations of Freudenreich into the ripening of Emmenthaler cheese. He was unable to discover in these cheeses those varieties of bacteria which had previously been supposed to be essential to the ripening of cheese, thus supporting in a remarkable manner the results of my observations on Cheddar Cheese.

There are several varieties of the butyric acid bacillus. The one previously referred to was the first known, and has been thoroughly studied by Prazmowski. A bacillus amylobacter, which is entirely different to that of the older writers, I have found in many of the cheeses, though not in all. It is seldom present in large numbers, and for one of the bacillus amylobacter there will be hundreds of other organisms present. It is, therefore, very evident that for cheese of the description made by Miss Cannon, which may be described as moderately quick ripening cheese, the bacillus amylobacter plays a very secondary part. What then are the bacteria present in such large numbers? I am not quite prepared to dogmatise upon this point, but the results hitherto obtained all point in one direction, namely, that it is the lactic acid bacillus. In a cheese examined soon after it is made, the bacilli are possessed of all the properties which characterise the bacillus acidi lactici as obtained from milk, but in course of time they seem to lose these properties, as they grow under different conditions. Thus, if a minute portion of new cheese be placed in some sterile milk, the milk curdles within a couple of days. If we keep the cheese, and from time to time place a little in some sterile milk, it will be seen that the power of curdling the milk is slowly being lost. At last it seems to entirely disappear. Yet place some of this same cheese in some milk from which the air is excluded, and the milk will be curdled. Although for a long time it will be possible to obtain a growth of this lactic acid bacillus on gelatine, yet after a time even this is most difficult, and finally nothing will grow upon a plate culture. The long confinement of the organism apart from the atmosphere appears to change its nature, and causes it to lose its most characteristic property. But the fact remains that it is this lactic acid organism which has brought about whatever changes have taken place in the cheese, and which we describe as "ripening."

The microscopical and bacteriological examination of a large number of cheeses each year, cheeses of varying ages and quality, soon revealed the fact that the number of bacteria in the cheese varied very considerably. For some time after the manufacture of the cheese, the number of bacteria increased, but the older the cheese after the period of ripeness the more difficult it was to find living organisms, and in 1892 I found that there came a time in the life of the cheese when "not a single aerobic organism could be found." Subsequent work has proved two facts, first that the organisms which in the early stages of ripening increase with such rapidity are almost entirely the lactic acid bacilli, and secondly, that there are at times present in the cheese organisms (ærobic) which survive until after the death of the lactic acid bacilli. These organisms, however, in course of time also appear to die. It is evident that if a cheese could once attain to this condition without having developed a taint, such a cheese might keep good indefinitely, and to attain such a result is the highest aim of the Cheddar Cheese-maker.

Summary of the part which the Bacillus Acidi Lactici plays in the manufacture of a Cheddar Cheese.—The bacteriological observations made during the past eight years have, in my opinion, conclusively proved the following three points regarding the lactic acid bacillus.

1st. That by its growth and the resulting production of lactic acid, most of the organisms which are present in the milk due to air contamination are gradually destroyed, while even those which are not destroyed are frequently checked in their growth.

2nd. That up to the time of vatting the curd, all the operations in the manufacture of the cheese are dependent upon, and subservient to, the growth of the bacillus acidi lactici in that curd.

3rd. That the subsequent ripening of the cheese is also dependent upon this organism.*

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* In the 14th annual report of the Wisconsin Agricultural Experiment Station, 1897, Messrs. Babcock and Russell published an article on "Unorganized Ferments of milk; a new factor in the ripening of cheese," in which they endeavour to prove that the ripening of cheese is due to such unorganized ferments. There are three points in this article to which I wish to draw attention. First, Messrs. Babcock and Russell are scarcely justified in stating that "this question of cheese-ripening" is one "where the pendulum has swung from a purely chemical explanation to a biological theory in which micro-organisms *alone* are thought to be the cause of *all* the changes that occur in the ripening process." They state that "from a chemical standpoint, this change (the ripening of curd) is a hydrolytic one, i.e., the insoluble casein takes up water, and is hereby converted into a larger number of molecules that are both soluble and diffusible," and "as this transformation in cheese is of a hydrolytic nature, it was thought probable that the acid formed by the lactic bacteria might be the active agent in this change, and that the bacteria themselves were not directly concerned in the process; but after a series of experiments covering many months, this hypothesis was abandoned, as so many conflicting results were obtained."

In 1892, I pointed out that the action of the acid in the curd was to draw away the lime from the casein. And stated, "the difference between freshly coagulated curd and cheese might be described by saying that the one was a compound of lime and casein, the other was free casein." All my subsequent work confirms this view.

Secondly, that unorganised ferments might have some influence in the ripening of cheese had not escaped my attention. In my report for 1894 occur these words:—"One reason which has been given to me by Scotch makers for the large amount of rennet used, is that it helps to ripen the cheese more rapidly." And an experiment was made that year which confirmed this opinion.

Thirdly, when we come to study the Wisconsin experiments closely, we find that they are by no means conclusive. The arguments of the authors are based from commencement to end upon the assumption that in the presence of anaesthetics bacteria cannot grow. I use assumption advisedly because we find in the report this sentence: "Under these stringent conditions, bacterial activity must have been completely excluded," and again, "bacterial action was believed to have been thoroughly excluded." But I fail to find conclusive proof that bacterial influence was not at work in their experiments, in fact, they throw considerable doubt upon their own results by this pregnant sentence: "An examination showed that the milks failed to keep, owing to bacterial action, although liberal quantities of anaesthetic were added."

It is a remarkable fact that the results they obtained are always most marked when bacteria would be most likely to be present. Thus, when examining the slime from a separator, they state, "the proteids in the slime digested more rapidly than in the skim milk." Again, the slime from a factory separator is found to have more power than the slime

Pure Cultures as Starters.

During the first year of my observations on Cheddar Cheese-making, 1891, I found that the principal bacteria in the cheese were the bacilli of lactic acid. In the succeeding year experiments were made to see how far this knowledge might be turned to account, by inoculating the milk with these organisms.

Since then many experiments have been made, but the results obtained were such that I purposely refrained from introducing the use of pure cultures of bacteria into Cheddar Cheese-making in Somerset, and for the following reasons. First:—In my opinion it would have been foolish for me to put forth, for the guidance of cheese-makers, any ideas which, when they attempted to carry them into effect, would be found wanting in practical value. I had come to the conclusion from my observations that inoculating the milk with a pure culture of the lactic acid bacillus would not insure a good cheese. Other things being equal, the greater the number of lactic acid bacilli in the milk, the greater the chance of a good curd, but I am still of opinion that this organism alone will not produce that nutty flavour which is so much sought after as being the essential characteristic of an excellent Cheddar Cheese. The second consideration was that the presence of the bacillus acidi lactici in abundance would not entirely counteract the evil influence of bacteria which produce taints. Hence I considered it to be my first duty to discover the causes of these taints, whence they arise, and how to prevent them. It may be urged that the necessity of cleanliness, which is in other words the procuring of milk free from injurious bacteria, is well known to all cheese-makers. I can only say that if known, it is not invariably practised, and that, even where it is practised, and in the dairies of the best cheese-makers, taints will arise at times, and utterly baffle the skill of even the most experienced makers. Thirdly: I had observed that when there happened to be naturally an excess of lactic acid organisms in the milk, so that acidity developed rapidly, many makers were utterly unable to cope with the conditions, and the resulting cheeses were too acid. It was very evident that the use of pure cultures of lactic acid bacteria would greatly augment this difficulty, and that until some

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from a private dairy separator, and again, "in gravity cream, the amount of enzymes would be much larger than in separator cream."

A careful study of this article confirms my opinion that while it is quite possible that milk may contain enzymes, which play a certain part in the ripening of curd, as does probably the enzyme of rennet, yet the authors have failed to prove that these enzymes play so important a part as they assume. In fact this theory utterly fails to explain why two cheeses made from the same milk, one containing, when vatted, a high proportion of acid, and the other a low proportion of acid, should take different times to ripen. Yet the curd with high acidity would be ripe one or two months before that with low acidity.

accurate method of estimating the acidity during the process of cheese-making was in general vogue, the cheese-makers were not in a position to make full use of the discoveries of science. But the use of the apparatus for testing acidity, which had been one outcome of these investigations, was growing rapidly, and in 1897 it became necessary to again turn my attention to the question, whether cheese-makers might utilise pure cultures of the bacillus acidi lactici, and if so, how?

There are several difficulties to be contended with in the use of pure cultures. The first, which with some care can be overcome, is to carry on, from day to day, the culture of the desired organism without its becoming contaminated. The second difficulty is far greater, and, as yet, I do not see how it is to be overcome without considerable modification of the method of manufacturing Cheddar Cheese at present adopted in the West of England.

The lactic acid organism grows comparatively slowly, whilst many of those organisms which produce taints grow rapidly. Now it is self-evident that, if we desire to use the lactic acid organism in the form of a pure culture, we must give it every advantage we can. In the present system of making Cheddar Cheese, the evening's milk, when brought into the dairy, has a temperature of about 80°-90° Fahr., and care is taken that the temperature shall not fall below 70° Fahr. by the morning. Hence, as these temperatures are favourable to their growth, the bacteria present in the milk are rapidly growing during the whole of the night. It would, therefore, seem of little value to introduce a pure culture into the milk in the morning, as at most the bacteria could only have a slightly beneficial influence under such circumstances. The employment of pure cultures has been most successful in the production of butter, because it is possible to first destroy all bacteria present in the milk as it comes into the dairy, by heating it to a temperature which is destructive to bacteria. This is termed pasteurisation. It is not possible, or at least exceedingly difficult to pasteurise milk which is intended for cheese-making. The only other method of checking the growth of bacteria is to cool the milk to a very low temperature. In the West of England, with the present form of cheese-tub, this would be found a difficult task; in Scotland, where the milk tubs are surrounded by a water-jacket, it is less difficult, provided there is a good supply of cold water. The scarcity of cold water in many of the cheese-making districts of the West of England is so great, that even the introduction of the jacketed tub would not materially help the cheese-maker there. Such were the reasons why I had not attempted to move more rapidly in the use of pure cultures of bacteria. During 1897, many experiments were made to see how far some of these difficulties might be overcome.

The Preparation of a Pure Culture.—The way to do this in the laboratory has been already described; but it is evident that the preparation of a pure culture from day to day in the dairy cannot be carried out in glass vessels. I therefore had some tall cylindrical metal vessels prepared for the purpose. The vessels were of tin, and the lid removable. There were two openings in the lid, the centre one intended for the stem of a metal stirrer, and the other for a thermometer, both of which are packed in cotton-wool. The stirrer consists of a perforated disk of tin attached to a strong rod, which must be perfectly smooth, and pass up and down in the cotton-wool with ease.

The vessel is sterilised by passing high-pressure steam into it from the boiler. Some newly drawn milk is next placed in the tin and sterilised by placing the vessel in boiling water and keeping it there for twenty to thirty minutes. To obtain the best results, this sterilising must be repeated the next day, so that, if a pure culture were being used every day, the cheese-maker would require to keep three tins in use. If the milk in one of these tins is inoculated with a pure culture on the evening of the first of the month, the milk is stirred from time to time, and the culture will be used the next night to inoculate the evening's milk. A portion, however, must be kept over and immediately used to inoculate a tin of previously sterilised milk, so that this may be ready to use for inoculating the evening's milk on the second day. Only in some such manner could a pure culture be used in every-day practice. Experiments were made to see how this would work, and to determine the amount of inoculated milk which might be used, and at what temperature the culture should be kept during the twenty-four hours it was in the tin. The experiments were far from satisfactory, and had to be stopped before any definite, or rather final, results were obtained. The first experiment was made by using ½ gallon of milk in the tin and keeping the inoculated milk at a temperature varying from 75° to 85° Fahr. during the night, and up to 95° Fahr. during the day. The result was the development of too much acidity, and only one quart of the culture was used for inoculating the evening's milk. But even this was too much, and resulted in developing an excessive amount of acidity in the evening's milk, which in the morning amounted to ·37 per cent., so that the experiment was a failure.

In the second experiment, both the temperature at which the inoculated milk was kept, and also the time after inoculating, were reduced. Only one quart of milk was used, which was inoculated at 10.30 a.m., kept at a temperature of 85° Fahr. for ten hours, and placed in the evening's milk at 8.30 p.m., the acidity then being ·27 per cent. Next morning, the evening's milk had an acidity of ·33 per cent., and the mixed milk 0·23 per cent. It was renneted at 7.35 a.m.; cut at 8; broken at 8.5. First scald on 8.45, temp. 90° Fahr. Second scald on 9.10, temp. 100° Fahr.: stirred five minutes, and settled ten minutes. Whey drawn 9.25. Curd not piled: twice cut, and turned five times. Ground and vatted at 12 (noon). Acidities:—

Whey after breaking	·17 per cent.
„ when drawn	·23 „
Drainings after 2nd cutting	·55 „
„ „ 2nd turning	·71 „
„ „ 4th „	·85 „
Liquid from press	·89 „

Other experiments have been made, which all show that the use of a pure culture to be applied to the evening's milk, under the conditions which at present exist in the cheese dairies of Somerset, is attended with considerable risk, even when the culture is kept at the ordinary temperature of the dairy for twenty-four hours which must elapse between inoculating the culture and inoculating the evening's milk. In all these experiments, however, it was evident that the use of a pure culture of bacillus acidi lactici diminished any taint which might be in the milk. But on no occasion have I ever obtained by the use of a pure culture of the bacillus acidi lactici that nutty flavour or aroma which is the great desideratum in Cheddar Cheese. Hence, I think I am justified in stating that the first consideration with the cheese-maker must be to keep the milk pure. If this is done, the stale whey from the preceding day may be used, as it has been from time immemorial, to obtain the beneficial results which come from having in the mixed milk a sufficient number of lactic-acid-producing bacteria. For, as pointed out years ago, if the milk is originally free from taints, the whey taken from the tub immediately after breaking is exceptionally free from bacteria other than the bacillus acidi lactici, so that it is practically a nearly pure culture.

When, owing to a taint in the preceding day's milk, the stale whey could not be employed, fairly successful results have been obtained by using as a starter ripened milk. This has been prepared by placing about ten gallons of the evening's milk in a small warmer, heating this to 98° F., and keeping it on the top of the heating apparatus over-night, lightly covered with a thick cloth to prevent dirt entering the milk, and to retain the temperature. In this way the milk ripens very rapidly. In the morning the whole of the evening's milk is warmed as much as it may be, and this ripened milk is put into it. The ripening process continues, and the absence of sour whey is to a large extent made up for.

The Organisms Injurious to Cheddar Cheese.

By far the greatest difficulty that the cheese-maker of the present day has to meet is one which he is totally unable to account for, and little knows how to contend against. It is the occurrence—sometimes only for two or three days at a time, but sometimes for long periods—of distinct taints in the curd, which will more or less deteriorate the resulting cheese. Sometimes they arise, one knows not how, in the dairies of the very best cheese-makers, disappear in a day or two as suddenly as they came, and with no more apparent cause for their disappearance than there was for their appearance. From time immemorial they have baffled all cheese-makers, while in some parts of the country they have rendered cheese-making almost impossible, certainly unprofitable.

When my investigations into the manufacture of Cheddar Cheese were commenced in 1891, the cause of the many taints found in cheese were practically unknown.

As was the case less than half a century ago with very many of the diseases to which man is liable, the origin of these taints, which may be looked upon as diseases of curd, had been vaguely supposed in some way to be connected with dirt. The diseases of man were thought to be more prevalent in certain districts, or upon certain soils; and a similar impression had prevailed with regard to the diseases or taints of curd. Hence there had arisen a widespread belief that upon such soils good cheese could not be made.

Taints due to Bacteria.—The progress of science has within comparatively recent years proved beyond doubt that these diseases which had baffled the wisest physicians to account for are the result, not of dirt, as generally understood, nor yet of any peculiar locality, but are due to the presence in the human being of infinitely minute vegetable organisms known as bacteria. In studying science in connection with dairying, I had watched these discoveries, and was drawn to the conclusion that, in all probability, the diseases of curd might also be due to bacteria, and not necessarily to what is ordinarily termed dirt, nor yet to any special peculiarity connected with soil or locality. Such conclusion, however, was founded mainly upon theory, and was supported by very little, if any, direct evidence. There had been a certain amount of negative evidence forthcoming. Thus, although the School had been located in places where it was well known difficulties arose, which also arose at the School when located in those districts, yet no satisfactory cause could be found for them. The local belief that it was due to the soil or to the herbage had, by the analyses of the soil by the Society's Consulting Chemist, Dr. Voelcker, and by the careful examination of the herbage by the Society's Consulting Botanist, Mr. Carruthers, been proved to have no foundation. For in no case was any substance or plant found which could possibly give rise to the taint present in the curd and peculiar to the district. This negative evidence had materially strengthened my belief that, in course of time, and by continued investigation, it would be proved that the taints of cheese, like the diseases of man, were produced by bacteria. Hence a considerable amount of work was done each year in this direction, but it was not until the fourth year of the observations that I was able to announce that one taint was undoubtedly produced by the presence of a particular organism in the milk. For four years I had been groping in the dark, so to speak, when—having conclusively proved that the taint, commonly known as "spongy curd," is the result of a micro-organism growing in the curd—I had found the key to all the difficulties and taints which curd and cheese are liable to, and, in course of time, hoped to isolate and describe, and perhaps find the source of, if not the remedy for, those bacteria, which it was almost certain would be found to be the cause of other taints.

To discover the origin of taints is one of the most difficult problems which the investigator in cheese-making has to attack.

During the autumn and winter of 1897 there were several outbreaks of typhoid fever in England. Here was a disease produced by a definite organism which is well known to bacteriologists, and can be easily discovered in any substance which contains it. Yet everyone now knows how difficult it proved to discover the cause of these outbreaks, to trace the typhoid bacteria to their source. Those who are versed in dairy matters will readily understand the difficulty of tracing the source of bacteria which are injurious to cheese. Many of these have not yet been discovered. Even those which have been are so slightly studied, as compared with the typhoid bacillus, that it is not yet always possible to trace them to their source.

In spite of every possible endeavour, many of these organisms have so far entirely baffled me. Taints there were on many occasions, and samples of the milk, whey and curd were then most carefully examined, but no organism could be isolated which when grown in milk would cause a similar taint.

Precautions necessary when Taints present.—Medical men tell us, and have conclusively proved, that the various diseases to which men are liable, such, for instance, as diphtheria, pneumonia, or tubercle, are each the result of the growth of a special organism in the human body. The farmer knows that the same is true of many of the worst diseases to which his herds are liable: it is only necessary to mention pleuro-pneumonia among cattle, and swine fever among pigs. We know that diseases produced by such micro-organisms are frequently contagious: that it is merely necessary for a perfectly healthy animal to come into contact with, or sometimes only into the neighbourhood of, animals so diseased, in order to become themselves contaminated with the bacteria, and thus to contract the disease which the organisms produce. Such knowledge teaches us a lesson, and points to the necessity of certain precautions being carefully observed by the cheese-maker, should he by any accident get into his dairy a diseased curd—by which I mean a curd containing any taint. Let him remember that the mere contact of his hands with such curd is sufficient to convey the bacteria which cause that taint to the surface of any utensil which he may subsequently handle. It is therefore imperative when any taint arises to get that curd out of the dairy, so far as possible, before the evening's milk

comes in. On no account should any of the whey which has come from the tainted curd be used in the next day's cheese. In fact the whole of the whey should be got out of the dairy as quickly and as thoroughly as possible, and every utensil should be cleaned with, if possible, more than usual care; but especially *the handle of the breaker* with which that cheese was made.

Sources of Taints.—The following have been found to be some of the sources of those organisms which give rise to taints in the milk or curd.

Atmosphere.—An impure atmosphere where the cows are milked. This may arise from many causes, principal among which is the presence in the neighbourhood of some source of foul air, especially that which emanates from decomposing animal or vegetable matter.

The custom of milking the cows always in one part of the field is so universal in Somerset, that I fear it will be no use my protesting against it; but a moment's consideration will convince anyone who knows the state these milking-places get into, that the custom could well be dispensed with. In the heat of summer the droppings of the cows soon dry, and when trampled upon are scattered as dust and contaminate the atmosphere in which the cows are being milked.

If it is difficult to obtain the milk fairly pure when the cows are milked in the fields, it is far more difficult to do so when they are milked in a stall or shed, unless the shed be kept scrupulously clean. The floors of many sheds are so badly laid that this is quite impossible, and even when it is possible, sufficient care is not taken by the men to keep the sheds clean. This is far more easily done if water be used when cleaning out the sheds, than if the floor be merely brushed.

The above sources of taints are such as can be avoided with a little trouble. But there is a possibility of the atmosphere being a source of other difficulty in a manner not yet understood.

Geographical Distribution of Taints.—It is at the present day almost, if not quite, impossible to say what organisms can or cannot come from the atmosphere. Being consulted by dairy farmers in different parts of the country, it came to my knowledge that the troubles which were being felt at the Cheese School in 1893, were also being met with in other parts of the country. Thus, a cheese-maker in the Midlands sent a sample of milk giving trouble. In it were found exactly the same organisms as were present at the Cheese School, and which I associated with the tainted curd, although there had been no opportunity of proving the assumption correct. Similar results were obtained with milk received from Buckinghamshire, and also from Essex. Enquiries soon brought the information that fermenting curd, and a difficulty in making good cheese, was being found in many places, even by those who were making upon totally different systems. I was informed that no such difficulty had been met with by the Cheddar Cheese-makers in the West of Scotland.

The season in the West of Scotland was entirely different to that of the West of England.

Now, if a tainted or peculiar condition of milk appears over a large district, or part of the country, and does not appear in another part, and the only difference that we can find between these localities is a climatic difference, are we not justified in assuming that this had something to do with the presence or absence of the taints in the milk?

Though this may not be the correct explanation, as we know little about the geographical distribution of bacteria, yet we have strong grounds in support of this reasoning if we may judge by analogy. It is a well-known fact that certain diseases produced by bacteria, will at times be prevalent over large areas, and for a certain time, while not present in other parts, and that they will disappear as suddenly as they came. We say that there is an epidemic of a disease. Is it not possible that there are epidemics of diseases or taints which affect milk, brought about by bacteria, just as there are epidemics of diseases among men? This, at least, was the only possible explanation which would satisfactorily account for the facts met with in 1893. Even if further work may prove that it is not a tenable hypothesis, still it will be very serviceable as a working hypothesis for guidance in future investigations. It points, however, to the necessity for this research work being extended, and not confined to one part of the country only.

Impure Drinking Water.—Perhaps the most prolific source of taints is impure drinking water. The ponds, which are the principal drinking places on so many farms, and which in hot weather become more or less dried up, are so contaminated with the droppings of the cattle as to be little better than sewage, and are undoubtedly the worst offenders.

In many parts of the country, the cows drink from dykes or ditches. The banks of these are so high and steep, that it is necessary to make special slopes down to the water for the cattle to obtain it. The water at these drinking places becomes contaminated with the droppings of the cows, and during the very hot weather, when the cows will stand in the water, if not at other times, it gets splashed on to the teats, dries there, and when the cows are milked, some of this dirt gets into the milk. Nowhere is so much difficulty in cheese-making found as in those parts which have a bad or sluggish water supply. Unfortunately such water is liable to be contaminated not only by cattle, but frequently by the drainage of cottages on the banks of the dyke.

The evil effect of sewage is not confined to these dykes. I have found that even the streams which pass through some farms, and in which there is a much greater flow than in the dykes, are so contaminated with sewage that if the cattle are allowed to obtain access to these streams, there is almost certain to be a taint in the curd. This has been proved over and over again. At Mark, at Haselbury, and again at Long Ashton, there have been striking instances of the effect of contaminated water upon the cheese. It is often said that cheese-making is more difficult now than it was some fifty years ago. Yet, upon investigation, it will be found that better premises exist for dairies, that better apparatus can be procured, and that in nearly every respect the modern cheese-maker is working under conditions which are an improvement on those of his ancestors. Still the difficulties seem greater. May it not be that the true cause of these difficulties is to be found mainly in the contamination of the streams of the country, which has taken place during that period, largely owing to the introduction of modern sanitary arrangements by which nearly every stream in the country has been converted into an open sewer? The chief trouble from impure water is "spongy" curd. I have made some inquiries to try and discover in what respects districts less liable to spongy curd differ from those where it is prevalent, and, so far as can be judged, it seems less frequent where the streams come direct from the hills with little chance of sewage contamination, and also where the streams have a stony bottom, so that the water runs clear, and is not subject to frequent contamination from the dislodged mud of a bank. Moreover, looking back through the records of the Dairy Schools in past years, it is noticeable that spongy curd was not found at Vallis, where the water supply was from a spring, and was brought into troughs from which the cattle could drink. Nor was it prevalent at Axbridge, where the water supply was from dykes cut in the peat or moor land, quite away from sources of contamination by sewage. On the other hand, it has been prevalent at Butleigh, at Mark, and at Haselbury, where in each place the water supply has been more or less liable to contamination with sewage.

Now, we cannot ensure the purity of the streams, though this is a matter with respect to which every dairy farmer who takes an interest in local matters may well bestir himself. In the meantime, however, something else must be done, and it seems to me that the best, the most simple, and the least expensive plan will be, wherever possible, to prevent the cows gaining access to the streams by supplying them with water in troughs. In selecting a site for these troughs, care should be taken to have them as far as possible from the place where the cows are milked.

This has been done on several farms with remarkable advantage. Especially has this been the case at Mark. Indeed, I am quite certain that the reason why many fields have an especial bad repute for cheese-making, is because in these fields the cattle gain access to some contaminated pond or stream. On most cheese-making farms it would be money well spent to put up drinking troughs for the cattle, and pump the water into these as required. In my experience, where the cattle have been supplied with water in troughs there has been far less trouble in the cheese-making than where they drink from a stream or pond, into which they can get.

The Teats and Udders of the Cows.—These will become contaminated with dirt, and it is necessary to have them most scrupulously cleaned just before milking. Sores on the teats are most troublesome and at times are far too numerous. The scabs from these sores in milking become detached, and are to be found in the strainer; both the scabs themselves and the matter which exudes from the sore when the scab is torn off contain bacteria, which are productive of trouble in cheese-making and which can be found in the milk. Equally injurious is a sore in the teat or udder, and milk from such a cow should on no account be used for cheese-making.

The Hands of the Milkers.—Speaking generally, whatever soils the hands of the milkers will certainly contaminate the milk. The milkers hands should not only be well washed before milking but, if necessary, during milking time. Some of the principal sources of gathering dirt to which they are subject are as follows:—

Milk Stools.—The filthy state of the milking stools on some farms is almost incredible. It is impossible for a milker to take up the stool with his hands which are generally damp, if not wet, though they ought not to be, without getting some of the dirt from the stool on to his hands and thence into the milk. All the milk stools should be periodically well scrubbed, and every endeavour made to keep them clean during the cheese-making season.

Spans.—It is the custom in Somerset to span the cows when milking, that is, to tie the legs together. The span used is generally made of rope, which is a very absorbent substance. Now, should a cow dung when being milked, it is highly probable that some of this dung would splash on to the span. As soon as one cow is milked, the milker takes off the span and places it upon the next cow to be milked. In doing so, his hands become contaminated with the material upon the span, and as soon as he commences milking this material passes into the milk. Judging from the foul condition which the span gets into in the course of only a few days, I am quite convinced that the use of "spans" is an absolutely certain method of contaminating milk. When used, they should be frequently scalded, but, strange to say, there seems to be a strong dislike on the part of the milkers to having them cleaned. Why so many of the cheese-makers of Somerset persist in employing them, when over the greater part of England they are unknown, passes my comprehension. My advice is, get rid of spans! It may not be possible to do so at once, but by degrees it can be accomplished, and once done, farmers will wonder why on earth they used them so long.

Drinking Cider or Beer during Milking.—This custom should on no account be allowed. Cider, especially old cider, contains numerous bacteria, some of which appear to be injurious to cheese-making, hence, it should not be drunk during milking, and if taken immediately before, the hands should be well washed after drinking it, and before milking.

Dirty or Defective Utensils.—No careful cheese-maker would allow any utensil to be dirty, but some are not sufficiently alive to the importance of having the utensils free from slight defects. The merest pin-hole will harbour bacteria, and has been found by me to be a source of taint. This is especially the case if the pin-hole lead to a covered space as is sometimes the case, with, for example, a pail, containing a slip of brass on which is marked the capacity. The most minute hole will allow milk to leak in behind this strip of brass, and to be a source of constant contamination to all the milk subsequently placed in that vessel.

Flies. — These at times are very troublesome. Many will get into the milk during the period of milking, more especially at certain times of the year, and particularly during a very dry and hot season. Probably milkers take very little heed whether flies get into the milk or not; but I am certain that it is necessary to prevent this as much as possible. One knows how flies settle upon any dung in a field, they take some of this upon their bodies or feet, and carry it to the cows or any other article upo which they next settle. Now, having examined the bacteria i. the dung of cows and horses, I find certain forms present which are not generally, and should not be, in milk. Finding these bacteria in milk on several occasions, I discovered that the bacteria were carried to the milk by flies. Many investigations were made, and these proved, without doubt, that when flies were very numerous in the milk, these bacteria were also numerous.

Whitewash in very warm weather appears to attract flies, hence, they are sometimes numerous in the dairy during the great heat of the summer, and during that period the milk is generally more tainted than later on. Again, I have noticed that whey, when there are large numbers of flies in it, will ferment in a quite peculiar manner.

Dirty Milking.—It is an accepted fact that milk, as it comes from the cow, with the exception perhaps of the first ounce or so, is free from bacteria.* Hence, the bacteria which get into it before it enters the dairy must come: First, from the air which it passes through in its passage to the pail. Second, from the pail itself. Third, from the hands of the milkers, or fourth, from the teats, udder, or body of the cow. The prevention of these sources of contamination constitute what is usually termed cleanliness, and it is evident that the majority of taints are undoubtedly preventible. Unfortunately, the necessity of cleanliness in milking is not so well recognised by farmers as it should be, and I have invariably noticed that when cheese-making is started on a farm where milk selling has formerly been carried on, there is considerable difficulty in making good cheese, because the milk is never collected in so cleanly a manner as it should be.

Survival of Taints.—A careful examination of very many of the cheeses has revealed the fact, that, of the organisms which caused the various taints, only a few varieties survived in the cheeses, and these only in some few of them. What is the explanation of this fact? It is that sufficient acidity was produced in the curd before it was vatted to ensure the destruction of the invading organism. When the curd was put up with too little acidity, the taint was subsequently more or less perceptible in the cheese. On the other hand, if too much acidity were produced, then the cheese, though it would not be a good one, was at least free from any taint. But this is not always the case. There are other taints which do increase during the ripening of the cheese, and the reason for this is evident, that the bacteria which cause them are not destroyed by the lactic acid. Moreover, there are some taints which appear to arise in cheese some time after it has been made, and, so far as I can judge, after it has become ripe. The cause of this is not yet certain, but some results which have been obtained during these investigations lend support to the following explanation. Examination of such tainted cheese has shown that the older a cheese the fewer the aerobic organisms present. The late Rev. J. Constable, who took great interest in these investigations, sent me a sample of cheese which far surpassed in abomination any I have ever tasted. In this cheese not a single aerobic organism could be found. This points to one of two conclusions, which are im-

* Since writing the above I have received from Messrs. V. A. Moore and A. R. Ward, Bulletin No. 158, Cornell University Agricultural Experiment Station, wherein are recorded some remarkable results. I am not altogether surprised at these results, as my own work had gradually forced upon me the possibility of such a discovery. The inquiry was "concerning the source of gas and taint producing bacteria in cheese curd," and "has brought out several facts, heretofore generally denied, concerning the source of bacteria in fresh milk." The research demonstrates that "bacteria do exist sometimes in the milk ducts of the udder itself, as well as in the teats." It also shows that "certain species of bacteria when once introduced into the udder are able to remain there for a considerable length of time, thus becoming a constant source of contamination."

portant. First, if a taint is caused by an aerobic organism it evidently remains long after its cause has been destroyed, and is therefore due to the formation of a definite chemical compound. Here is a new field for chemical research. Or, secondly, it may be that these taints are due to the action of anaerobic bacteria, and this would account for my failing to discover them. There are some well-known facts which support this supposition. The cheese-maker finds that if there is a taint it is well to open up the curd as frequently as possible, thus allowing the air to get to it, and forward the growth of acidity; and it is generally recognised that the sooner a tainted cheese is sold the better, for the taint augments with keeping. Both of these facts support the view that some taints are due to organisms which do not need air for their growth and development.

The Vinegar Taint.

In the early part of the year there is a taint frequently present in the curd to which I have given the name of the vinegar taint, because it produces in the curd a smell similar to that of vinegar. I have sometimes thought it similar to "aldehyde." In addition to the production of this peculiar smell in the curd, it has the power of rapidly increasing the formation of acidity. This taint was first noticed in 1892, when I thought that it might be due to the presence of a variety of bacillus acidi lactici, and drew attention to the fact as follows:—

One fact which has been very forcibly impressed upon me during the observations, is that at times the development of acidity in the process of cheese-making is far more rapid than at others, even though the initial acidity of the milk was the same as usual, and during subsequent treatment, no cause for the variation was apparent.

This taint again occurred in 1893, and was reported on as follows:—

When this taint is present, the curd sours very rapidly, and requires to be closely attended to. Such was the cheese made on the 27th of April, 1893, which was put away at 2.6 p.m., although the average time of vatting for the month was 4.34 p.m.; it will also be noticed that though the acidity of the whey coming from the curd after second cutting was only ·94 per cent., yet the acidity of the liquid from press was 1.12, which is very high. On the 16th and 21st of May, a similar rapid development of acidity took place; in the one instance the cheese being vatted at 12.55, and in the other at 2.10, although the average of the month was as late as 4.57 p.m.

In 1894, when the School was located at Mark, the vinegar taint was again present, more or less frequently up to the 18th May, and I obtained certain organisms, somewhat characteristic cocci, which were subsequently found at Cossington in the early part of 1896. They had not been present at Crewkerne in 1895.

I was thus led to pay some attention to this coccus. It is exceptionally large (Fig. 13), does not form chains, but is fre-

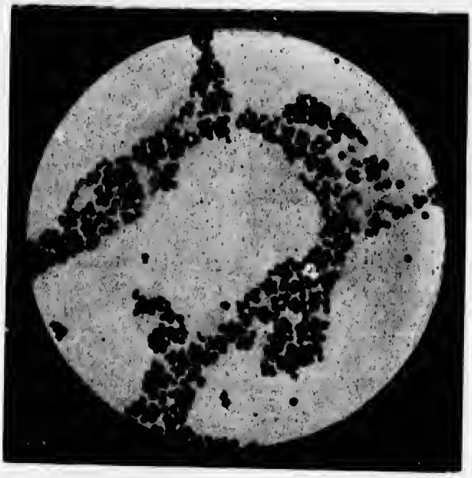

Fig. 13.—Coccus of Vinegar Taint.

quently found in pairs; the adjacent sides of the two cocci being so flattened that they look like one large organism with a dividing line* separating it into two rounded-end cones.

Growing on the plate (gelatine) culture the colony is very small and perfectly spherical. In course of time, growth being very slow, a pit-like cavity of liquefied gelatine is noticed, at the bottom of which lies the little colony. Examined under the microscope at this stage it is seen to have partly lost its clear circular edge, which is now slightly irregular. The colony is opaque, no internal structure is visible, and it possesses a slight yellow colour. Later on, it seems to burst, and particles float out into the liquid gelatine. It is one of the most slowly liquefying organisms I have met with. It retains stain by Gram's method.

A stab culture in gelatine after some time begins to show liquefaction, which at the surface gradually extends to the sides of the tube, and the liquefied portion takes the shape of a sac, at the bottom of which is a white or slightly yellow deposit, while the liquid gelatine is slightly cloudy.

The organism when grown in milk slowly produces a curdling effect, and the precipitated curd takes a characteristic pinkish tinge.

* This under the microscope is a clear unstained space, the organisms being deeply stained.

On agar an ochre-coloured growth is formed, and on potatoes a light ochre-coloured growth. Experiments were made with this organism in the usual manner, and the vinegar taint was obtained. The cheese, when ripe, was not good, and had a wrong flavour.

A second experiment was made, the milk being divided into two parts, one inoculated, one not inoculated; and again the inoculated milk produced an inferior cheese to the milk not inoculated.

As to the origin of this micro-coccus. Fortunately, owing to its power of retaining a stain when treated by Gram's method, which by far the greater number of organisms found in milk are not able to do, it was comparatively easy to examine various probable sources of contamination. The coccus was soon found in cow's dung, and so long as it gave trouble in the dairy it was always to be found in this material. Then came a period when the coccus was no longer found in the curd. Again the cow's dung was examined from time to time, but none of the cocci could be discovered. Towards the end of the season the organism again made its appearance in the curd. Once more the dung was examined, and again the coccus was found in it. There can be little doubt but that its presence in the milk and curd was accounted for, as several other organisms may be, by want of cleanliness, and the remedy is evident. But from a scientific point of view this subject raises another and more interesting problem, how came the micro-organism into the dung? And to this question I have been unable to find any conclusive answer.

Thus for several years the vinegar taint had given much trouble from time to time.

Miss Cannon, whose sense of smell is more acute than mine, tells me that there are several varieties of the vinegar taint.

Bad as this taint had been in preceding years, it had never been so bad and so constant as it was at Fenswood Farm in 1897.

It was therefore surprising that when the taint was most marked at Long Ashton, the micrococcus above described could not be found in the curd. This led me to search for another organism capable of producing the taint, but, in spite of every effort and long-continued bacteriological work, the cause of this taint could not be discovered. As frequently happens, however, that which baffles the most persistent efforts of investigation is discovered by what may almost be termed an accident. So it was in this instance. When making experiments with pure cultures of the bacillus acidi lactici, it was decided to use for each experiment a culture from a different source to those previously employed. On one occasion, instead of obtaining the results expected from the use of a pure culture of the lactic acid bacillus, we were surprised to obtain a most powerful vinegar taint. The result of this experiment will best be realised if I quote from the notes made in the diary at the time.—"Tin of milk inoculated with No. 24b. at 7 a.m., kept in dairy at 67°-70° F. Evening's milk inoculated at 8 p.m.; the culture had a strong smell. Next morning the evening's milk smelt strongly of vinegar, and had 0·20 per cent. acidity. Miss Cannon says she never smelt vinegar taint so strong in milk before. The process went on very quickly, the curd being vatted at 12.10. The vinegar taint increased in strength rapidly, and the smell filled not only the dairy but the whole house. It was what Miss Cannon calls the stale vinegar taint. The curd, when placed immediately beneath the nose, smelt strongly of bay or laurel leaves."

This organism had escaped attention before because it was almost identical with the bacillus acidi lactici, not only in growth on the plate, but also in the pure culture on gelatine. Under the microscope, its shape is almost identical with that of the bacillus acidi lactici, and when grown in milk it causes the milk to curdle in almost the same time as that bacillus. Hence it is not to be wondered at that this organism had escaped notice. Having found it, attempts were made to distinguish it from the bacillus acidi lactici by the ordinary means of cultivation, but without success, except that it was easily detected in a milk culture by the pungent vinegar smell which it produced.

The appearance of the vinegar taint was not long waited for in 1898, for on the 19th April, it was present in the curd to a marked degree, combined with its characteristic and peculiar smell of bay or laurel leaves. The result was also similar to that produced in 1897, namely, an excessively rapid development of acidity, so that the curd was vatted at 12.10. This was not the first time that the vinegar taint had been present in the curd, but it had not been so highly developed on any previous day. It occurred from time to time up to the 17th May, then was not present until the 12th June, was present again on the 24th and 25th June, and was not again present during the season. The organism which produces the taint was isolated on several occasions and carefully studied, and was found to be identical with that found in 1897. In spite of every effort, I have been unable to find any difference between it and the bacillus acidi lactici, except this marked power which it possesses of producing the strong pungent smell of vinegar and bay leaves not only in the curd but also, though to a much smaller extent, in a milk culture. It may be a species of lactic acid organism, but on this point I am unable to dogmatise. Its close resemblance to the lactic acid bacillus renders it most difficult to investigate, for it always seems associated with the bacillus acidi lactici, at least we have never been able to find it in any substance where the bacillus acidi lactici was not present.

As to its source the results obtained have not been conclusive. At Haselbury, in 1895, there were two herds. Separate cheeses were made from time to time from the milk of each of these herds to determine if any difference were noticeable. It was found that the milk from the Rushy Wood herd frequently produced the vinegar taint, when the other milk did not. Now, the Rushy Wood cattle were milked in the stalls, the others in the fields. This fact, coupled with the prevalence of the taint in the spring, when the cattle are generally milked in the sheds, also with its prevalence at Ashton in 1897, when the cattle were milked in the sheds, causes the taint to be peculiarly associated with stall-milking.

It is, however, only right to mention that, so far as can be judged, it is almost always found in stale milk, where this has accumulated, for example, in the crack of a faulty vessel, or in a cloth which has been used to wipe up milk and has not been properly cleaned afterwards. These were proved on several occasions to have been the cause of the taint.

The effect of the vinegar taint was to hasten the production of acidity. Now, to quote the words of Miss Cannon, "when the curd ripens quickly, *i.e.*, during making, the cheese ripens quickly." This statement I have found by actual observation to be accurate, and Mr. Hill, when examining the cheeses, would always find these cheeses "too acid" or "slightly stingy." Analysis also shows that a curd containing the vinegar taint almost invariably has too much moisture.

The practical remedy for this taint is a higher scald to obtain a drier curd, and the production in the curd of less acid than usual prior to grinding.

Spongy (or Holey) Curd.

As its name denotes, this taint is characterised by the production of holes in the curd. It is frequently met with, and especially when the cows are feeding upon the "scouring land" peculiar to Somerset.

In 1894, the first distinctive proof was obtained that this taint was due to a specific micro-organism, and in subsequent researches it was found that there were at least four others capable of producing spongy curd. As the result of a careful study of the bacteria found at Mark, in 1894, I was led to suspect that some of these cultures were very similar to a well-known organism, the bacillus coli communis. In 1895, Mr. J. P. Laws, who was studying the bacteria found in London sewage for the London County Council, supplied me with a pure culture of this organism, which is a constant inhabitant of sewage. One of the first experimental cheeses made in 1895, was with milk into which this organism had been placed the preceding night.

The milk inoculated with this bacillus coli communis produced a spongy curd.

My next experiment was made with the organism, discovered in 1894, and found to produce a spongy curd, to see whether by being kept growing on artificial food during the winter it had lost its power to produce sponginess. A spongy curd resulted from the experiment, showing that this power of producing gas and blowing the curd into a sponge is a characteristic peculiarity of the organism not destroyed by successive cultivation. After prolonged and careful investigation, I have little doubt but that the organism of 1894 is also a variety of the bacillus coli communis.

Subsequently two other organisms were discovered which are varieties of this same bacillus, and one which was distinct, the bacillus guillebeau.

The bacillus guillebeau is found in the milk of animals suffering from sore teats.

I will deal, in the first place, with those organisms which if not all identical are yet so similar that they may be classed as varieties of the bacillus coli communis. The first of these, discovered at Mark, and found subsequently at Haselbury, for the sake of distinction will in future be referred to as bacillus coli communis No. 1. (Fig. 14.) The effect of this organism was

Fig. 14.—Bacillus Coli Communis, No. 1.

not only to make the curd spongy, but to produce a most objectionable fæcal smell, which is frequently met with in curd. This smell is sometimes present in the curd to a slight extent without there being any noticeable sign of sponginess, which may occur when the organism though present is not in large numbers, or may be due to other organisms.

Further investigation soon proved that there was another organism capable of producing a spongy curd, which, though very similar to the one just described, had certain distinctive peculiarities, so that it may be designated bacillus coli communis No. 2. (Fig. 15.)

This organism was found at Haselbury even more frequently than the former. It differs slightly in form, and in growth from

Fig. 15.—Bacillus Coli Communis, No. 2.

No. 1, and also appears to have a slightly different action upon the curd, for while, like bacillus coli communis No. 1, it forms holes, on the other hand, it does not produce the fæcal smell, or only to a slight extent. This organism was found in the droppings of both cows and fowls.

It is not possible to imagine a farmyard without fowls in abundance, but, in view of the facts above stated, it appears desirable to prevent them coming nearer to the dairy than is inevitable. More especially is it necessary not to put the cleaned trunks and milking pails out to dry where fowls are running about, as their droppings, especially in hot dry weather, may become dried up and scattered in the dust. This dust would settle upon the milk pails, and the organisms which it contained would find their way into the milk and produce spongy curd.

One characteristic of both these organisms is that, as a rule, they prevent the development of acidity in the curd, so that whenever they are present in the milk, the cheese takes much longer to make than it otherwise would. This has been made strikingly noticeable in all the experimental cheeses as compared with the cheeses made on the same days from milk which had not been inoculated. When, therefore, a cheese shows signs of sponginess it is well to take special precautions to insure obtaining sufficient acidity, and not on any account to hasten the manufacture of the cheese. Those who have the acidity apparatus can easily find out at what rate the acidity is being produced, but without the apparatus it is most difficult to judge.

If, however, sufficient acidity be produced in the curd before it is vatted, then, unless the organism is present in large numbers, the cheese improves in the ripening-room. So far as can be judged from experiments made on the ripe cheeses, the organisms would seem to be mostly destroyed during this ripening process. But the cheese is never of the best quality.

The appearance of the curd when either of these organisms is present is characteristic and well-known. It shows numbers of small holes or eyes spread throughout the curd, varying in number according to the amount of the contamination present, but the holes are always small.

Sometimes a far more spongy curd than usual was produced with large holes quite distinct from those resulting from the organisms above referred to. These curds were investigated, the organisms present being isolated and cultivated, and among them was one which, so far as it is possible to judge from memory and my note-books, had not been met with in former years. This subsequently proved to be the bacillus guillebeau. (Figs. 16 and 17.) An experimental cheese was made with milk

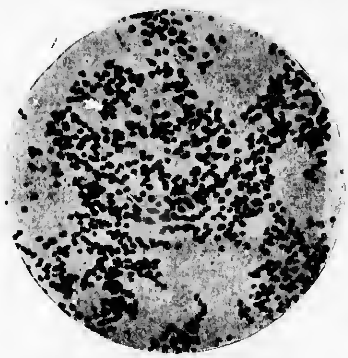

Fig. 16.—Bacillus Guillebeau.

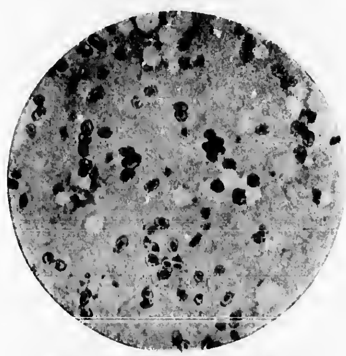

Fig. 17.—B. Guillebeau in Milk.

into which this organism had been placed. The curd was blown into holes much sooner than on any former occasion, and so numerous were the holes, so great the amount of gas formed, that the curd finally rose and floated upon the whey. The following illustration (Fig 18) is a reproduced photograph of this

Fig. 18.—Spongy Curd.

curd. This photograph is about one-half the natural size of the piece of curd photographed. In attempting to discover the source of the organism to which this remarkable result was due, I obtained two others which produced similar large holes in the curd during the latter stages of the cheese-making process. One was found in the mud taken from the bed of the brook from which the cows drink. The other, B. coli communis, No. 3 (Fig. 19) was found in cow's dung. A more complete and scientific description of these organisms, which are also probably varieties of the coli communis, is appended hereto.

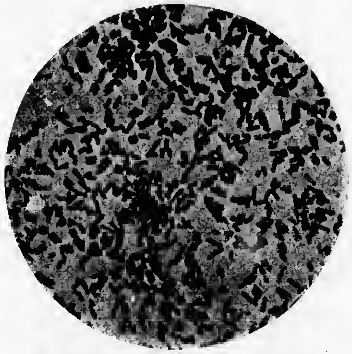

Fig. 19.—B. Coli Communis, No. 3.

The result of this bacteriological work proves that there are, at least, five organisms capable of producing spongy curd, and that one of these also produces the faecal taint so often found in curd.

The presence of the bacteria which produce spongy curd is, I find, easily discovered, as one and all produce an abundance of gas when grown in a gelatine shake culture. Their presence is also frequently noticed in the whey, which during the night will ferment to such an extent that in the morning the whey cream will be blistered and frothy.

The Source of these Organisms.—The varieties of coli communis are all organisms characteristic of sewage and obtained their name from the fact that they were originally found in the large intestine or colon. I was therefore prompted in looking for the source of these contaminations to search for the presence of sewage where it should not be.

As will be seen from the plan opposite p. 50, the water supply at Haselbury was a stream which after passing through the village of Haselbury, ran through some of the fields of the farm. This water was examined bacteriologically on several occasions, and while sometimes the bacillus coli communis could be found in the water, at other times it could not. When the mud on the banks of the stream at or near the places where the cattle would drink was examined, then the organism was always found. By tracing this stream upwards houses were found which, so far as could be discovered, in some instances drained into the stream. Now, sewage is known to be highly contaminated with the bacillus coli communis, hence it would be possible for the organism to find its way into the stream from this source, and, as the contamination by the sewage in a small village would be intermittent, this might account for the organism being found in the stream at one time and not at another. The presence of the organism in the mud on the banks where the cows drink is easily accounted for, as such places are invariably contaminated with the cow's droppings, which I proved to contain the bacillus coli communis. This bacillus is rapidly destroyed by sunlight. Hence it is desirable to keep the banks and surface of the streams free from excess of growth, and as clean as possible.

We have then two sources from which water may be contaminated with one organism which produces spongy curd, first the entrance of sewage into the stream from cottages upon its bank, and secondly, of droppings from the cows, when they get into the stream to drink. The water splashing upon the cows, and subsequently drying upon them would, with the movements of milking, become dislodged and fall into the milk, and not even the washing of the teats would completely prevent this contamination.

While my investigations were in progress, and quite unknown to me, the British Medical Journal had appointed a special commission to inquire into the quality of the milk sold in some of the poorer districts of the Metropolis. In addition to a chemical examination of the samples, a bacteriological examination was made, which resulted in the commission reporting that "every sample examined contained specimens of the bacillus coli communis."

It seems evident that, whether from the dirt on the cows or from their being milked in an impure atmosphere, one of the principal contaminations to which milk is liable is the presence of the bacillus in question.

I have not yet found distinct evidence of milk being contaminated with the bacillus coli communis floating in the atmosphere from the dried-up droppings of the cows, yet there is every reason to suppose that such contamination not only might, but does arise, and that it is one cause of the difficulty of obtaining pure milk when the cows are milked in the stalls.

While these scientific results prove beyond a doubt both the cause and the origin of spongy curd, it is certain that experience had already indicated these sources of trouble to practical cheese makers.

Thus in answer to certain inquiries which were made in 1895, regarding the prevalence of spongy curd, I received, among others, a letter from Mr. Henry McFadzean, the able teacher of cheese-making in Galloway, containing the following paragraphs *re* spongy curd:—

"I have no hesitation in saying that the cause is from the water. It was in a few cases I have known caused by the cows getting to very bad water, and whether or not the drinking or their standing in it, caused it, I am not quite certain, but that one or both caused it, I am quite certain.

"I have also seen holey and spongy curds got from milk that was partly spoiled, by the milk from a cow having a chill or weed in the vessel or udder being put in amongst the rest; this is a great trouble, and occasionally cheeses are spoiled by makers not knowing of, or watching for, such a cause."

A striking illustration of how this trouble of spongy curd may arise, happened at Long Ashton in 1898. One day the curd was terribly spongy. Inquiries were at once made to ascertain what had happened out of the ordinary course. It was found that some of the cows had been allowed to get into a paddock, adjoining the yard, where there was a pool of dirty stagnant water, from which some of them drank and into which of course they went more or less. They managed to get into this paddock twice, and each time a spongy curd was produced. To make sure that it was the water it was examined bacteriologically, and in it was found one of the most typical spongy organisms, which was also found in the curd on the days when this was spongy. This organism when cultivated in gelatine (shake culture) produced abundance of gas, blowing the gelatine into a veritable sponge.

Some time later this taint again arose in the curd, and it was found that the cows had not been into the paddock adjoining the yard, so a new source had to be looked for, and was at last discovered. The field Hop and Mead (No. 5) is on the slope of a hill, on the top of which are some cottages known as Providence cottages. The sewage from some of these cottages is allowed to pass into a receptacle in the rock which, when it is full, overflows on to the Hop and Mead. This appears to have happened early in July, and when the cows were next turned out into this field the curd became both spongy and tainted with a peculiar taint that had not been previously noticed. Now, considering that the landlord had gone to the trouble and expense of having the Bristol Water Works Company's water laid on to a trough in this field, it seems almost incredible that any of the cows should take the trouble to mount the hill and get at this dirty, foul-smelling pool in order to try and lick up some of the liquid therein, but such had happened, for the cows were watched, and one or two were seen to do this. The spot was immediately railed off, and that source of trouble and the trouble itself were got rid of.

THE ORGANISMS WHICH PRODUCE SPONGY CURD.

BACILLUS COLI COMMUNIS. No. 1.

This organism is a short bacillus of varying length, averaging about 1·5 micron,* and the breadth ·6 to ·7 micron. The ends are slightly pointed, giving the organism an egg shaped appearance. Long rods are occasionally formed.

Source.—Sewage, curd (frequently), and fowls' dung.

Growth.—*Plate Culture on Gelatine.*—The surface colonies are flat and spreading, having very irregular borders. Held up to the light appear light blue in colour. No liquefaction ensues.

Streak Culture on Gelatine.—Slightly raised growth along the line of inoculation, while the growth spreads rapidly on either side, forming a very thin dull-white film, with a smooth and shiny surface and very irregular edge.

Stab Culture in Gelatine.—Large gas bubbles are formed. Growth takes place in the stab, and a white film spreads over the surface of the gelatine.

Streak Culture on Agar.—Growth along line of inoculation slightly raised, with thick spreading film on either side, edges straight.

In Beef Broth.—The organisms are deposited, the liquid remaining clear.

In Milk.—At a temperature of 70° Fahr. the organism multiplies rapidly, growing singly, and not assuming the long rod form. The milk is not curdled.

Stains.—Stains readily in fuchsine.

Spore Formation.—Doubtful.

Motility.—Very slowly motile.

Remarks.—The size of the organism appears to vary greatly, according to the age of the culture and the nature of the medium on which it is grown. Thus on agar the organisms are longer than when grown on gelatine.

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* A micron is the 1000th part of a millimeter, or about the $\frac{1}{25000}$ part of an inch: for brevity it is usually written μ.

Milk inoculated with this organism produces a spongy curd having very small holes, and with a strong fæcal smell. The development of acidity is retarded.

BACILLUS COLI COMMUNIS. No. 2.

This organism is a short bacillus of varying length, on an average 1·2 μ long, and ·7 μ broad, the ends being distinctly rounded, many appearing almost circular, and when grown on agar is shorter and stouter than when grown on gelatine, with a length of about 1 μ, and breadth of ·8–·9 μ. The organisms occasionally grow together to form rods about 3-4 micra in length.

Source.—Whey cream, curd, fowls' droppings.

Growth.—*Plate Culture on Gelatine.*—A white, slimy, circular colony, very raised in centre, and spreading round the sides. The gelatine does not liquefy.

Streak Culture on Gelatine.—The bacillus grows rapidly, forming a broad white thicker growth than No. 1, and having a characteristic rough corrugated surface. The edges of the growth are very uneven, and have a smoother and less corrugated appearance than the interior.

Stab Culture in Gelatine.—Abundant production of gas.

Streak Culture on Agar.—A thick raised white streak with smooth and shining surface, with slight unevenness about the edges.

In Beef Broth.—The organisms grow as a deposit in the broth, the broth remaining clear.

In Milk.—The organism when grown at a temperature of 70° Fahr. does not curdle the milk, and grows singly or in pairs, longer forms not being produced.

Stains.—Stains with difficulty

Spore Formation.—Probable.

Motility.—Very slowly motile.

Remarks.—This organism is shorter when grown on agar than when grown on gelatine, which, together with its characteristic growth on gelatine, distinguishes it from Bacillus Coli Communis No. 1. Milk inoculated with the organism produces a spongy curd very similar to that produced by Bacillus Coli Communis No. 1, but the fæcal smell is scarcely noticeable. Acidity is retarded.

SPONGY CURD BACILLUS. No. 3.

This organism is a long rod bacillus of 2·5 μ in average length, and ·8 μ broad. The smallest rods are about 1·5 μ long, and the organisms join into rods as long as 5 micra. The rods have distinctly rounded ends.

Source.—Cow dung, and curd.

Growth.—*Plate Culture on Gelatine.*—Colonies minute and circular, with regular edge and very much raised, having a slightly yellow tinge by reflected light, and opaque under microscope by transmitted light.

Streak Culture on Gelatine.—The growth is spreading, edge irregular, and slightly raised. It is slightly corrugated down the middle, but the sides are smooth and flat. Growth in some respects similar to each variety of Bacillus Coli Communis.

Stab Culture in Gelatine.—Large gas bubbles are formed.

Streak Culture on Agar.—Growth, along line of inoculation, slightly raised, and spreading on either side to form a very thin flat film with shiny and smooth surface, having slightly raised irregular or indented edges.

In Beef Broth.—Growth mainly sinks to the bottom, the broth remaining slightly cloudy.
In Milk.—The bacilli are slightly shorter and inclined to grow in pairs. No curdling of the milk ensues.

Stains.—Stains readily in fuchsine solution.

Spore Formation.—Appears marked.

Motility.—None.

Remarks.—The organism is in many respects similar to Bacillus Coli Communis and may be a third variety. Curd made from milk inoculated with this organism contains very large holes, quite different to those produced by the Bacillus Coli Communis, and does not possess the characteristic fæcal smell. The development of acidity is not retarded.

SPONGY CURD BACILLUS. No. 4. *Qy.* BACILLUS GUILLEBEAU (*a*).

A small, nearly square bacillus, which, being very minute, was at first thought to be a coccus.

Source.—Curd.

Growth.—*Plate Culture on Gelatine.*—The colonies are much raised, with smooth and shiny surfaces, dirty white in colour, and of slimy consistency The gelatine is not liquefied.
Streak Culture on Gelatine.—The growth is rapid, and presents a thick, moist, and shiny appearance, is dirty white in colour, and of such slimy consistency that in a short time the whole growth slides down to the bottom of the tube. The organism when grown on gelatine appears to have a capsule.
Streak Culture on Agar.—A white spreading growth, slightly raised, having a smooth, flat, and shiny surface, and rather irregular crinkled edge. The growth does not slide down as in the gelatine culture.
In Beef Broth.—Sediment formed.
In Milk.—At 70° Fahr. the milk thickens into a pasty-like mass at the end of seven days.

Stains.—Stains readily in fuchsine. Methyl blue shows the capsuled appearance best.

Spore Formation.—Not observed.

Remarks.—When grown on agar there is no sign of a capsule, but on gelatine and in milk a capsule appears to be formed.
Milk inoculated with this organism makes a remarkably spongy curd, with such large holes that the curd floats. Smell nauseous. Acidity developes rapidly while curd in the whey, but afterwards proceed very slow.

SPONGY CURD BACILLUS. No. 5.

A very minute bacillus, with rounded ends, about ·7 μ long and ·4 μ wide.

Source.—In mud, at the edge of the stream from which cows drank.

Growth.—*Plate Culture on Gelatine.*—An irregular-shaped surface colony, white and spreading.
Streak Culture on Gelatine.—A thick, slimy, dirty-white growth, which gradually slides to the bottom of the tube, but does not liquefy the gelatine.
Streak Culture on Agar.—Very similar to that on gelatine, but is more inclined to spread, and does not slide off the surface.
In Beef Broth.—A sediment produced, the broth remaining clear.
In Milk.—Does not curdle nor digest the milk.

Stains.—Stains with some difficulty.

Spore Formation.—Not observed.

Motility.—Not observed.

Remarks.—Milk inoculated with this organism produces a spongy curd, but the holes formed are not large, nor yet numerous.

The Fæcal Taint.

This is probably the taint most frequently met with in the manufacture of Cheddar Cheese. It produces in the milk, whey, and curd a fæcal smell, which, though very faint at first, becomes quite strong before the curd is vatted, and is so unpleasant on some occasions that it makes one feel quite sick to be near the curd for any length of time.

During the past eight years repeated attempts have been made to isolate the organisms which produce this taint. Though feeling quite certain of having obtained them, yet, as it has not been possible to produce the taint at will by introducing them into the milk, I am not able to give that exact description of the organisms which has been given of the bacteria producing spongy curd.

One experiment, which it has never been my good fortune to be able to check by repetition, gave a remarkable result.

Two cheeses were made, one with half the ordinary milk, the other with the remainder of the milk inoculated with an organism supposed to produce fæcal taint. The ordinary milk produced a curd very strongly fæcal, whilst the inoculated milk produced a curd almost free from the fæcal taint.

These results were searchingly investigated at the time, 1895, and there can be no question as to their accuracy. But to explain this result is difficult. The only available supposition is that the bacteria, in the pure culture, with which the inoculation was made, during their prolonged growth, had produced sufficient of their own poison (antitoxin) to inhibit the growth of these organisms during the manufacture of the cheese. And this may be the cause of my repeated failures to produce artificially the fæcal taint.

When this peculiar taint is present, it is most difficult to know whether the curd has attained sufficient acidity for grinding or not. The acidity apparatus was found of very great advantage in helping to determine this most important point.

As illustrating the difficulty of judging the acidity when this taint was present, it may be mentioned that upon one such occasion, Mr. Cannon happened to visit the dairy. I asked him if in his opinion the curd was fit to grind. After examining it carefully, he said that it was; but, judging from the acidity test, it was not. I thought it would be a good experiment to have it ground then, and to try, when the cheese was ripe for sale, whether he was right or not. This cheese was made on the 25th June, 1893, and was tasted by Mr. Hill, Mr. Cannon himself, and Mr. Gibbons, on the 17th September. The result was a very inferior cheese.

Extended observation and experiments have proved that when this taint is present in the curd the best cheeses result when a high acidity is obtained before vatting. In such cases the organism which produces the taint, if not destroyed, is at least kept in check, and I have known many cheeses which when made had this taint, lose it during ripening and fetch a high price. But this only results when the acidity before vatting has been most carefully regulated.

Puffing of Cheese.

This trouble is almost always due to the absence of sufficient acidity in the curd when vatted, hence, I am of opinion that it is due to the organisms which produce, when present in abundance, spongy curd. But my results also indicate that there may be at times other causes. It has been stated that in studying the cheeses the anaerobic organisms were cultivated under vaseline. The milk in these tubes invariably curdles. But in some a large volume of gas is evolved, and the plug of solid vaseline is forced up into the tube sometimes to the very top thereof, or until an irregularity in the sides of the tube allows the gas to pass by. This formation of gas does not take place in every tube. One year it will arise only in one or two; another year when the cheeses are more liable to "puff" it is more frequent; hence I attribute the cause of this puffing to an anaerobic organism which has yet to be isolated. The study of bacteria is difficult when only aerobic organisms are concerned, but it is infinitely more difficult when the anaerobic bacteria need to be examined, and I have been able to do but little work in this direction.

Ropey Milk Bacteria.

These organisms have been found only rarely, and do not appear to materially affect Cheddar Cheese-makers.

In 1896 organisms which when grown in milk give it a slimy consistency, or produce what is known as "ropey" milk were more common than usual.

The organism which possessed this power to the greatest extent was a coccus (Fig. 20), which grows mostly in pairs, diplococci, and does not retain stain by Gram's method. On gelatine plate cultures the colonies are fairly large, circular, dirty-white in colour, and opaque. A streak culture on gelatine produces a rapid growth, white, thick, and with smooth, shining surface.

This organism when grown in milk causes the latter to thicken and become slimy, and subsequently a glutinous material appears to settle out of the milk.

An experimental cheese was made with milk inoculated with this organism. The curd was good and the cheese very good.

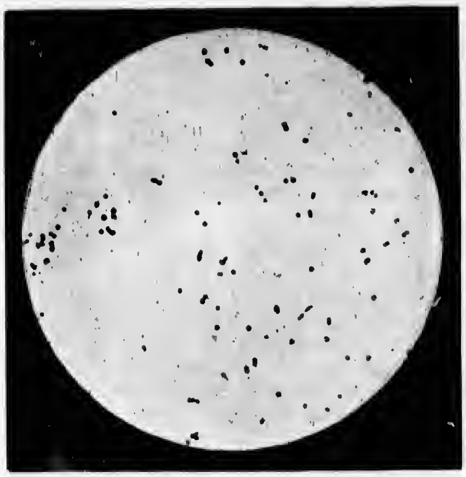

Fig. 20.—Coccus producing Ropey Milk.

It is thus satisfactory to know that one of the slime-producing organisms causes no injurious effect on the cheese. Indeed, though it was not possible to make further experiments, there appears no reason to suppose that any of the slime-producing organisms found had an injurious effect.

Mould in Cheese.

The tendency which all cheese has to go mouldy when cut does not appear to be due to the presence of moulds in the milk, from which the cheeses were made; for even when these moulds were unusually prevalent in the milk, yet in the cheeses themselves it was very rare to find the least sign of mould. In the few instances where mould was found, I attributed it to accidental impurity, due to the great difficulty of obtaining cheese cultures without more than ordinary exposure to the air. Hence, the well-known tendency of cheese to "go mouldy" must be atributed solely to its forming an admirable feeding ground for the moulds which fall upon it from the atmosphere.

Oidium Lactis.

This is a white mould, sometimes found in milk which does not liquefy the nutrient gelatine upon which the organisms are grown for the purpose of isolating and studying them. I could find little that was known about this mould. Dr. Warming, Professor of Botany, at the University of Copenhagen, in his Handbook of Botany, says: "It is uncertain whether it causes the souring of milk or not." I determined to set this point at rest. At first, the fungus when grown in milk, invariably curdled it, but, upon making a slide of the curdled milk, the bacillus acidi lactici was always present. At last a pure culture of the mould was obtained, and then it was found to have no curdling effect upon the milk. To prove that the uncurdled milk contained the mould, cultures were made from it, and a growth of the mould was invariably obtained. Although present in the milk so frequently it has not been found in a single cheese, nor can any effect be traced to its presence in the milk. As to its origin in 1892, after many fruitless attempts to discover its source, it was at last found growing abundantly in the earthenware drain-pipe which carried the whey to a receptacle in the farmyard. Here it grew luxuriantly, doubtless contaminating the surrounding atmosphere, and so entering the dairy and the milk. It only shows how careful the cheese-maker should be to seek, even at a distance, for causes of contamination which, at first sight, are not easily accounted for, and it proves the folly of allowing, as is often done, the pipe which carries away the whey to open into the dairy.

The organism, which was considered the bacillus amylobacter by the earlier writers, is, in my opinion, one form of the oidium lactis. I have only found this organism in one single cheese, and never in a good one. I found it in 1893, for the first time in a cheese which was of very inferior quality, cracked, and suffering from the cheese fly. In this cheese it was abundant.

Yeasts.

During the continuation of these experiments there have been found in the milk, curd and ripe cheeses, from time to time several varieties of yeast.

The organism most frequently present is perfectly spherical; only rarely can a budding cell be observed. The cells do not show the variations of shape so frequently seen in most yeasts, nor do they remain united in chains or bunches. On plate (gelatine) cultures, the colonies are mostly on the surface, being round, white, somewhat raised, and having a dull and crinkled surface. Streak cultures on gelatine grow rapidly, and produce a thick white streak one-eighth of an inch wide, with dull and wrinkled surface as if drawn up into folds. So far as I can judge, from the description given by Duclaux, this yeast appears to be very similar to his levure de lactose.*

* Ann de l'Institut Pasteur, 1887.

I have also found a second yeast very similar to the preceding, except that its cultures have a smooth and somewhat shining surface instead of the dry appearance of the above.

There are at times also present some oval yeasts similar to those found in fermenting liquids. I found that these yeasts were most difficult to grow in milk, and was therefore surprised at their frequent presence in the curd. Experiment, however, has shown that if the milk be at the same time inoculated with the bacillus acidi lactici, the yeasts grow with rapidity and ease. Experiments made with these yeasts all tend to show that they improve the flavour of the resulting cheeses, and much further study is required in this direction.

Rennet.

The bacteria present in rennet, even when this is of the best quality are numerous and varied. Moreover, I always find in rennet the round yeast previously referred to. The practical importance of these facts is to show that rennet is not a liquid inhibitory to the growth of bacteria, so that if it be kept in an impure atmosphere, or allowed to become contaminated in any way it will become a continual source of taint.

The Variations in the Kind of Bacteria found at different periods of the year and at different sites.

The bacteriological work which has been done each year in connection with these observations has been considerable, take for instance the year 1896.

Forty-eight plate cultures were made at Cossington, from which eighty-six pure cultures were obtained and studied.

These may be classified as follows:—

Cocci	liquefying	16
	non-liquefying	21
Bacilli	liquefying	8
	non-liquefying	31
Yeasts, &c.		10
		86

Similar work had been done at each Cheese School, and from the results thus obtained, it was discovered:—

First, that at different times of the year certain organisms make their appearance and subsequently disappear. Thus, in 1894, of 16 liquefying organisms—*i.e.*, those which have the power of causing the solid nutrient gelatine, on which they are grown, to be converted into liquid—three were found in April, four in May, and nine in June. Some of these were again found in the months of July and August, but subsequently it was very rare to obtain a liquefying organism.

Secondly, the taints have a certain periodicity. Thus the vinegar taint is almost always present in the spring of the year, it is followed with a tendency to spongy curd, and lastly with the faecal taint. Year after year I have noticed this characteristic periodicity in the taints.

Lastly, some of the organisms found frequently one year are scarcely, if ever, seen the next.

In 1896, as in former years, nearly all the liquefying organisms were found during the early part of the season, that is during April and May, in which months eighteen of the twenty-four liquefying organisms were obtained. The persistence of this peculiarity year after year seems to point to the fact that the variation is due to some unexplained peculiarity of the season.

Then again, the organisms which were most abundant in 1895—the varieties of coli communis—though present in 1896, more especially towards the latter part of the season, *i.e.*, from August to October, were not nearly so frequently found as in 1895.

Other organisms which were not found at all in 1895, were far more prominent in 1896. But many of these were very similar to, if not identical with, organisms found at Mark in 1894.

Now, the farm at Mark is only five miles, as the crow flies, from the farm at Cossington. The cows at Mark, or some portion of them, feed in the low-lying marsh or moorland which stretches away continuously till it merges in the moorland or marshes on which many of the cows supplying the milk at Cossington were kept. The thought naturally arises, can there be any common cause which accounts for the bacteria found in 1894 and 1896 being so similar?

Season or Locality.—Are certain bacteria found in certain districts and not in others? Is it locality or is it season which causes these strange fluctuations in the varieties of bacteria present each year during the cheese-making season?

One of the objects of investigation for the season of 1897, was to try and discover an answer to this question.

To this end the occupiers of the farms where the Cheese School had been held since the observations were commenced in 1891, were requested to forward me samples of curd in stoppered bottles, and by this means I obtained simultaneously a sample of curd of the same day's make, from each of the former sites of the Cheese School. This was done on three separate occasions, once in May, once in July, and once in September Fortunately, cheese was being made at all these dairies.

The samples were forwarded :—

By	From	Site of School in
Mrs. J. D. Armstrong	Vallis, near Frome ...	1891
Miss Tilley	Axbridge	1892
Mrs. Bethell	Butleigh	1893
Mrs. J. Peters	Mark	1894
Mrs. G. D. Templeman	Haselbury	1895
Mrs. Tucker	Cossington	1896

Plate and other cultures of these curds were made by my assistant the moment they reached him at Long Ashton, he having been previously instructed to prepare for them, so that there might be no delay in their investigation.

As soon as the colonies on the plate cultures were sufficiently advanced in growth, I went down to the Cheese School to examine them. The plates were merely numbered, so that I might not know from whence each came. From the peculiarities of the colonies on these plates, I was able at once to pick out at least two or three, and state whence they came. The plate of the curd from Haselbury was the one most easily distinguished, and next came those from Cossington, Mark, and Axbridge.

There was not, so far as my memory served me, any striking characteristic about the plate from Butleigh, except on one occasion; whilst the plate from Vallis I was not once able to discover.*

* Upon subsequently making enquiries of Mr. Armstrong (Vallis) as to whether the cheeses he had made in 1897 were different in any way to those he had made in preceding years—for the bacteria present in the curd were such as have invariably been present in tainted milk—I received a long letter from him, from which I extract the following :—

"Respecting the bad taints we had in June, there are three sources we think we may have got the taint from.

"1. Our cow-stalls are not so good as we could wish, and we have some trouble in keeping them clean and free from smell in very hot weather.

"2. Through the hot weather of this summer the cows were fond of getting into a pond, and sometimes got some of the pond dirt on their teats.

"3. We have been feeding a field that was sown the year the Dairy School was here, and that field contains a lot of weeds, including a large quantity of ox-eye daisies. The reason we think it might be caused by this is, we fed the same field some two years ago, and had a similar smell in the cheese ; my wife could smell it quite plainly when breaking down the curd.

"I may say we take every possible care with the milking, having the cows' teats washed when dirty, and provide the milkers with pinafores, which are washed every week. We also have the milking-stools washed every other day.

"Last year we had a splendid lot of cheese, we took three First Prizes, and sold four months cheese at 75*s*. per cwt. We have not been so fortunate this year ; we have a very good lot of July, August, and September cheese, but through May and June we had these bad taints, and do what we would we could not stop them."

It appears to me that the second cause suggested by Mr. Armstrong is by far the most probable one.

No two of the plates were alike; on each there were, more or less, characteristic colonies. Of course, the lactic acid colonies preponderated, for the time which had elapsed between the posting of the curd to my assistant and the examination of the same by him was sufficient to develop the acidity considerably, with the probable result of destroying some of the bacteria which would have been found, had the plate been made the moment the curd was ground.

The results of these investigations are, in my opinion, conclusive upon one point, namely, that the reason why certain bacteria have been found at one School and not at another is due to local and not to climatic causes.* It must not be supposed for a moment that climatic conditions have no effect; for, at present, we can only attribute the *fluctuations* in the varieties of bacteria which take place at each School during the seven months' season of cheese-making to climatic conditions.

The problem of far greater importance is, why should different localities be infested with different bacteria, whence do they come, and what conditions preserve them in one place, whilst in others they are not to be found, or at most only rarely?

Bacteria and Plants.—In 1898, following up this work, I thought it desirable to determine if there were bacteria on the plants of the fields, and if these bacteria were different or similar. The idea originated in May, when the grass of the limed and unlimed fields at Fenswood Farm was examined, and the bacteria, although in the main similar, were found to be slightly different. Subsequently, when going over the farm with Mr. Carruthers, I noticed the plant *Linum catharticum* (purging flax) was present in some of the fields, but did not appear to be present in others. Might it be that the variations in the bacteria at different sites was partly due to the different plants found in the pastures at these sites? The idea was interesting, and, on thinking of the well-known fact that both animal and vegetable parasites are found to have a marked preference for certain plants, it seemed to me quite possible that, if bacteria were found to be present on the plants, these, too,

* It is impossible for me to record these facts without recognising that they are quite opposed to what I had expected: that they throw a new light altogether upon the problems of cheese-making, and open up once again the question as to whether the universal belief among cheese-makers, that it is more difficult to make cheeses in some localities than in others, may not have a legitimate foundation. Still, one cannot consider that the opening-up of this question once again is altogether a retrograde step. The object of these investigations has been merely to discover the truth. In the past, because we could not find, either in the chemical analysis of the soil or in the botanical examination of the pastures, any support for these local suppositions, we were led to doubt their being founded upon fact. And we were justified in doing so, for it must not be forgotten that either to the soil or to the pasture all difficulties were invariably attributed. We ought not to assume, from the results of these few experiments that the matter is conclusively settled either one way or the other.

might exert a selective power. On the 29th June, milk cultures were made with *Linum catharticum* and *Ononis arvensis*, (Rest-harrow), small portions of these plants being placed in sterile milk tubes. The result of the examination of these cultures was to show a distinct difference. On 16th July the experiments were carried further. The sterile milk tubes were taken out into the fields. A piece of the plant was gripped with sterile forceps, cut off, and immediately placed in the milk. In this way five plants were examined—*Achillea millefolium* (Yarrow), *Dactylis glomerata* (Rough Cocksfoot), *Trifolium repens* (White Clover)— and the two previously mentioned. Subsequently, plate cultures were made from these, and the bacteria examined more closely. This experiment was repeated on the 10th August; but my assistant could not find the *Linum catharticum*, so only four milk cultures were made, three of the plants being taken from within 18 inches of each other. The bacteria found on the *Trifolium repens* were always very similar—more so than those on other plants. They were characteristic and different in both appearance and chemical action to those on the other plants. The bacteria on each of the four plants, taken at the same time, and from the same spot, were different. These are the two principal conclusions to which I have come from a very careful examination of all the results obtained. It would not be possible here to give in detail a description of the various bacteria found; it must suffice to say that the results lead me to believe that there are distinct bacteria on the various plants, or at least that some bacteria are found more often and more certainly on some plants than on others. The subject is one which cannot possibly be dealt with in a few experiments like these, but is worthy of the most careful attention on the part of botanists. It appears to open up an entirely new field of bacteriology—one of considerable interest, and may be of great practical utility.

Part VII.

Experiments on the Various Methods of Making Cheddar Cheese.

Experiments on the Candy System.—Experiments on the Scotch System.—Some Thoughts on the Various Systems.—The Relative Advantages of Different Systems.

Experiments on the Candy System of Cheddar Cheese-making.

In 1892 some experiments were made to try the effect of a high scald, and subsequently Mr. Candy informed me that, in making some of the experimental cheeses of 1892, I had very closely followed his system without being aware of it. The conclusions to which those experiments led were, that in Cannon's system the whey was pressed from the curd mainly by means of acidity, but that in Candy's system the whey would be expelled mainly by means of heat. In 1893 I determined to study more closely a system of Cheddar Cheese-making which depended upon a high scald. The best-known of these is Candy's system. To make sure that I understood it, I wrote out a description, and sent it to Mr. Candy, who returned it in due course, with the information that it was not sufficiently accurate in some of the details, and that he thought it would be better for me to come to his place and study the system there. This I did, and on the last day of my visit, made the cheese, so far as possible, Mr. Candy watching me, and pointing out and correcting all errors in my manipulation. Mr. Candy subsequently published a full description of his method of cheese-making, which is reprinted on p. 15 of this report.

Mr. Candy, in order that I might see how this system was varied to meet different degrees of acidity or ripeness in the milk, was kind enough to take the trouble to obtain the milk each day in a different stage of ripeness. The following table shows the acidity developed in the various stages of manufacture at Mr. Candy's :—

Table of Acidities at Mr. Candy's.

—	3rd Oct.	4th Oct.	5th Oct.
Mixed milk before renneting	·20	·205	·21
Whey before breaking	·12	·12	·13
Whey when drawn	·13	·13	·14
Draining from piled Curd	·17	·15	·15
First drainings on cooler...	·17	·16	·15
Second " "	·21	·19	·17
Third " "	·24	...	...
First draining after cutting	...	...	·22
Second " " "	·33	·30	·31
Third and last draining after cutting ...	·33	·30	...
Liquid from press...	·83	·92	...

If we compare the above figures with the acidities obtained on Cannon's system, it will be at once seen that the development of acidity in Candy's system is very slow.

There can be little doubt that we have here a complete confirmation of the deductions previously stated, namely, that while Cannon seeks to obtain the necessary dryness of the curd before grinding by means of acidity, Candy obtains that dryness at an earlier stage by means of heat, and develops acidity subsequently. The principle common to the two systems, is to obtain a curd before vatting which shall contain only a certain amount of whey, and that whey possessing a certain acidity, and it will be found that this is the ultimate aim of every method of Cheddar Cheese-making which exists.

I went direct from Mr. Candy's to the School at Butleigh, and there, on the 6th October, made a cheese upon his system. The analysis proved that the amount of moisture in the curd was almost identical with that which Miss Cannon obtains in her curd. Mr. Candy informed me that cheese made upon his system required longer to ripen than three months. This statement of Mr. Candy's which it may be taken for granted is based upon experience, is a confirmation of the opinion which I ventured to express in 1892, and which all subsequent work has confirmed, namely, "that a cheese made with low acidity requires longer to ripen than a cheese with high acidity."

Tainted Milk.—In Candy's system the curd is exposed to the air while on the rack, but in Cannon's system it is kept encased in cloths, and with a weight on it. An experiment was therefore tried, to determine whether there would be any difference in the two methods when working with milk containing the fæcal taint. The milk was divided in half, one half treated on Cannon's system, the other on Candy's. When Miss Cannon's curd was vatted at 5 p.m., it had the fæcal smell strongly developed, but was otherwise a good curd. In the curd made on Candy's system, the smell was perceptible, but not nearly so strong. When the cheeses were cut for sale, no trace of the taint could be found in either. Miss Cannon's cheese was the better of the two, but the superiority of this cheese was easily accounted for. Cheeses made on Candy's system are not ready for market so soon as those made on Cannon's system, hence the experimental cheese, though good, had not then acquired the flavour which would be developed with longer ripening.

Experiments on the Scotch System of Cheddar Cheese-making.

The Scotch system of making Cheddar Cheese as carried on in the Stewartry of Kirkcudbright, possesses certain distinct peculiarities which so far affect the principles that underlie cheese-making that it will be well to briefly describe the system as I have seen it carried out in the Stewartry and elsewhere.

The first consideration with the Scotch maker is to obtain the evening's milk of sufficient ripeness by the morning. This ripeness he tests by means of the rennet test. If the milk, after the whole of it has been brought to the right temperature for renneting, should not be of sufficient ripeness, then it is covered up and left to ripen; on no account would the rennet be added until the milk was sufficiently ripe.

The rennet is then added, in the proportion of 1 oz. to 27 gallons of milk, or one part of rennet to 4,320 parts of milk. This is the second striking point about the Scotch system, the amount of rennet used being about twice the quantity employed by the West of England cheese-makers. The curd is allowed to set for one hour, and is then by means of American curd knives cut three times in different directions until it is divided into small half-inch cubes. The advantage of using the American knives is that the amount of fat left in the whey is less than when the shovel-breaker is used. But there is one disadvantage which, unless care is taken, may more than counterbalance all the advantages. In order to use the knives with ease the curd must be firm, more so than is necessary with the old shovel-breaker. There can be little doubt but that this has gradually brought about the custom of using more and more rennet, until at last, as already shown, it has become double the amount generally used in the West of England. This excess of rennet is detrimental to the manufacture of cheese of the finest quality.

The curd is scalded to 97° F. The cheese being made in jacketed tubs, this scald is produced gradually, taking about 45 minutes. The curd is then stirred for 25 minutes, allowed to settle, the whey drawn, and the curd taken out of the tub and placed upon a cloth over a rack in the cooler. The curd when taken out of the tub on to the cloth is crumbled up into fine particles, and the whey taken up with the curd drains through the cloth. The curd having been thoroughly broken up, and the excess of whey allowed to drain off, is covered with cloths and allowed to rest 30 minutes. It is then turned, and again broken up, but not so fine as before. It now gradually solidifies, and is next cut into blocks about 1 ft. square, on the surface, and about 3 or 4 ins. in thickness. These are piled together, turned occasionally, and finally ground. The curd is then spread over the cooler, and when sufficiently cool is salted and put into the vat.

In the early stages of the manufacture of this cheese, the system adopted is very similar to the Candy system, but it has one distinct peculiarity, namely, the crumbling of the curd into small fragments when it is taken from the tub to the cooler. The effect of this crumbling process is to admit the air into the curd in a manner, and to an extent which does not happen in any other system of Cheddar Cheese-making with which I am acquainted. And the result of this aeration is to promote the active development of the bacteria, more especially of the lactic acid organisms present in the curd. Owing to this the development of acidity is rapid, and sufficient acidity is obtained in the curd before vatting, although this takes place about 2 p.m. The saving of time by this method of cheese-making as compared with either the Candy or Cannon system is considerable. The determinations of acidity which I made in Scotland showed that fairly uniform results were obtained, and about the same amount of acidity was developed as in the English systems. Thus, in one instance, which will suffice for quotation, the acidities were as follows:—Mixed milk, ·22 per cent; whey, when curd taken to cooler, ·30 per cent.; drainings from curd when it was considered fit to grind, ·67 per cent.; liquid from press, 1·03 per cent. The difference in the acidity of the liquid coming from the curd when it was considered fit to grind, and that of the liquid from the press is explained by the fact, that after being ground the curd is spread out to cool and air gains access to it and promotes the growth of the acid-forming organisms. The same result is obtained in Candy's system. Indeed, we are forced to the conclusion that it is this unrecognised development of acidity in the curd when cooling that enables many people to make a good cheese by this system, who are unable to make it by the Cannon system, where the amount of acidity in the curd has to be determined by the sense and experience of the maker before the curd is ground and put away.

Some experiments have been carried out on the Scotch system of making Cheddar Cheese, to determine certain points. The first was to discover why, in this system, the cheese is made in so short a time.

This experiment was with milk having an acidity of ·22 per cent. To obtain this acidity, great care had been taken in the ripening of the evening's milk, for it seemed obviously necessary to obtain it, if rapid results were to be secured. On the other hand, being convinced that the use of an excessive amount of rennet was detrimental to the manufacture of a good cheese, only one part was added to 7,000 of milk. In all other respects the cheese was made on the Scotch system. The acidity of the liquid from the curd rose rapidly after it was taken to the cooler. The curd was ground at 1.30 p.m., left to cool, and vatted at 3.30 p.m. The acidity of the liquid from the press was 1·00 per cent. The cheese was good, but not so good as the best English Cheddar Cheese, being rather too dry. The chief peculiarity of the cheeses made on the Scotch system is their dryness. The analysis of the curd showed that it contained only 37·60 per cent. of water, whereas the average composition of the cheese made in the same month at the School showed 40·12 per cent. of water. Similar results have been obtained with samples of curd sent from Scotland; they all contain less water than should be present in a curd which will ripen into an excellent cheese. This is a natural result of using a large proportion of rennet coupled with a high scald.

Ordinarily a rapid cheese cannot be made unless the milk is ripe to start with. To ascertain if this held true of the Scotch system also, the second cheese was made with milk which showed less acidity. The result was that the cheese took as long to make as did a cheese made from the other half of the milk by Miss Cannon on her system. Neither of the cheeses was vatted until 7.40 p.m., and both contained the same amount of acid present in the curd. The liquid from the press of the cheese made on the Scotch system contained 1·03 per cent. of acid; of that made by Miss Cannon 1·02 per cent. of acid.

These experiments conclusively show that the value of the Scotch system, so far as its rapidity goes, depends primarily upon obtaining sufficient ripeness in the milk to start with, and that, failing this, it is as long a process as Cannon's system. When ripe, the cheese made on the Scotch system showed the peculiar dryness which had characterised the former experimental cheese.

In the preceding remarks upon the Scotch system of making cheese, it has been stated that opening up the curd and leaving it in a fine state exposed to the air immediately after taking it from the tub, and, again, for cooling before vatting, ensures the development of acidity. It may not unnaturally be asked, upon what grounds is such a statement made. It is based upon a number of observations and determinations of acidity, and is conclusively proved by the next experiment.

A cheese was being made by Miss Cannon in the usual way. When the curd was removed from the tub, it was divided into two parts, each of which was subsequently treated in the usual manner up to the first turning. The acidity of the liquid which came from the curd at this stage was ·78 per cent. Half the curd was then ground and spread out to cool, the other half was wrapped up in cloths, as usual, to keep the heat in the curd and promote ripening. The second half, after remaining wrapped up for half an hour, was ground and salted, and the cooled and uncooled portions were vatted within a few minutes of each other. The acidity of the liquid from press of the curd which had been opened up to cool was 1·14 per cent.; the acidity of the liquid from press of the curd which had been wrapped up was only 1·09 per cent. although the temperature of the latter was, when in the vat 8° F. higher than that of the cooled portion. This experiment affords very conclusive evidence of the effect of opening up the curd to the atmosphere, and proves that the development of lactic acid is promoted more by the free access of air than by temperature.

One reason which had been given to me by Scotch makers for the large amount of rennet used was that it helped to ripen the cheese more rapidly. An experiment was made to test this point. The milk was divided equally between Miss Cannon and myself. She used one part of rennet to 9,000 parts of milk; I used one part of rennet to 4,500 parts of milk. So far as possible, the cheeses were made alike; but Miss Cannon's curd made with less rennet contained less acidity than the curd made with the larger proportion of rennet. Hence the result cannot be relied upon as due solely to the action of rennet, nevertheless when the cheeses were sold the one made with most rennet showed more fat, and was slightly the better cheese, having ripened more thoroughly than the other.

Some Thoughts on the Various Systems of Cheese-making.

The various systems of cheese-making now in vogue were described in Part I., and in the preceding pages certain facts are recorded which have been proved by experiment in connection with three of these systems. It may now be well to ask, first, whether there is any reason why there should be so many systems; secondly, whether some systems are more suitable to certain conditions than others; and thirdly, whether it would not be possible to construct a system of cheese-making which should combine the advantages of each? These questions may be discussed from two standpoints, the one having regard to a system which should be suitable for a private dairy, where only one or two cheeses are made in the day, and the other to a factory system, where a large quantity of milk has to be dealt with at a time. I do not think that Cannon's system is suitable for factory purposes, for the large amount of labour which it would entail in dealing with the curd during the processes of cutting and turning would be quite insurmountable. As regards cheese-making in a private dairy, it may be well to consider seriatim the points which have been raised.

There is, I think, ample reason to believe that the various systems which have arisen are not entirely due to chance, though undoubtedly they are so to a large extent. These investigations have shown that, owing to the variations in the composition of milk, even from farms in the same county, there is a need for some variation in the methods of manufacture. If milk were a liquid of uniform composition, then it would be unnecessary to have more than one system of Cheddar cheese-making. But milk is not of such a nature. It is a liquid of very varying composition, varying not only from month to month and year to year on the same farm, and from the same stock, but varying also in the same month and in the same year upon different farms, even in the same locality. That this difference is partly due to the breed of the cattle I am quite prepared to admit, indeed I will go so far as to say it is chiefly due to breed. But at the same time, in my opinion, it is also partly due to food, and this again to the nature of the soil and the herbage natural to that soil, and there can be little doubt but that it is this variation in the composition of the milk yielded at different farms which has led to the various systems of cheese-making.

This brings us to the second problem as to whether some systems are more suitable to certain conditions than others.

There can be but one answer to this question, and that is in the affirmative. Take, for example, the milk which was yielded at Long Ashton in 1897 and 1898, with its marked deficiency of casein. Here it is evident, from the results of experiment, and also from theoretical considerations, owing to the high proportion of moisture in the curd, that a higher scald than that used in Cannon's system would give better results than the ordinary scald of 94° F.

Lastly, we pass to the consideration of that far more difficult problem as to whether it would be possible to construct a system which should be able to combine the advantages of all others. To commence with, it must be clearly realised that one part of a system often depends upon some preceding part. Thus, for example, the high scald in Candy's system is necessary to contract the curd because that curd does not contain a sufficient number of the lactic acid producing bacteria to cause the contraction of the curd by the development of acid. Had Candy used sour whey, as does Cannon, it would be difficult under ordinary conditions to also employ such a high scald. Hence the necessity of a low scald in Cannon's system. Let me take another illustration. Owing to the fact that, when the curd is taken to the cooler in the Cannon system, it already contains a large proportion of acid, and, owing to the low scald, a large proportion of whey, it is necessary that the remainder of this system should be designed to get rid of this whey as rapidly as possible lest sufficient acidity be produced, and the curd be ready to grind before it is sufficiently dry. Hence the system of wrapping it up in cloths and putting pressure upon it, and of cutting and breaking it up into fine pieces from time to time.

But in Candy's system all the operations subsequent to the curd being placed upon the cooler are devoted merely to the development of acidity, and no account is taken of the moisture in the curd. This, in fact, has already been expelled to a sufficient extent, and any surplus remaining is certain to be expelled naturally as the acidity develops.

Lastly, let us examine the Scottish system. The great care taken to ripen the milk has produced more acidity than would be present in the mixed milk employed in Candy's system, yet scarcely less than would be present in Cannon's system, where sour whey had been used, and there is a growing tendency on the part of Scotch makers to employ sour whey. Thus we get in the first place, as regards acidity, an approximation to Cannon's system, next, in the high scald, we have one of the characteristic features of Candy's system. What is the result? The curd is dry and comparatively acid as well. Hence the subsequent operations are directed to cooling and consolidating the curd as rapidly as possible without pressure, as in Cannon's system, yet without that long and tedious waiting for the development of acidity which is the chief drawback to Candy's system.

It will be seen how difficult is the task of endeavouring to combine in one system all the advantages of those now existing.

The results of these observations all tend to demonstrate the advantage of using sour whey, or some other means of adding to the milk a culture of the lactic acid bacillus. If this can be done, and the evening's milk well ripened, then I am in favour of a higher scald than that employed in Cannon's system, yet one not so high as that of Candy, a second scald of 100° F. would, I think, be ample. We should thus obtain a curd containing ample acidity, and yet slightly dryer than the Cannon curd. Instead of piling the curd in the tub, I should prefer to draw off all the whey, carry the curd to the cooler, and break up fine as in the Scotch system, so as to get rid of the whey, and open up the curd to the atmosphere, as this would promote a subsequent rapid development of acidity. The curd should then be brought together with the object of consolidating it as soon as possible, and be kept warm during this process. Acidity should now proceed with fair rapidity and also all excess of moisture come away from the curd. And lastly, the curd, if properly manipulated, should, when ground, not be at too high a temperature to vat. This system would be applicable either in a farmhouse or in a factory. Moreover, it would be possible by such a system to so manipulate the curd as to develop in it, by the time it was ready to grind, either a higher or lower percentage of acid, according to whether a rapid or slow-ripening cheese was required.

It will be evident from what has preceded, that no system of cheese-making can be carried on throughout the year, and on every farm, without modification. Thus, in the early part of the year, when there is always difficulty in obtaining sufficient acidity in the mixed milk, it would be necessary to lower the temperature of the scald lest the curd should get too dry before sufficient acidity had been developed in it. On the other hand, where acidity had developed too rapidly, it would be necessary to increase the temperature of the scald. The tendency of the curd to get too cool, during the early spring or autumn months, would have to be carefully guarded against by means of a stove in the dairy. In fact, every dairy should be kept at a temperature of 60° to 65° F. during the cheese-making season, whatever the temperature may be outside.

The Relative Advantages of Different Systems.

After a very careful investigation of the various systems of cheese-making, I have come to the conclusion that as good a cheese can be made by any one as by any other. As a rule, when a maker fails to make good cheese, it is not the fault of the system, but is due to want of cleanliness or want of sufficient skill. Nothing is more disastrous than for a maker who has not met with success to alter his system or to take up another. The only course for him to pursue is first to discover, from those who possess experience of the system which he has adopted, in what respects he has failed to carry the system out properly, and then to remedy these defects.

Part VIII.

THE MANUFACTURE OF CHEDDAR CHEESE BY CANNON'S SYSTEM. THE MOST IMPORTANT ACIDITY DETERMINATIONS IN THIS SYSTEM.

The Manufacture of Cheddar Cheese by Cannon's System.

The experiments and observations, which have been made at the Cheese Schools of the Bath and West and Southern Counties Society were confined for the most part to this one system of manufacture only. This system should now be clearly understood in all its details, and in the following description and explanation of that system the results of these observations are combined. We have first to deal with

The Evening's Milk.—This is brought into the dairy and strained through fine muslin into the cheese-tub. The acidity should then be estimated and recorded. The temperature of the milk when brought in varies from 87° to 91° F., and to prevent the cream rising it is necessary to gently stir the milk at intervals of 15 minutes during the first hour if the temperature of the milk is as high as 90° F., or the dairy is about 70° F., and at longer intervals as the milk cools. When the weather is warm more frequent stirring is needed than when the weather is cool. But if the milk is cold (say 78°-80° F.) when brought into the dairy, it would be advisable to warm it gently, say to 86°, 88° or 90° F., according to the temperature of the dairy. If the dairy is above 58°-60° F., the milk would not require to be heated quite so high. This heating of the milk is to help promote ripeness or acidity, as the milk, if at a low temperature, would not ripen sufficiently during the night.

In the morning the acidity of the evening's milk should be again estimated.*

Then the evening's milk is skimmed, and the cream placed in the warmer with a portion of the evening's milk. This portion will vary with the time of year and the temperature of the evening's milk in the morning. In June, July, and August, about one-half will be necessary; in the spring and autumn, more than half may be necessary.

The Morning's Milk is now strained into the tub containing the remainder of the evening's milk.

* The rise in acidity will show whether the milk is very ripe or not. It should be only ·01 to ·03 above the evening acidity.

Then the quantity of milk in the tub and in the warmer should be noted, and also the temperature of each.

It is essential in cheese-making to know the quantity of milk that is being dealt with. Without possessing this knowledge it is impossible to ascertain whether the cows are maintaining their yield, and paying for their keep; to judge whether the amount of cheese made is what it ought to be; to accurately estimate the quantity of rennet which should be used; and, generally, to conduct the many operations of cheese-making by a sure and not hap-hazard method. Therefore the necessity of having both the cheese-tub and warmer accurately gauged cannot be too strongly urged upon all cheese-makers.

While it is customary to find cheese-tubs with a gauge, it is seldom that the warmer has one. Yet to facilitate and ensure accuracy in cheese-making, it is advisable to have accurate gauges for both cheese-tub and warmer. The gauges should not be fixed to the tub, but made to suspend from the rim thereof, so that they can be easily removed and cleaned. Those at present supplied with cheese-tubs are not graduated finely enough. They are only marked to show 5-gallon differences, whereas it would be easy to sub-divide each of these divisions into 5, so as to gauge the exact number of gallons present. These marks might reach only half-way across the gauge. Greater care should also be taken to place the cheese-tub exactly horizontal; frequently there is a difference of two or more gallons in the reading of the gauge, according to its position on the tub. In such case it is necessary to take the readings at two opposite points, and the mean of the two readings will show the quantity of milk present.

Heating Evening's Milk.—The first operation is to bring the whole of the milk to the correct temperature for renneting. This temperature is 84° F.

In order to estimate the temperature to which the portion of evening's milk in the warmer should be heated, it is necessary to first note the quantity of milk in the tub and its temperature. If the milk in the tub be exactly 84° F., then evidently it is only necessary to heat the portion of evening's milk in the warmer to 84° also. But if the milk be above 84°, then, in order to cool it down, the milk in the warmer must not be heated to 84°, and, on the other hand, it must be heated above 84° when the milk in the tub is below this temperature. The milk, however, must not be heated above 90° F., and hence it is that the quantity of evening's milk heated must depend upon the time of year, as this affects both the quantity and temperature of the milk in the tub. It is always advisable to have plenty of evening's milk in the warmer.

In order to show how to calculate the temperature to which the milk in the warmer should be raised, let us assume there are 60 gallons of milk in the tub at 83°, and 20 gallons in the warmer. Each gallon in the tub has to be raised 1 degree, which represents 60 degrees of heat, therefore the 20 gallons must be raised 3° above the temperature required so as to give these 60 degrees of heat up to the milk in the tub. The temperature required is 84°, to which add the 3° required, and we obtain 87° as the temperature to which the evening's milk must be heated.

On the other hand, if the 60 gallons were at 86° F., they would have to be lowered 2° each, or 120 degrees of heat, which is the same as lowering 20 gallons 6 degrees each. Hence, the 20 gallons would be required at a temperature 6° below 84°, or at 78° F.

The rule may be stated thus. Multiply the number of gallons of milk in the tub by the number of degrees which they have to be raised or lowered, and divide the number so obtained by the gallons of milk in the warmer. The result shows the number of degrees above or below 84, to which the milk in the warmer must be brought.

Example.—There are 17 gallons of milk in warmer and 51 in tub at 82° F. The milk in the tub has therefore to be raised 2° F.

Multiply 51 × 2 = 102
Divide by 17) 102 (6
102

Add 6 to 84, and we obtain 90° as the temperature to which the 17 gallons have to be raised.

Whey Added.—A certain quantity of whey, which has been reserved from the previous day's make, is now heated in the warmer to 84°, and added to the milk to ensure sufficient acidity. The quantity depends mainly upon the temperature to which the evening's milk has fallen during the night, as also upon the acidity in the morning. If it remains above 70° F. in the morning, about 1 gallon of sour whey should be used for every 50 gallons of milk; if under 70° but above 65°, from 2 to 3 gallons would be desirable. The quantity must, however, depend upon the judgment of the maker. When the acidimeter is used if the rise in acidity has been only ·01 a full amount of whey may be added, but if it has risen ·03, only a small quantity or even none at all would be necessary, especially in very warm weather. In some instances, where the dairy is small and the milk remains at a high temperature all night, it is not necessary to add any whey. Should there have been any taint in the previous day's milk, it would be unwise to add any whey from that day's make. It will then be necessary to keep the heat in the evening's milk during the night, by covering the tub over with a cloth, not forgetting to stir so as to prevent the cream rising.

Renneting.—The next operation is to add the necessary quantity of rennet. After adding the rennet the milk is thoroughly well stirred for 10 minutes. When the milk is very ripe—which will have been noticed if the cream tasted a little sour before being put into the warmer, as also by the quantity of acid present, a shorter period will be sufficient. The tub is then covered over, three laths being first laid across the top of it, and upon them a "wrapper" of sackcloth. This will maintain the heat in the milk and keep out dust.

Measuring Rennet.—To use the proper quantity of rennet is one of the most important points in cheese-making. The quantity will depend upon the time of year, the composition of the milk, and the strength of the rennet. The first two can only be estimated from experience and by careful observations from day to day. The latter can be easily determined by the aid of a few instruments. It is impossible to lay too much stress upon the importance of using the correct quantity of rennet, and that this shall be pure and clean. If rennet be added in excess, a hard curd will be obtained; and when insufficient is used, a soft curd ensues, causing white whey and a considerable loss of fat, unless the very greatest care is subsequently exercised.

A good rennet extract will cause 9,000 times its own volume of milk to set in a firm curd in 45 minutes. Seeing then the remarkable strength of the rennet extract, it is most necessary to have a means of very accurately measuring out the quantity necessary.

Some cheese-makers use merely an old tea-cup, and wonder why they do not get the same results with their cheese day after day. Some use the ordinary medicine glass divided into teaspoons, but this is not nearly accurate enough. At my suggestion, Messrs. Townson and Mercer, of 79, Bishopsgate Street, London, have made a two-ounce graduated glass cylinder-measure, having 200 divisions, each of which represents 100th part of an ounce. With this measure it is easy to accurately measure out the necessary quantity of rennet, while to calculate what this quantity is will be very simple. Multiply the number of gallons of milk by 16, and divide by 9, the result will show the number of divisions of rennet necessary.

For example: 72 gallons of milk are in the tub, multiply this by 16, the result is 1152, which divided by 9 gives 128; and therefore 128 divisions of rennet will be required, in other words, 1·28 ounces.

This will be correct when the proportion of rennet to milk is 1 to 9,000; if the proportion is to be 1 to 8,800, then divide by 8·8, or if 1 to 9,200, then divide by 9·2.

Testing Rennet.—To test the strength of the rennet, proceed as follows. Take 6 oz. of milk, warm to 84° F., add 10 divisions accurately of rennet; stir well for a second or two, and note carefully how many seconds elapse after adding the rennet before the milk sets firmly; the time will vary according to the strength of the rennet. To facilitate noting the exact time when the milk sets, a little bit of cork may be floated on the 6 ozs. of milk; it will suddenly stop moving the instant the milk sets. The number of seconds which it takes to set the milk should be noted on the bottle or in a note-book.

In this way, it is after a little experience easily possible to tell whether any new rennet bought is adulterated or of the same strength as the old, for if not, it will take longer for the 10 divisions of rennet to curdle the 6 ozs. of milk.

Cutting the Curd.——The curd should be ready to cut fifty minutes after the rennet was added, and when it has attained a certain degree of firmness, which is judged by cheese-makers in various ways, some by pressure with the fingers on the top of the curd, others by the way in which the curd breaks over the finger, or, better still, over a clean glass thermometer. The curd should break with a clean fracture, and not fall away in little pieces on either side. When this consistency is obtained, but on no account before, the curd is "cut." This is usually done with a breaker, great care being necessary to cut it evenly, thoroughly, and yet gently, so as to prevent any loss of fat. The American curd knives may be used instead of the breaker, and are infinitely better. Subsequently, the curd is allowed to settle until the whey has risen. The time which elapses before the whey rises and the curd is fit to break will vary nearly every day, and the whey is allowed to rise more thoroughly in autumn than in summer. When the whey rises quickly—one hour from the time of renneting—it indicates that a quite sufficient quantity of acid was present in the milk; but if the whey rises more rapidly, there was an excess of acidity; while, if it takes longer than one hour from time of renneting, then there was a lack of acidity, in which case the stirring during scald will have to be continued for a longer period than would otherwise be necessary.

Breaking.— When the whey has properly risen, the "breaking" of the curd commences. The curd must be broken gently but evenly for half an hour, at the end of which time it should be in a uniform state of fine division, and in pieces about the size of peas.

After breaking, the curd is allowed to settle for 5 minutes. Sufficient whey is then dipped out and put aside for the morrow's cheese.

First Scald.—A quantity of whey is now placed in the warmer, and heated to such a temperature that when it is again mixed with the portion in the tub, the latter is raised to a temperature of 88° F. The heated whey should be added gradually, the contents of the tub being slowly stirred the whole time. As a rule it is found that if one-fourth the contents of the tub are heated to 110° F. this will be sufficient. This is called the first scald. Should the acidity be developing more rapidly than usual it is desirable to raise the first scald to 90° F. instead of 88° F.

The temperature to which this portion of whey must be heated may be estimated by means of a similar calculation to that adopted with the evening's milk. Thus, if there are 60 gallons in tub and 15 in warmer, the temperature in tub is, say, 83°, hence 60 gallons have to be raised 5 degrees each, or 300 degrees of heat; the 15 gallons in the warmer must therefore be heated 20 degrees above the required 88°, or to 108° F.

While the whey is being warmed, the hand is passed round the sides of the tub from top to bottom, so as to separate any curd which may cling to the sides. The curd must be kept stirred while the whey is being heated. The hot whey having been added, the curd is well yet slowly stirred for 15 minutes and then allowed to pitch or settle for 5 minutes. When the acidity is rising rapidly it is only desirable to stir for from 5 to 10 minutes.

Second Scald.—A fresh portion of whey is placed in the warmer, usually about one-seventh the contents of the tub, and heated to 130°, and sufficient is gradually added to the tub to raise the contents to a temperature of 92° F. This is the second scald. Later in the year the temperature of the second scald is raised to 94° F.*

The whey for the second scald must never be heated above 130° F. so more must be taken when a higher scald is required. The curd is kept continually stirred in this scald until it has acquired a certain degree of firmness. This firmness is estimated by the sense of touch of the maker, some of the curd being pressed in the hand. Others use the hot-iron test. The curd should attain a condition which is technically termed "shotty." Ordinarily, this condition is obtained after about 30 minutes' stirring, though sometimes it may take much longer. In fact, it cannot always be obtained, and the curd is then known as "sweet." When the curd is sufficiently hard, the contents of the tub are very rapidly stirred round into the condition of a whirlpool, so as to gather the curd into the centre, and the curd is then allowed to settle. The acidity of the whey should now be tested. If the acidity be correct, the curd should remain for 15 minutes, but if "sweet," and not firm, it must remain for a longer period, in fact it should remain until the acidity is nearly the same as that of the mixed milk before renneting. Subsequently the whey is drawn off through a strainer into the whey leads. The curd is then "piled."

Piling Curd.—This operation consists in turning up the outer rim of curd, which lies on the bottom, and immediately

* If the acidity is going very rapidly it is desirable to make the second scald higher, 96°, 98°, or even 100° F., according to the rate at which the acidity is developing.

around the side of the tub, and throwing it back on to the centre pile of the curd, more especially around the edge, so as to build up in the middle of the tub a solid circular block of curd, the edge of which is about six inches from the side of the tub. The crumbs of curd in the strainer are placed on the top of the pile, and well pressed in with the hands. The curd is next cut with a knife into blocks about 6 to 8 inches square—this being about the height of the piled curd. The centre blocks having been turned over, the outer ones are placed upon them, the heap cut round with a knife, so as to remove all projecting edges, and the portions cut off placed on the top. All the crumbs are next carefully swilled down with whey from the sides of the tub, and from around the pile, collected in the strainer, and then placed on the top of the pile. The piled curd is covered with thin cheese-cloths and wrappers, and the curd is allowed to drain, as a rule, until the whey only comes in drops from the tub. This will take from 5 to 30 minutes; even longer if the curd is "sweet." The acidity of the liquid from the piled curd should be estimated. It should be about half as much again as that of the mixed milk. When the curd is too firm from an excess of acidity, it is sufficient to cover it when draining with thin cloths only, and when the acidity is very high, the curd need not be piled, but simply turned, and at once removed to the cooler.

Ripening of Curd.—The curd is next cut into six or eight blocks, one-half taken to the "rack" in the "cooler," broken with the hands into small pieces, and tied up tightly in a cloth. The remaining half is treated in a similar manner, and the two bundles are then placed one on top of the other, and subjected to pressure by being covered with a tin pan reversed, on which are placed a cloth, a thick board, and a heavy weight. (See Fig. 22, p. 222.) The weight varies from 56 lbs. to 84 lbs., according to the quantity of curd. The whole is wrapped round with cloths to keep the heat in the curd, and so promote its ripening. Should, however, the curd contain an excess of acid, it is not advisable to wrap it up.

The curd is left thus for half-an-hour, during which time a certain amount of liquid drains away from it. When the curd contains an excess of acid, from 5 to 15 minutes is sufficient time to elapse both at this stage and between the subsequent turnings throughout the ripening process.

First Cutting.—The curd is taken out of the cloth and cut with a knife vertically, say from N. to S. and E. to W., at distances of one to two inches, so as to produce oblong pieces of curd one to two inches square, and about 4 inches in length; when soft and acid it is cut finer than when sweet. These pieces are well mixed together, again tied up in the cloths, the bundles being reversed so that the upper one is placed underneath. The bundles having been treated as above described, are subjected to the same pressure for a further period of half-an-hour. Again some liquid drains away.

Second Cutting.—The curd is taken out of the cloth, cut as before, then pressed down so as to lie at an angle of 45° with the cooler, and again cut across, so that each oblong piece becomes divided into three or more cubes of about one inch each in size. When the curd is very sweet it is cut into larger, about two-inch, cubes. The cubes are packed up as before, and subjected to pressure for half-an-hour. The acidity of the liquid which drains away should be estimated, and compared with that of the drainings from piled curd, as it will afford evidence of whether the acidity is developing rapidly or slowly.

Turning the Curd.—The curd is then opened up, broken into lumps by being pressed against the rack, again tied up and subjected to the same pressure as before for half-an-hour.

This operation is repeated sometimes twice or thrice, at regular intervals of half-an-hour, except when the curd is slow to ripen, as frequently happens in the spring and autumn. It may then be necessary to leave one hour between each turning, or even longer after the second or third turning.

The turning of the curd proceeds until it has attained the requisite degree of ripeness. The curd should then be dry and solid when cut, leathery and flaky when torn asunder, of good taste and smell, and sufficiently acid. The acidity must be estimated in the whey draining from the curd, and not until this shows sufficient acidity should the curd be ground.

No part of the manufacture of Cheddar Cheese requires more judgment, experience and natural aptitude than to determine when the curd has attained that condition in which it may be considered fit to grind.

Grinding and Salting.—The curd is then passed through the curd mill, spread on the cooler and salted. The quantity of salt used is $2\frac{1}{2}$ lbs. to 112 lbs. of curd. The salt is thoroughly mixed with the curd, which is then placed in the vat, each portion as it is put in being pressed down carefully so as to pack the vat evenly.

Pressing. — The vat is then put under the first press, pressure being applied very slowly and increased gradually until full pressure is applied, this should take from 30 minutes to one hour. Pressure is then taken off, the cloths pulled up, then a tin follower put on under the wooden one and full pressure applied. Here it is left over-night. The acidity of the liquid from press should be estimated and should be five times that of the evening's milk. Thus should the evening's milk have had an acidity of ·18, the liquid from press should have an acidity of ·90. It is above all things necessary to obtain in the curd before it is vatted a sufficient amount of acidity; without this it is not possible to make either a good cheese or cheese of uniform quality, while by securing it many of the taints which are a constant source of trouble to Cheddar cheese-makers are destroyed.

Next morning the cheese is removed from the first press, and dry cloths having been put on it, it is placed in the second press, which should exert slightly greater pressure.

This operation is repeated the third day, still greater pressure being now placed upon the cheese. On the morning of the third day the cheese is greased, a cloth pinned tightly round it, and a cap placed on each end. The cheese is then returned to the press, and the next morning is bound, weighed, labelled, and taken to the cheese room.

Where many cheeses are made, it is advisable to have two cheese-rooms for ripening the cheese. The temperature of the one to which the cheeses are first taken should be maintained as far as possible between 63° and 68° F. The second room may be cooler, with a temperature of 58° to 63° F. For three or four weeks after the cheeses are made, they must be turned every day; and subsequently they should be turned every few days until sold.

Such is a description of the method of making Cheddar Cheese adopted at the School of the Bath and West and Southern Counties Society. But, in addition to a close attention to the details herein mentioned, it is essential to the production of a good cheese that the following conditions be observed.

Cleanliness.— First and foremost, it is necessary that the greatest care be taken in milking, to prevent any contamination getting into the milk. And should the milk in the evening be brought into the dairy before the day's cheese has been vatted, the cheese-maker must wash her hands before touching any of the apparatus used for the evening's milk.

The apparatus and all utensils employed must be kept scrupulously clean by thorough washing and scalding, not the least trace of curd being left anywhere. Badly made, as also worn-out, utensils, cannot possibly be thoroughly cleansed, and must be rejected. The dairy itself must be kept clean and well ventilated, and nothing should be kept in it except what is absolutely required for the cheese-making. The floor must be well laid, and all cracks, open joints, &c., filled in with cement, and the drain should be an open one. Should any milk or whey be spilt on the floor, it must immediately be wiped up with a clean flannel or mop.

In addition to the minute attention to details which has been insisted on, it is essential that an ever-watchful intelligence should be possessed, and constant observation exercised, by every cheesemaker who aims at the rare result of producing throughout a whole season, cheese of the best quality, at once rich, mild, and uniform in character.

Nothing short of the most exact attention to every detail herein set forth will ever secure the manufacture of cheese of this high quality.

THE MOST IMPORTANT ACIDITY DETERMINATIONS IN CANNON'S SYSTEM.

Those who, in carrying out this system, use the acidimeter are anxious to know which are the most important acidity determinations. It will be well to answer this question, and, at the same time, to draw attention to the most striking points in the results which may be obtained, even at the risk of repeating what has already been stated in the preceding pages.

The acidity of the evening's milk is the first determination necessary, and this should be made when it is brought into the dairy, and again in the morning. If the evening's milk has been kept sufficiently warm, the acidity will have slightly risen during the night from say ·19 per cent. to ·20 per cent. If the dairy has been close and its temperature high, the acidity may have risen to ·21 or ·22 per cent., as frequently happens during the months of August and September.

It is not absolutely necessary to take the acidity of the morning's milk, but that of the mixed milk must be taken most carefully before renneting, for it will be the key to the day's proceedings. It is always desirable to begin cheese-making with milk sufficiently ripe, and the best acidity to aim at obtaining is ·20 per cent. The next determination of acidity necessary is in the whey when the curd is thought to be sufficiently firm to stop stirring. The whey if fit to be drawn off should then have an acidity of ·01 or ·02 below the mixed milk when renneted. If it has not, it will be necessary to allow the curd to settle, and to wait until the acidity is developed. It takes about 15 minutes to rise ·01 per cent. in acidity. The acidity will rise as the whey comes from the curd, and will reach in the end ·01 to ·02 above what it was when stirring ceased.

It is well to adopt the standard of ·01 per cent. below that of the mixed milk as the best acidity for the whey to acquire before it is drawn off; but, under exceptional conditions, it may be necessary to draw off the whey before it has acquired the standard acidity.

The next determination of acidity desirable is that of the drainings from the piled curd on the tub, for it will give some idea of the rapidity with which the cheese should subsequently be handled. If it is found that the acidity from the piled curd is less than half as much again as that of the whey, then, in all probability, the subsequent development of acidity will be slow, and the necessary precautions should be taken to hasten it so far as possible, more especially by keeping the curd warm. But if the acidity of the liquid from piled curd is more than half as much again as the whey, then acidity is developing rapidly, and care must be taken to hasten on subsequent operations accordingly.

The subsequent determinations of acidity will be made to determine when the curd is fit to be ground. There is no stage in the manufacture of a cheese more difficult to estimate than this. If the acidity apparatus were used for this determination only it would well repay its cost and the trouble of learning to use it properly. The acidity of the liquid which comes from the press is the final determination made. There will, as a rule, be a close relation between these two estimations, varying mainly according to the weather, or rather the temperature of the curd, which again is due mainly to the temperature of the dairy.

The rate at which the cheese will ripen will depend upon the acidity of the liquid from press more than upon any other factor, assuming of course that the cheeses are kept at a uniform ripening temperature. If the acidity be low, the ripening process will be slow; if the acidity be high, the ripening process will be rapid. The composition of the milk from which the cheese is made plays an important part in determining the quantity of acid which is permissible in the liquid from the press, in other words, in the curd when this is taken to the cheese-room. The richer the milk, the more acid there may be present in the curd. We have seen that the richer the milk the higher the acidity of that milk, hence, after careful consideration of all the facts obtained in these investigations, I have come to the conclusion that the acidity in the liquid from press should be five times that of the original acidity of the milk, that is of the evening's milk, not of the mixed milk prior to renneting.

Such are the chief determinations of acidity required.

At no time will the cheese-maker find greater benefit accrue from the use of the acidity apparatus than when dealing with tainted milk. Of the more frequently present taints the faecal taint is characterised by delaying acidity, and the vinegar taint by causing a rapid development of acidity. Many of the cheeses made at the present day are inferior owing to the presence of these taints. But if when the former taint is present, a sufficient amount of acidity is developed in the curd before it is put in the press, the taint will pass off during the subsequent ripening. And when the vinegar taint is present the development of acidity can be checked, and so prevent the cheese from acquiring an acid or stingy flavour. Hence by the careful use of the acidimeter both these troubles can be largely controlled.

Part IX.

The Conditions Essential to the Manufacture of Cheddar Cheese of High Quality.

The Dairy.—The Equipment of the Dairy.—The Cheese Room.—Knowledge and Skill.—A Daily Record of Work.—Summary.

The Conditions Essential to the Manufacture of Cheddar Cheese of High Quality.

The first and absolutely essential condition of the manufacture of "best" cheese is, as has been clearly shown in this report, to have milk of normal composition, from healthy cows, and perfectly clean. Without this, no skill and no care will ensure success.

Next, it will be necessary to have the proper conveniences with which to make the cheese. These are a suitable dairy and cheese-room properly equipped with apparatus.

The Dairy.

It would appear to be self-evident that the room in which cheese is made should be suitable for the purpose for which it is intended, yet, after eight years' experience of Somerset dairies, I regret to state that very few are in any sense properly constructed. Hence, at nearly every site which has been selected for the Cheese School of the Bath and West of England Society during the past eight years, some, and in most cases considerable, alterations have had to be made before the dairy was considered suitable.

It may be well then to give some account of the requirements of a good cheese dairy. The first consideration is that the room should be so placed as to be free from unpleasant smells. As a rule the pig styes are placed far too near the dairy, or the window of the dairy opens on to the farmyard, which is surrounded with horse-boxes or cattle stalls. In such cases it is necessary not to use the pig-styes or cattle-stalls during the period of cheese-making. Another source of foul air obtaining access to the dairy is the presence therein or close by of drains. There should on no account be any drain in the dairy. I have known the cheese of the best makers spoilt owing to the whey lead which stood in the dairy being connected with a drain which went direct to the pig styes. When the wind was in a certain quarter, the foul gas in this drain found access to the dairy and spoilt nearly a whole season's make of cheese.

All the liquid from the dairy should pass out by an open surface course leading to, and opening over, an outside drain which is well trapped. In some farmhouses the privies, which are simply earth closets, are far too near the dairy and cannot fail to be the source of an impure atmosphere which enters at the windows. Lastly, the dairy should be separated from the dwelling-house, and not open, as is frequently the case, into the kitchen or scullery. Nor should it be near the pantry. The old idea of converting the dairy into a pantry ought by this time to be exploded, still, I have seen within recent years fairly high game in a cheese dairy.

Within reason, the larger the room the better, though, if the atmosphere be kept pure, and cool, it is quite possible to make good cheese in a small dairy. The room should by preference face north. But if open to the east, or south, or west, the sun, during the time of making, must be prevented, by blinds, from shining into the room.

Good ventilation is a primary necessity, and this should be obtained without draughts. It is best procured by two windows which should be covered with fine wire gauze, so that, when the windows are open there is less chance of a draught. Moreover, the wire gauze keeps out flies and insects which at times are very troublesome.

During the early spring, and again in the autumn, it will be necessary to keep the dairy heated. There is no better means of doing this than by a slow combustion stove on the Tortoise principle or one similar thereto. The heat from these stoves can be regulated, they keep in for a considerable time without attention, are clean, and safe.

A similar stove will also be required in the cheese ripening room.

The floor of the dairy should be concrete or cement or well laid stone, so that it may be even, and have no cracks in which milk or whey can lodge.

The walls should be well plastered and whitewashed. An excellent wash for this purpose is made with two-thirds white lime and one-third cement. Care must be taken to have no size in the whitewash, or it will attract flies to such an extent that they will become a nuisance.

One or two wooden shelves and a small cupboard, both at such a height that they can be readily reached, and so kept clean, are also necessary.

The Equipment of the Dairy

The utensils used in cheese-making are not numerous, and these, and these only, should be kept in the dairy.

The cheese tub (Fig. 21) mainly in vogue is a round metal (tin lined copper) tub, not jacketed. It should be provided with

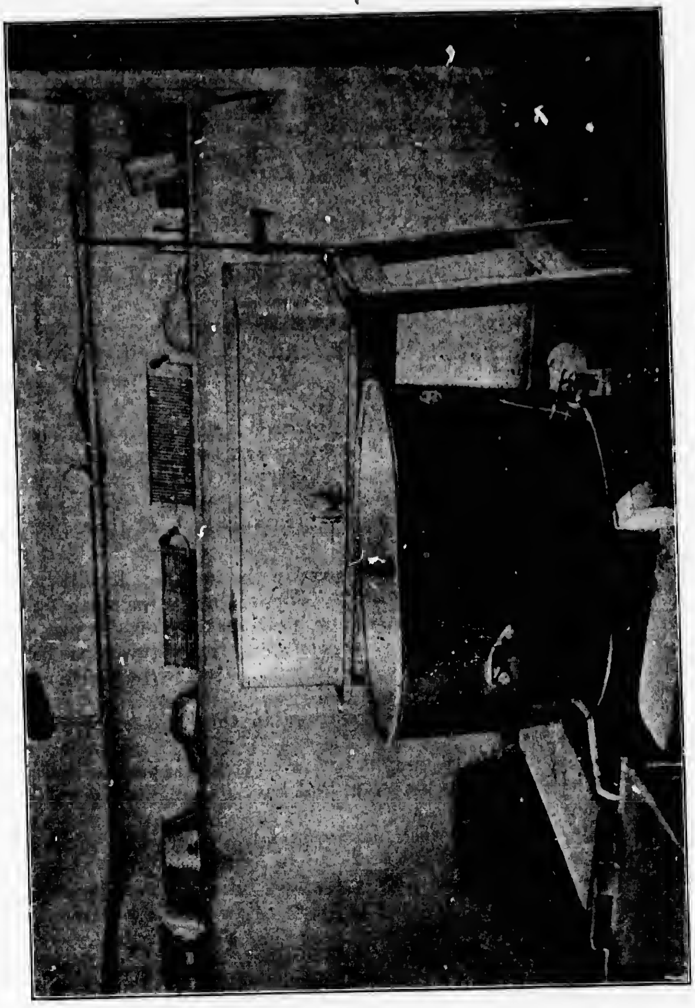

Fig. 21.—A Cheese Dairy. The Milk Tub and Warmer.

a very large tap the plug of which can be lifted out, and raised on a wooden stand so as to be within easy reach of the cheese-maker, and thus do away with needless stopping. No rim should be soldered on to the top of the tub.

In many dairies the milk and whey have to be carried outside the dairy in buckets and heated in large milk vessels standing in a copper of hot or boiling water. This system entails much labour, and, so far as I am aware, it has no special advantage to recommend it.

At the Bath and West Cheese School, this heating of the milk has always been done by means of steam in a warmer placed in the dairy, close to the cheese tub. The steam is generated in a boiler, one of the best for the purpose being that of Messrs. J. B. Petter and Sons, Yeovil. This boiler has the advantage of supplying both hot water or steam for cleaning the utensils, and there is probably nothing so cleansing as steam.

A metal cooler containing a rack, the cheese presses (Fig. 22), a cheese mill, and a stool on which to place the cheese when it is being bandaged are the principal other utensils. The cheese presses are three in number, and the second should subject the cheese to greater pressure than the first, and the third to greater pressure than the second. It is very doubtful whether the ordinary cheese presses do this, also what pressure they exert. The influence of varying pressures on the resulting cheeses is a subject which deserves investigation. Frequently the whey lead is kept in the dairy, but it is better, where possible, to keep it outside. A weighing-machine should be in the diary to record the weight of each day's cheese before the cheese is taken to the ripening room. The smaller utensils are the strainer, the breaker, a skimmer and bowls, the rennet measure, acidimeter, and record book, etc., etc.; these may also be kept in the dairy.

The American curd knives, which are seen in Fig. 21, have not as yet been largely introduced into the dairies of Somerset, but as will be gathered from this report, they deserve further attention. These knives consist of an oblong frame, in which are set, at distances of about half an inch apart, very sharp knives, running the whole length of the frame. Two such frames have to be used, each capable ot reaching to the bottom of the cheese vat. In one the knives are set vertically, and in the other horizontally.

Nothing should be in the dairy which is not used daily in the manufacture of the cheese.

The Cheese Room.

This should be above the dairy, and there should be a lift from the dairy to the cheese room, so that the cheeses can be easily removed to the latter. The floor of the cheese-room should be of wood, and it is most undesirable to have a cheese-ripening room with a stone floor, or one just above the ground. Freedom from damp, uniform temperature, and ventilation, are the chief necessities of a cheese ripening-room. At the same time no draught should ever play on a cheese while it is ripening, hence some precaution is necessary as to how the ventilation is obtained. The cheeses should be placed upon shelves and not on the floor of the room. It must not be forgotten that the top of the room will be warmer than the bottom. Hence, the

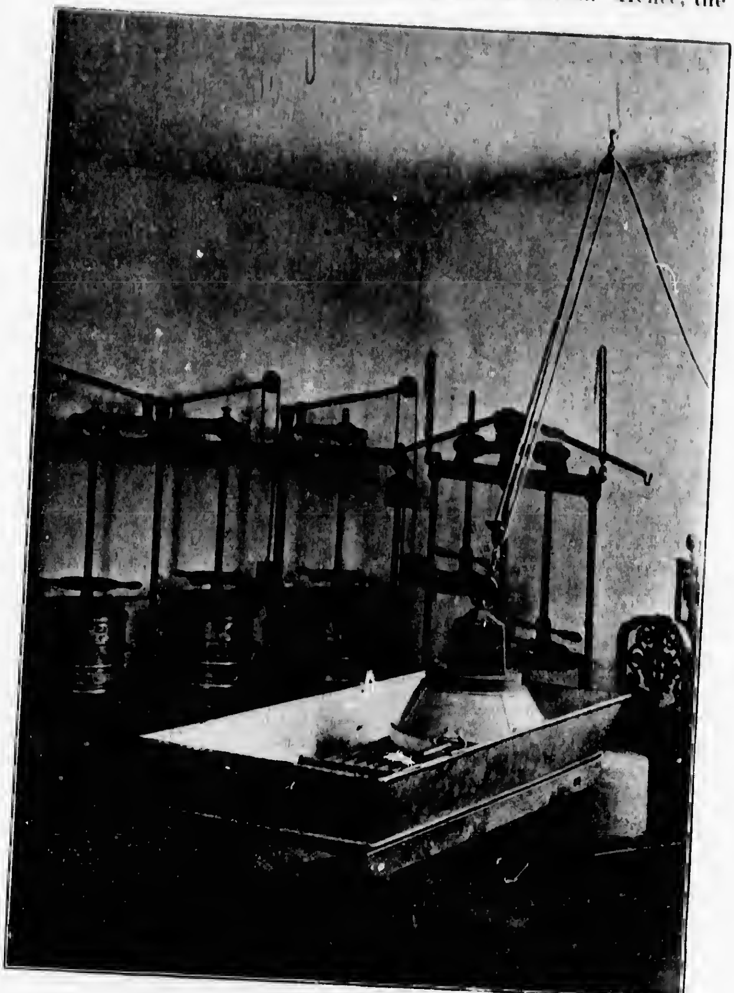

Fig. 22.—A Cheese Dairy. The Cheese Presses, &c.

newest made cheese should be placed on the highest shelves. There should be a maximum and minimum thermometer (Fig. 4, p. 31) in the cheese-room, as also a hygrometer (Fig. 5, p. 32). In cold weather the temperature must be kept constant by means of a stove.

Knowledge and Skill.

Assuming that the conditions previously referred to are obtained it will be necessary for the cheese-maker to possess the knowledge of how to use them. What is it that the practical cheese-maker has in view, whether consciously or unconsciously, in subjecting the milk and curd to the many operations requisite to the manufacture of a cheese? It is to obtain the curd, with the least possible loss of fat, in such a condition that it will ripen into a good cheese.

The tests applied by the maker to ensure this result are empirical, and depend upon the senses of touch and taste and smell. Hence, the cause of failure with many to produce a first-class cheese is due mainly to their not possessing naturally, or as the result of education or experience, the requisite delicacy or degree of sensitiveness in touch and taste and smell. For instance, some people can judge by the sense of taste with a fair degree of accuracy, whether the curd is fit for grinding, while others seem utterly unable to do this. On the other hand, some are never able to form a correct judgment, by the sense of touch, of the condition of the curd when in scald, and whether it is fit to allow the whey to be drawn, though frequently those, who at a later stage are unable to estimate its fitness for grinding, appear to have no difficulty in estimating whether the curd is fit to permit the whey to be drawn or not. Evidently, to overcome this natural inaptitude of estimating the various stages in the progress of the curd, it would be necessary to substitute some means of determining them, which would not depend upon individual capacity. This problem attracted my attention in 1891, and to solve it the first thing necessary was to determine what that condition was which Miss Cannon with such remarkable ability, estimated by her exceptionally keen senses of taste, touch, and smell. Was it a chemical condition, capable of being determined by chemical methods of investigation?

The result of the eight years of observation has been to prove, that all these conditions which the cheese-maker in the past had to determine by means of taste and smell, are chemical conditions which may be estimated with greater accuracy by chemical means. Thus the fitness of the curd to settle in scald is coincident with the whey attaining an acidity approaching the acidity of the milk before renneting, on an average it will be slightly less (see Appendix, Table 2), at times slightly more. The latter conditions are obtained most frequently in the autumn, as may be seen from the following examples:—

September, 1891	...	average acidity of		mixed milk	...	·224	per cent.
" "	...	"	"	whey	...	·232	"
October, 1891	...	"	"	mixed milk	...	·214	"
" "	...	"	"	whey	...	·217	"

From the time of drawing the whey to the time of grinding the curd every step in the manufacture, excepting the time curd remains piled, proceeds by time stages of certain duration, and no special aptitude is required until it becomes necessary to judge whether the curd is fit for grinding or not. This, without doubt, is the time when the greatest demand is made upon the cheese-maker's judgment, and when any large error will hopelessly ruin the cheese. An error in judgment at any previous stage may, by a skilful maker, be very largely counteracted in subsequent operations, but not so any error at this stage. The difficulty of judging the condition of the curd at this stage has in the past probably been the greatest difficulty the cheese-maker had to contend against. How difficult it was, may be seen from the following figures, obtained before the value of the acidimeter had been proved. On August 30th, 1891, the acidity of the liquid last coming from the curd before grinding was ·84 per cent., three days before on the 27th it was ·93, and three days before that, on the 24th, it was as high as 1·05 per cent. In September we find the acidity ranging from ·87 on the 18th, to 1·10 per cent. on the 15th, and in October from ·92 on the 22nd to 1·15 per cent. on the 9th.

If so skilful a maker as Miss Cannon was unable to judge of this stage with no greater degree of accuracy than is shown by these figures, what, we may ask, would be the condition of the curd before grinding in the hands of a less skilful maker?

Thus the two stages in the manufacture of a Cheddar Cheese most difficult to determine empirically are; first, when to stop stirring, and to draw the whey, and secondly, when to grind the curd.

The introduction of the acidity apparatus has done away with these difficulties, and although I am well aware that the use of the acidity apparatus is not actually a condition essential to the manufacture of good cheese, yet I am convinced that for many makers it is a necessity, and that for all it will prove of advantage. By its use the cheese-maker can determine the acidity of the whey, and so decide when to draw this off, and by so doing will secure not only the proper development of acidity in the future stages of cheese-making, but also materially diminish the time which the cheese takes to make. Lastly, it has been amply proved that the acidity of the whey which drains from the curd, when in the cooler, is a sufficiently accurate guide to the condition of the curd before grinding, and by securing uniformity in this acidity, the cheese-maker will also ensure uniformity in the quality and ripening properties of the cheese. Whether the cheese be made on Cannon's system, Candy's system, or the Scotch system, matters not; the acidity of the liquid from the press must for one and all be uniform from day to day. Nor should it vary except within narrow limits. Speaking generally, the acidity of this liquid should never fall below 0·80 per cent., nor rise above 1·20 per cent., and the nearer it can be kept to 1·00 per cent. the better.

But the accurate determination of these acidities will not alone ensure a good cheese. Equally important will it be to pay strict attention to temperature, time, and every other factor which can be accurately determined. Moreover, these must be recorded.

A Daily Record of Work.

The record of observations kept by me for scientific purposes is too detailed for the ordinary routine of the cheese-maker; it would not only occupy too much of his time, but, what is by no means a small consideration, would use up too much of the standard soda solution, the cost of which appears to stand somewhat in the way of the more general use of the acidimeter.

Still the use of the acidimeter has steadily increased in Somerset, and it has been considered desirable for some time past, to teach each pupil at the Society's School how to employ it. Therefore, in 1897, the time appeared to me to have arrived when a record of acidities, &c., should be kept in the dairy by the pupils, which should be such as they might subsequently use in their own homes and work. Hence, for this record, I determined to select only the most important data of each day's work. On the opposite page is a blank copy of this record book as kept by the pupils in 1898, and every cheese-maker might keep with very little trouble and considerable advantage a similar record.

THE STUDENT'S

PAGE 1.

Day of Month.	Observations on Cattle, Fields, Water Supply, &c.	Evening's Milk.						
		Volume.	At Night.		In Morning.			
			Temp.	Acidity.	Temp. of Milk.	Temp. of Dairy during night. min.	Temp. of Dairy during night. max.	Acidity.
		galls.	° F.		° F.	° F.	° F.	

PAGE 3.

Day of Month.	Time when Curd cut.	Acidity of Whey before breaking.	Time of breaking.	Time scalding commenced.	Temp. of Scalds. 1st.	Temp. of Scalds. 2nd.	Time taken in stirring.	Acidity of Whey after stirring.	Time in Scald.	Whey. Acidity when drawn.	Whey. Acidity of drainings from piled Curd.
					° F.	° F.	mins.		mins.		

PAGE 5.

Day of Month.	Relating to Curd. Temp. in Vat.	Relating to Curd. Weight when Vatted.	Relating to Curd. Time of Vatting.	Acidity of liquid from Press.	Weight taken to Curing Room.	Loss in Press.	Curd from 1 gallon of milk.	Ripe Cheese. Date when sold.	Ripe Cheese. Weight when sold.	Ripe Cheese. Loss during ripening.
	° F.	lbs.			lbs.	lbs.	lb.		lbs.	lbs.

RECORD BOOK.

PAGE 2

Morning's Milk.		No. of Cows in Milk.	Total Vol. of Milk.	Stale Whey.		Mixed Milk, &c.			
Volume.	Acidity.*			Volume.	Acidity.	Acidity before Renneting.	Time of Renneting.	Rennet added.	Proportion.
galls.			galls.	galls.				ounces.	

PAGE 4.

Time Curd remains piled.	Time Curd taken from Tub.	Temp. of Curd when taken from Tub.	Acidity of Whey draining from Curd.							Salt added.	Temp. of Dairy during day.	
			When taken to Cooler.	After 1st cutting.	After 2nd cutting.	After 1st turning.	After 2nd turning.	After 3rd turning.	After 4th turning.		min.	max.
min.		° F.								lbs. oz.	° F.	° F.

PAGE 6.

Observations on quality of Curd, Cheese, &c.

* It is not always possible to mix the whole of the morning's milk together so as to take the acidity.

No cheese-maker can ever hope to attain success unless a careful record of the work done daily is kept; and every cheese, before being taken to the curing-room, should have sewn on it a label showing the date of manufacture. Then whether the cheese be good or bad, it will be possible to turn back to the record and discover the cause of this success or failure.

No cheese-maker so self-educated need fear but that in time he will produce Cheddar Cheese of the highest quality.

Summary.

The conditions which are essential to the manufacture of good Cheddar Cheese may then be summarised as follows:—First, a suitable dairy, and cheese-room, properly equipped. Second, apparatus free from defects, and scrupulously clean. Third, milk of normal composition, from healthy cows, and perfectly clean. Fourth, skill and forethought in the making. Fifth, the acurate determination of all those factors of acidity, temperature, and time, which can be determined accurately. Sixth, the careful daily record of these determinations. Seventh, a study of this record to determine the causes of the best and worst cheeses produced.

APPENDIX

APPENDIX.

TABLE I.—RECORD OF OBSERVATIONS MADE AT THE BATH AND WEST

1	2	3	4	5	6	7	8	9		10	11
	Relating to Evening's Milk.										
			At Night.				In Morning.				
Day of Month.	Name of Field.	Volume of Milk.	Time.	Temperature of Dairy.	Temperature of Milk.	Acidity.	Time.	Temperature of Dairy.		Temperature of Milk.	Acidity.
		Galls.	P.M.	° F.	° F.	%	A.M.	min.	max.	° F.	%
31–1	Sharnam's Large Leaze	59	6.30	65	86	·22	7.10	64	68	70	·23
1–2	Ditto ...	60	6.30	64	87	·22	...	...	...	...	...
2–3	Moor House, Large Leaze	...	...	...	...	...	7.15	62	66	70	·24
3–4	Ditto ...	60	6.20	64	87	·23	7.15	61	64	68	·24
4–5	Ditto ...	61	6.5	63	86	·23	7.20	61	63	69	·23
5–6	Ditto ...	57	5.30	63	85	·21	6.45	61	65	68	·24
6–7	Ditto ...	64	6.30	64	87	·21	7.5	63	64	70	·22
7–8	Ditto ...	64	6.20	66	86	·22	7.10	64	67	73	·24
8–9	Ditto ...	62	6.40	66	87	·21	7.10	65	68	73	·24
9–10	Ditto, 12 acres	63	6.45	69	92	·23	7.10	66	70	74	·26
10–11	Sharnam's Large Leaze	60	6.30	67	89	·22	7.20	65	70	72	·24
11–12	Ditto ...	58	6.20	66	90	·22	7.20	65	68	70	·25
12–13	Ditto ...	55	5.10	65	90	·23	7.15	63	66	68	·25
13–14	Ditto ...	61	6.30	66	85	·23	7.7	63	66	69	·23
14–15	Ditto ...	63	6.35	62	86	·22	7.0	61	65	70	·24
15–16	Ditto ...	63	6.30	63	86	·22	7.7	62	64	69	·23
16–17	Ditto ...	60	6.15	62	85	·23	6.40	61	64	67	·24
17–18	Moor House, Large Leaze	63	6.35	62	87	·22	7.15	61	64	69	·23
18–19	Ditto ...	58	6·30	64	86	·22	7.10	60	62	67	·23
19–20	Large Leaze, 14 acres ...	54	5.45	62	82	·22	6.50	60	63	67	·23
20–21	Ditto ...	58	6.30	63	84	·22	7.0	60	63	67	·23
21–22	Ditto ...	66	6.15	63	83	·22	7.10	62	64	71	·25
22–23	Ditto ...	62	6.10	64	90	·21	7.15	62	65	71	·25
23–24	Ditto ...	59	6.30	63	87	·21	7.10	62	64	69	·23
24–25	Ditto ...	60	6.45	64	87	·21	7.3	63	65	69	·22
25–26	Moor House, Large Leaze	61	6.40	64	86	·21	7.30	63	65	70	·23
26–27	Ditto ...	57	6.0	67	90	·21	7.15	64	67	71	·24
27–28	Mixed Fields...	60	6.30	66	91	·21	7.30	65	69	72	·24
28–29	Ditto ...	57	6.20	65	90	·22	7.30	65	70	68	·21
29–30	Ditto ...	57	6.30	64	90	·21	7.15	63	67	69	·24
Average		60	6.2	64	87	·22	7.10	62	65	69	·23

OF ENGLAND SOCIETY'S CHEESE SCHOOL, JUNE, 1892.

12	13	14	15	16	17	18	19	20	21	22	23
MORNING'S MILK.			Total Volume of Milk.	MILK HEATED.		STALE WHEY.		MIXED MILKS, &C.			
										Rennet added.	
Name of Field.	Volume of Milk.	Acidity.		Quantity.	Temperature.	Quantity.	Acidity.	Acidity before Renneting.	Time of Renneting.	Volume.	Proportion by Volume.
	galls.		galls.	galls.		lbs.			A.M.	ounces.	
Sharnam's, Large Leaze	64	·21	123	43	86	4	·48	·23	7.40	2·14	9196
Ditto ...	67	...	127	...	...	...	...	...	7.38	2·18	9321
Moor House, Large Leaze	...	·20	126	40	89	4	·45	·23	7.35	2·14	9420
Ditto ...	68	·21	128	40	90	4	·47	·22	7.40	2·17	9437
Ditto ...	67	·21	128	39	91	4	·45	·22	7.45	2·17	9437
Ditto ...	70	·21	127	43	85	4	·45	·23	7.10	2·16	9407
Ditto ...	65	·21	129	41	84	4	·45	·22	7.43	2·19	9424
Ditto ...	65	·22	129	40	81	4	·14	·23	7.25	2·19	9424
Ditto ...	65	·22	127	39	79	4	·45	·24	7.27	2·16	9407
Ditto, 12 acres	66	·22	129	31	79	none	...	·23	7.35	2·19	9424
Sharnam's Large Leaze	64	·21	124	28	90	4	·45	·22	7.48	2·11	9403
Ditto ...	71	·22	129	30	84	4	·46	·24	7.55	2·19	9424
Ditto ...	73	·21	128	43	90	4	·44	·23	7.41	2·17	9437
Ditto ...	67	·22	128	45	90	4	·44	·23	7.40	2·17	9437
Ditto ...	67	·22	130	43	90	4	·44	·23	7.25	2·21	9411
Ditto ...	66	·21	129	36	90	4	·43	·23	7.33	2·19	9424
Ditto ...	69	·21	129	38	90	4	·46	·23	7.35	2·19	9424
Moor House, Large Leaze	65	·21	128	34	90	4	·46	·23	7.38	2·17	9437
Ditto ...	69	·21	127	34	88	4	·41	·22	7.41	2·15	9451
Large Leaze, 14 acres ...	72	·21	126	35	90	4	·42	·22	7.22	2·15	9376
Ditto ...	66	·21	124	30	90	4	·41	·22	7.47	2·11	9403
Ditto ...	69	·21	135	27	90	4	·41	·22	7.40	2·28	9473
Ditto ...	69	·21	131	38	90	4	·42	·22	8.20	2·23	9399
Ditto ...	69	·21	128	32	88	4	·41	·22	7.35	2·17	9437
Ditto ...	64	·21	124	30	90	4	·42	·21	7.33	2·11	9403
Moor House, Large Leaze	68	·21	129	33	90	4	·44	·22	7.52	2·21	9339
Mixed Fields...	66	·20	123	30	86	4	·44	·22	7.40	2·12	9283
Ditto ...	65	·20	125	29	84	3	·46	·22	7.55	2·12	9434
Ditto ...	60	·20	117	24	90	4	·46	·22	7.45	1·99	9407
Ditto ...	63	·21	120	27	90	3	·46	·23	7.42	2·04	9411
	67	·21	127	35	87	4	·44	·22	7.39	2·16	9403

TABLE I.—RECORD OF OBSERVATIONS MADE AT THE BATH AND WEST

	24	25	26	27	28	29	30	31	32	33	34	35	36
						Temperature of Scald.				Relating to Whey.			
Day of Month.	Time when Curd cut.	Acidity of Whey before breaking.	Time of breaking.	Acidity of Whey put aside.	Time Scalding commences.	First.	Second.	Time taken in stirring.	Time in Scald.	Temperature when drawn.	Acidity.	Acidity of draining from piled Curd.	Time Curd remains piled.
	A.M.		A.M.		A.M.			min.	h. m.				min.
31–1	8.22	·16	8.35	·17	9.40	88	90	75	2 5	87	·22	·29	30
1–2	...	...	...	...	...	...	...	...	...	...	...	...	...
3–3	8.22	·16	8.40	·17	9.35	88	90	60	2 5	86	·23	·33	35
3–4	8.25	·16	8.45	·16	9.40	88	90	60	2 5	87	·24	·53	35
4–5	8.30	·15	8.55	·16	9.50	88	90	60	2 20	87	·22	·33	40
5–6	7.55	·15	8.15	·15	9.10	88	90	60	2 15	86	·21	·30	30
6–7	8.30	·15	8.50	·16	9.50	88	90	60	2 20	86	·21	·28	45
7–8	8.10	·16	8.30	·17	9.34	88	90	60	1 51	87	·21	·27	35
8–9	8.14	·16	8.27	·17	9.30	88	90	60	2 0	87	·23	·30	35
9–10	8.15	·16	8.35	·16	9.32	88	90	60	2 8	86	·23	·34	30
10–11	8.32	·16	8.50	·17	9.44	88	90	60	1 53	87	·23	·32	25
11–12	8.40	·16	8.57	·18	9.52	88	90	60	1 48	86	·22	·30	35
12–13	8.26	·16	8.51	·18	9.51	83	90	60	2 9	85	·21	·34	30
13–14	8.27	·16	8.50	·17	9.51	87	90	60	2 9	82	·23	·35	23
14–15	8.12	·15	8.35	·16	9.35	88	90	60	2 0	84	·20	·24	50
15–16	8.21	·15	8.40	·16	9.45	88	90	60	1 45	87	·21	·26	35
16–17	8.20	·15	8.45	·15	9.49	88	95	90	2 35	89	·27	·43	20
17–18	8.35	·16	8.45	·16	9.40	88	90	60	2 0	86	·21	·26	35
18–19	8.35	·15	8.55	·16	10.0	88	90	60	1 52	86	·22	·28	25
19–20	8.20	·15	8.37	·16	9.33	88	90	60	2 7	86	·23	·29	35
20–21	8.45	·15	9.7	·16	10.5	88	90	60	1 50	86	·22	·27	30
21–22	8·25	·16	8.52	·17	9.47	88	90	47	1 37	86	·23	·30	25
22–23	9.12	·16	9.30	·17	10.25	88	90	60	1 50	85	·22	·28	45
23–24	8.30	·14	8.45	·15	9.40	88	90	60	2 0	87	·21	·27	32
24–25	8.20	·14	8.40	·15	9.40	88	90	71	2 13	88	·22	·32	37
25–26	8.45	·15	9.2	·15	10.7	88	94	20	2 8	92	·23	·45	15
26–27	8.30	·16	8.43	·17	9.45	88	90	45	1 31	88	·25	·35	30
27–28	8.40	·15	9.0	·17	10.0	88	90	47	1 35	87	·23	·34	30
28–29	8.35	·15	8.55	·15	9.57	89	90	45	1 41	86	·23	·34	35
29–30	8.30	·15	8.55	·16	9.54	88	90	45	1 43	87	·22	·33	30
Average	8.28	·15	8·47	·16	9.46	88	90	56	1 59	86	·22	·32	32

OF ENGLAND SOCIETY'S CHEESE SCHOOL, JUNE, 1892—*continued.*

37	38	39	40	41	42	43	44	45	46	47	48	49	
		Acidity of Whey during Treatment of Curd.								Salt Added.			
Time Curd was taken from Tub.	Temperature of Curd when taken from tub.	When taken to Cooler.	After 1st Cutting.	After 2nd Cutting.	After 1st Turning.	After 2nd Turning.	After 3rd Turning.	After 4th Turning.	Acidity of Curd when milled.	Weight.	Percentage.	Temperature of Dairy.	
										lbs. ozs.		min.	max.
12.50	85	·41	·50	·70	·81	·92	...	...	6·20	2 10	2·15	64	67
...	...	...	...	...	...	...	...	...	...	...	...	...	...
12.50	87	·50	·64	·80	·86	·92	1·01	...	7·20	2 9	1·94	62	65
12.55	88	·53	·65	·80	·84	·92	·97	...	4·00	2 11	1·99	61	64
1 20	86	·52	·67	·82	·89	·91	...	..	5·60	2 11	2·05	61	64
12.25	87	·47	·60	·73	·84	·88	·96	...	4·90	2 10	2·01	62	66
1.30	85	·42	·50	·62	·73	·80	·82	...	5·00	2 12	2·06	64	67
12.35	86	·38	·50	·71	·86	·90	·97	...	4·20	2 12	2·08	64	67
12.40	86	·46	·60	·74	·81	·88	·94	...	7·10	2 11	2·05	66	72
12.40	87	·45	·69	·87	·91	·96	...	...	6·30	2 12	2·05	67	72
12.35	87	·53	·68	·82	·91	·96	...	...	4·00	2 10	2·02	66	69
12.50	86	·49	·64	·80	·88	·95	1·04	...	4·40	2 12	2·04	65	67
1.5	86	·46	·60	·75	·39	·98	...	...	5·20	2 12	2·13	63	66
12.55	84	·55	·75	·97	1·09	...	...	...	3·90	2 12	2·02	62	65
1.00	87	·41	·61	·80	·94	1·05	...	...	6·40	2 13	2·07	62	64
12.35	87	·42	·58	·77	·89	·97	1·08	...	5·20	2 12	2·03	62	64
1.15	89	·63	·79	·90	1·01	...	...	...	4·00	2 12	2·07	61	64
12.50	85	·40	·58	·78	·95	1·00	...	...	3·60	2 12	2·03	61	62
12.50	85	·43	·56	·76	·87	·97	1·08	...	{ 3·90 3·80 }	2 11	2·07	61	64
12.45	86	·45	·60	·79	·87	1·01	1·09	...	5·00	2 11	2·05	61	64
1.0	86	·41	·51	·68	·76	·94	1·01	...	3·90	2 10	2·06	62	65
12.25	86	·39	·53	·64	·75	·83	1·03	1·06	4·20	2 15	2·11	62	66
1.30	88	·44	·57	·71	·78	·89	·95	...	6·00	2 14	2·13	63	65
12.50	86	·42	·54	·68	·80	·86	·96	1·00	{ 4·30 4·30 }	2 13	2·11	63	66
1.5	88	·54	·65	·78	·89	· 3	1·00	...	5·30	2 11	2·05	63	66
1.2	87	·57	·67	·75	·83	·96	...	...	...	2 12	2·08	63	67
12.15	88	·57	·71	·80	·92	·99	...	...	4·30	2 10	2·03	66	69
12.55	87	·56	·67	·82	·89	·93	...	...	4·00	2 11	2·09	66	70
12.40	87	·60	·74	·88	·93	...	...	...	4·20	2 8	1·99	66	68
12.35	88	·54	·69	·83	·93	...	...	...	4·00	2 10	1·97	64	67
12.51	87	·48	·62	·78	·87	·93	...	...	4·60	2 11	2·05	63	66

TABLE I.—RECORD OF OBSERVATIONS, JUNE, 1892—*continued.*

	50	51	52	53	54	55	56		57		58		59		60
	RELATING TO CURD.			RELATING TO CHEESES.											
							Temperature of Cheese Room.				Hygrometer Readings.				
							Morning.		Evening.		Morning.		Evening.		
Day of Month.	Temperature in Vat.	Weight when Vatted.	Time of Vatting.	Acidity of liquid from Press.	Weight taken to Cheese Room.	Loss in Press.	Min.	Max.	Min.	Max.	Wet.	Dry.	Wet.	Dry.	Weight of Cheese when sold.
		lbs.	P.M.		lbs.	lbs.									lbs.
31-1	74	128	6.55	1·14	118½	9½	63	68	63	64	62	64	62	64	109½
1-2	...	...	...	...	119	...	..	...	...	...	...	...	...	...	110
2-3	74	132½	5.37	1·21	122	10½	57	63	58	62	58	59½	60	63	112½
3-4	73	135½	6.0	1·21	127	8½	56	61	53	60	56	58	58	60	115
4-5	74	131	5.45	1·16	121½	9½	58	59	58	61	57	59	60	62	112½
5-6	75	130½	5.25	1·18	120	10½	58	61	58	64	58	60	63	65	112
6-7	75	133	9.0	1·18	122	11	60	64	57	62	61	63	59	62	113½
7-8	75	132	8.50	1·15	119½	12½	62	67	58	67	61	63	59	63	112
8-9	77	130½	7.15	1·24	120	10½	62	67	66	74	62	64	70	73	111½
9-10	78	134	4.40	1·18	121	13	67	72	68	74	66	70	71	74	112½
10-11	77	129½	4.55	1·20	118	11½	66	74	66	68	65	67	66	70	109½
11-12	73	134½	6.0	1·20	123½	11	64	68	64	64	63	65	63	65	114½
12-13	74	135	5.30	1·15	125	10	58	64	58	63	58	61	61	64	117
13-14	77	136	4.10	1·10	127½	8½	58	62	58	62	57	59	60	62½	117½
14-15	74	135½	5.50	1·09	126	9½	53	61	56	61	55	58	59	62	117
15-16	74	135½	5.45	1·18	125	10½	57	61	58	59	57	59	58	60	117
16-17	76	132½	4.40	1·14	125	7½	56	58	57	58	56	57½	56	58	113½
17-18	73	135½	5.50	1·13	125½	10	54	59	55	60	55	57	58	61	116½
18-19	72	129½	6.0	1·14	121	8½	54	60	57	62	57	59	58½	61	112
19-20	73	131	5.25	1·16	121½	9½	56	60	54	63	56	58	59	62	113
20-21	72	127	6.30	1·16	117½	9½	56	60	57	59	57	59	59	61	109
21-22	72	139	6.30	1·19	127½	11½	58	60	59	64	58	60	62	64	119½
22-23	73	134½	7.10	1·18	125½	9	60	63	60	62	61	63	60½	62½	115½
23-24	73	133	6.50	1·17	124	9	59	61	57	64	59	61	62½	64	114½
24-25	76	131	6.0	1·14	120	11	60	63	60	64	60	62	62	64	112
25-26	77	132	5.0	1·13	121	11	61	63	61	66	60½	62	65	67	113
26-27	78	129	4.0	1·19	117	12	64	66	64	69	63½	65	68	70	109
27-28	78	135	5.10	1·22	123	12	64	69	62	67	65	67	63	65	112½
28-29	77	125½	4.0	1·16	116	9½	64	69	63	67	65	67	65	67	107
29-30	76	133	3.50	1·13	121	12	61	66	62	65	62	64	62	64	112
...	75	132	5.37	1·16	122	10	60	64	60	64	60	62	61	64	113

RECORD OF ANALYSES—JUNE, 1892.

Day of Month.	Composition of Mixed Milk. Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Composition of Whey. Solids.	Fat.	Ash.	Composition of Curd. Water.	Solids.	Fat.	Ash.
31–1	87·70	12·30	3·26	2·54	·39	5·39	·72	7·02	·34	·55	39·15	60·85	32·17	2·55
1–2	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2–3	87·62	12·38	3·43	2·59	·41	5·21	·74	6·98	·43	·56	41·00	59·00	31·05	2·50
3–4	87·58	12·42	3·36	2·57	·40	5·33	·76	6·98	·36	·56	41·25	58·75	30·37	2·55
4–5	87·76	12·24	3·16	2·55	·39	5·40	·74	6·92	·34	·55	41·55	58·45	29·78	2·60
5–6	87·62	12·38	3·30	2·57	·40	5·39	·72	6·81	·37	·56	40·65	59·35	30·25	2·60
6–7	87·80	12·20	3·13	2·57	·37	5·41	·72	6·84	·40	·56	40·00	60·00	30·47	2·40
7–8	88·08	11·92	3·01	2·78	·38	5·07	·68	6·88	·38	·56	41·25	58·75	29·97	2·40
8–9	87·96	12·04	2·96	2·72	·37	5·23	·76	6·95	·30	·55	41·65	58·35	28·60	2·40
9–10	87·80	12·20	3·09	2·88	·36	5·15	·72	6·90	·27	·57	40·85	59·15	30·97	2·40
10–11	87·60	12·40	3·35	2·77	·37	5·17	·74	6·95	·38	·55	41·85	58·15	29·27	2·40
11–12	87·62	12·38	3·39	2·73	·40	5·12	·74	6·98	·36	·56	41·50	58·50	29·51	2·45
12–13	87·58	12·42	3·36	2·78	·42	5·12	·74	6·97	·37	·57	39·75	60·25	30·94	2·45
13–14	87·64	12·36	3·31	2·69	·39	5·23	·74	7·02	·36	·55	41·60	58·40	29·22	2·40
14–15	87·50	12·50	3·40	2·56	·40	5·38	·76	6·94	·39	·55	41·45	58·55	29·81	2·55
15–16	87·82	12·18	3·16	2·61	·41	5·28	·72	6·89	·26	·56	42·45	57·55	23·08	2·45
16–17	87·96	12·04	3·05	2·56	·39	5·28	·76	6·82	·41	·57	40·80	59·20	29·90	2·45
17–18	87·50	12·50	3·45	2·62	·39	5·32	·72	6·93	·40	·55	41·40	58·60	28·88	2·50
18–19	87·82	12·18	3·13	2·61	·41	5·29	·74	6·91	·34	·53	41·60	58·40	28·18	2·45
19–20	87·96	12·04	3·02	2·50	·40	5·40	·72	6·72	·38	·55	42·40	57·60	28·21	2·35
20–21	87·76	12·24	3·14	2·68	·38	5·28	·76	6·91	·27	·55	42·15	57·85	28·47	2·50
21–22	87·86	12·14	3·08	2·66	·38	5·28	·74	6·97	·29	·56	40·85	59·15	29·35	2·35
22–23	87·98	12·02	3·07	2·62	·39	5·26	·68	7·01	·32	·57	40·85	59·15	29·16	2·45
23–24	88·08	11·92	3·01	2·74	·40	5·03	·74	6·87	·40	·55	41·20	58·80	30·01	2·50
24–25	87·82	12·18	3·18	2·69	·38	5·21	·72	6·91	·32	·54	41·00	59·00	29·40	2·45
25–26	87·96	12·04	3·15	2·69	·41	5·09	·70	6·82	·31	·55	...	...	...	...
26–27	88·24	11·76	2·72	2·70	·40	5·18	·76	6·92	·35	·56	41·10	58·90	29·02	2·40
27–28	87·88	12·12	3·00	2·63	·39	5·40	·70	6·89	·33	·55	40·50	59·50	29·90	2·50
28–29	87·80	12·20	3·15	2·63	·38	5·30	·74	6·94	·33	·55	41·55	58·45	28·09	2·40
29–30	87·96	12·04	3·07	2·64	·40	5·21	·72	6·97	·35	·56	40·65	59·35	29·54	2·45
Average ...	87·80	12·20	3·17	2·65	·39	5·26	·73	6·91	·35	·55	41·14	58·86	29·59	2·46

TABLE 2.—RESULTS OF OBSERVATIONS.—AVERAGE FOR EACH MONTH OF EACH YEAR, 1891—97.

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1890, Cossington; 1897, Ashton.)

1	3	4	5	6	7	8	9		10	11	13	14	15
	RELATING TO EVENING'S MILK.										MORNING'S MILK.		
		At Night.				In Morning.							
MONTH AND YEAR.	Volume of Milk.	Time.	Temperature of Dairy.	Temperature of Milk.	Acidity.	Time.	Temperature of Dairy.		Temperature of Milk.	Acidity.	Volume of Milk.	Acidity.	Total Volume of Milk.
	galls.	p.m	° F.	° F.	per cent.	a.m.	min.	max.	° F.	per cent.	galls.	per cent.	galls.
April 1892	37	6.7	55	81	·18	7.8	52	55	65	·19	44	·17	81
1893	50	6.0	64	83	·18	..	57	65	65	·19	59	·19	109
1894	47	6.51	58	85	·21	7.6	56	59	68	·22	55	·21	192
1895	54	5·48	58	88	·176	6.46	56	59	69	·184	70	·180	124
1890	62	6.20	62	81	·184	6.49	61	69	75	·194	69	·181	131
1897	39	6.13	63	87	·198	..	62	67	73	·207	46	·198	85
Average ..	48	6.13	00	84	·188	6.57	56	62	69	·107	57	·188	105
May 1892	50	6.13	62	82	·21	7.15	60	61	67	·23	50	·20	100
1893	71	6.18	66	87	·18	..	61	66	68	·19	80	·19	151
1894	79	6.35	60	81	·22	7.13	58	60	68	·23	78	·22	148
1895	74	6.7	63	89	·100	6.54	60	93	70	·29	91	·19	165
1896	77	6.38	66	87	·186	6.54	63	66	71	·196	89	·177	166
1897	59	0.17	03	88	·185	..	66	63	73	·186	70	·184	129
Average ..	67	6.21	63	86	·195	7.4	60	04	70	·206	78	·102	145
June 1892	00	6.2	04	87	·22	7.10	62	65	66	·23	67	·21	127
1893	71	6.8	69	89	·18	..	64	70	70	·19	78	·18	149
1894	68	6.44	94	82	·21	7.5	62	64	69	·22	72	·21	140
1895	89	9.35	67	86	·20	0.54	65	67	72	·21	89	·19	169
1896	72	6.44	68	88	·172	6.51	66	69	73	·185	85	·166	157
1897	62	6.44	66	80	·170	..	65	07	71	·178	69	·108	131
Average ..	69	6.29	66	87	·192	7.0	64	67	71	·292	77	·187	146
July 1802	56	6.43	65	87	·21	7.18	63	66	69	·23	60	·21	116
1893	61	6.5	74	96	·18	..	67	75	72	·19	69	·17	136
1894	64	7.0	66	84	·21	7 6	64	67	70	·22	65	·20	129
1895	66	6.38	66	88	·26	6.57	65	67	73	·21	77	·19	143
1896	73	7.16	68	87	·196	6.47	67	69	72	·298	69	·190	142
1897	51	7.31	68	87	·146	..	66	68	71	·157	52	·144	103
Average ..	62	6.52	68	87	·100	7.2	65	69	71	·202	65	·184	127
Aug. 1861	39	5.47	64	89	·22	6.45	64	..	68	·24	52	·22	91
1892	47	6.31	66	87	·21	7.2	64	66	69	·23	53	·21	100
1893	68	6.28	71	89	·19	..	67	73	73	·20	75	·19	143
1894	55	7.15	65	82	·22	7.5	64	66	76	·22	58	·20	113
1895	56	6.7	65	88	·20	7.6	63	65	73	·22	78	·26	134
1896	62	6.54	68	86	·182	6.33	66	68	72	·196	57	·177	119
1897	47	7.40	68	89	·149	..	60	79	74	·154	44	·146	91
Average ..	53	6.40	67	87	·196	6.53	65	68	71	·208	60	·192	113
Sept. 1891	36	6.6	61	89	·21	7.0	60	63	70	·22	43	·21	79
1892	39	6.21	61	84	·21	7.15	60	62	68	·23	45	·22	84
1893	51	0.34	70	87	·18	..	63	71	68	·19	61	·18	112
1894	48	7.2	63	83	·22	7.10	62	64	69	·23	52	·22	100
1895	52	6.10	65	89	·20	7.2	64	66	74	·22	64	·20	116
1896	36	6.44	67	83	·180	6.50	66	67	74	·192	46	·177	82
1897	38	6.28	05	89	·162	..	62	65	74	·171	51	·159	89
Average ..	43	6.29	65	86	·194	7.3	62	65	71	·207	52	·195	95
Oct. 1891	24	5.50	58	86	·21	7.8	54	59	67	·21	28	·21	52
1892	26	6.2	66	76	·21	7.34	60	65	63	·22	32	·21	58
1893	38	6.5	62	84	·19	..	57	63	65	·20	45	·19	83
1894	34	6.43	64	79	·22	7.19	61	66	70	·23	40	·21	74
1895	36	6.17	64	84	·19	7.15	61	65	73	·26	45	·19	81
1896	27	6.49	65	89	·185	7.23	63	66	71	·26	37	·181	64
1897	34	6.12	62	87	·167	..	60	62	71	·176	48	·164	82
Average ..	31	6.17	63	82	·196	7.20	59	64	69	·205	39	·194	70

TABLE 2.—RESULTS OF OBSERVATIONS.—AVERAGE FOR EACH MONTH OF EACH YEAR, 1891—97.

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1896, Cossington; 1897, Ashton.)

	16	17	18	19	20	21	22	23	24	25	26	27
	MILK, HEATED.		STALE WHEY.		MIXED MILKS, &c.							
							Rennet added.					
MONTH AND YEAR.	Quantity.	To Temperature.	Quantity.	Acidity.	Acidity before Renneting.	Time of Renneting.	Volume.	Proportion.	Time when Curd cut.	Acidity of Whey before breaking.	Time of breaking.	Acidity of Whey put aside.
	galls.	° F.	galls.	Per cent.	Per cent.	a.m. h. m.	ozs.		a.m.	Per cent.	a.m.	Per cent.
April 1892	32	90	4·0	·34	·18	7.47	1·44	9031	8.41	·13	9.5	·11
1893	37	88	2·5	·40	·19	7.30	1·89	8997	8.22	·13	8.46	·14
1894	47	88	1·0	·40	·22	8.0	1·83	9006	8.48	·15	9.13	·16
1895	29	90	1·8	·34	·182	7.42	2·75	7483	8.35	·13	9.0	·14
1899	02	87	1·0	·34	·190	7.38	2·61	8000	8.33	·132	8.54	·156
1897	34	82	1·5	·43	·213	7.38	1·70	8000	8.27	·14	8.49	·152
Average ..	40	87	..	·37	·106	7.43	2·04	8110	8.34	·135	8.58	·148
May 1892	30	89	4·0	·40	·22	7.46	1·90	9135	8.31	·16	8.51	·16
1893	42	87	1·5	·40	·19	7.26	2·68	8995	8 20	·12	8.40	·13
1894	61	90	1·0	·30	·22	7.56	2·63	9011	8.41	·15	9.3	·16
1895	39	87	1·0	·49	·20	7.43	4·99	6194	8.32	·13	8.57	·11
1896	90	84	..	..	·189	7.34	3·32	8000	8.29	·137	8.50	..
1897	29	80	..	..	·187	7.34	2·85	7185	8.32	·122	9.5	·132
Average ..	45	87	..	·40	·201	7.40	2·09	8087	8.30	·136	8.55	·144
June 1892	35	87	4·0	·44	·22	7.30	2·16	9403	8.28	·15	8.47	·16
1893	36	88	1·0	·39	·19	7.20	2·60	9109	8.5	·12	8.29	·13
1894	57	87	1 9	·37	·22	7.42	2·51	8939	8.35	·14	8.54	·15
1895	40	83	1·0	·37	·20	7.45	4·31	6339	8.34	·13	9.1	·14
1890	59	83	..	..	·175	7.37	3·14	8000	8.28	·140	9.2	..
1897	31	82	1·5	·35	·175	7.32	3·50	0005	8.28	·121	8.58	·15
Average ..	43	85	..	·38	·197	7.36	3·04	7966	8.26	·133	8.51	·15
July 1892	33	89	3·0	·46	·22	7.46	1·97	9419	8.37	·15	9.3	·16
1893	28	85	1·0	·35	·18	7.18	2·37	8816	8.15	·12	8.39	·12
1894	49	86	1·0	·39	·22	7.42	2·14	8940	8.31	·15	8.54	·15
1895	48	89	..	..	·29	7.33	3·67	6010	8.28	·13	8.57	·13
1896	50	84	..	..	·198	7.23	2·84	8000	8.20	·146	9.3	..
1897	20	84	1·5	·39	·156	7.40	2·76	6005	8.34	·106	8.58	·11
Average ..	30	85	..	·40	·106	7.34	2·56	7865	8.27	·134	8.56	·13
Aug. 1891	21	84	4·0	·46	·24	7.29	1·70	8567	8.16	·10	8.40	·17
1892	34	87	2·0	·45	·23	7.45	1·73	9423	8.38	·15	9.25	·16
1893	29	84	..	..	·20	7.38	2·59	8817	8.31	·12	8.55	·13
1894	43	87	1·0	·36	·22	7.36	2·01	8821	8.37	·14	9.3	·15
1895	53	79	..	..	·21	7.36	3·59	6007	8.24	·14	8.50	..
1896	45	86	..	..	·185	7.15	2·41	8900	8.11	·138	8.54	..
1897	29	81	..	..	·150	7.40	2·42	5993	8 27	·195	8.54	·10
Average ..	36	84	..	·42	·205	7.34	2·35	7947	8.25	·136	8.54	·14
Sept. 1891	18	85	2·5	·44	·22	7.31	1·37	9269	8.18	·15	8.43	·16
1892	38	85	2·0	·44	·23	7.49	1 45	9302	8.36	·15	9.4	·16
1893	34	89	1·0	·42	·19	7.47	2·03	8818	8.42	·12	9.10	·12
1894	40	88	1·0	·34	·23	7.48	2·92	8024	8.36	·15	9.15	·19
1895	52	80	..	..	·21	7.34	3·19	6006	8.22	·14	8.48	·14
1899	39	85	..	..	·185	7.38	1·64	8000	8.24	·134	8.54	..
1897	34	79	2·0	·35	·169	7.53	2·30	6003	8.41	·110	9.13	·122
Average ..	36	84	..	·40	·205	7.43	1 99	7917	8.31	·136	9.1	·144
Oct. 1891	14	88	2·0	·41	·21	7.34	·91	9235	8.29	·13	9.8	·14
1892	36	90	2·0	·41	·22	8.5	1·04	9041	8.54	·14	9.27	·15
1893	32	87	2·0	·35	·20	7.45	1·51	8825	8.37	·12	9.1	·13
1894	32	90	1·0	·37	·22	8.23	1·74	6871	9.11	·14	9.33	·15
1895	30	86	2·0	·31	·20	7.46	2·18	6002	8.35	·13	9.8	·13
1896	29	89	..	..	·189	8.9	1·29	8000	9.0	·139	9.38	..
1897	34	81	1·0	·35	·172	8.0	2·18	6004	8.50	·116	9.17	·125
Average ..	30	87	..	·37	·201	7.57	1·55	7711	8.48	·131	9.19	·137

TABLE 2.—RESULTS OF OBSERVATIONS.—AVERAGE FOR EACH MONTH OF EACH YEAR, 1891—97.

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1896, Cossington; 1897, Ashton).

Month and Year.	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	45a	46
	Time Scalding commences.	Temperature of Scalds. 1st.	Temperature of Scalds. 2nd.	Time taken in stirring.	Time in Scald.	Relating to Whey. Temperature when drawn.	Relating to Whey. Acidity.	Relating to Whey. Acidity of drainings from piled Curd.	Time Curd remains piled.	Time Curd was taken from Tub.	Temperature of Curd when taken from Tub.	Acidity of Whey during Treatment of Curd. When taken to Cooler.	After 1st cutting.	After 2nd cutting.	After 1st turning.	After 2nd turning.	Acidity of drainings from Curd before grinding.	Acidity of Curd when Milled.
	a.m.	° F.	° F.	min.	h.m.	° F.	Per cent.	Per cent.	min.	h.m.	° F.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
April 1892	10.0	88	90	52	1.56	86	·17	·22	47	1.10	86	·35	·62	·61	·75	·85	·85	4·00
1893	9.40	88	92	39	1.45	88	·16	·21	34	12.29	89	·34	·46	·76	·85	·91	·93	3·11
1894	10.14	88	93	40	1.43	00	·19	·25	34	12.51	80	·38	·52	·68	·72	·75	·82	9·06
1895	9.51	88	92	39	1.34	90	·16	·22	22	12.12	89	·33	·49	·71	·86	·93	·94	..
1896	0.36	88	92	43	1.44	90	·169	·247	29	12.21	88	·38	·59	·80	·90	..	·90	..
1897	0.38	83	92	38	1.30	91	·183	·271	16	11.40	90	·30	·56	·78	·02	·94	·93	1·74
Average.	9.51	88	92	42	1.43	89	172	·236	30	12.27	88	·36	·54	·72	·83	·87	·90	..
May 1892	9.51	88	00	55	1.49	86	·20	·26	44	12.57	86	·40	·50	·65	·79	·83	·92	5·24
1893	9.43	88	92	33	1.32	89	·17	·23	29	12.14	89	·35	·50	·69	·82	·89	·94	2·70
1894	10.1	88	94	37	1.38	91	·20	·28	26	12.36	91	·46	·66	·85	·92	·96	1·00	4·6
1895	9.49	88	92	36	1.29	90	·17	·23	25	12.5	91	·35	·53	·72	·75	·83	·92	·92
1896	9.52	88	93	48	1.43	91	·207	·301	24	12.22	91	·42	·59	·75	·84	·93	·92	1·00
1897	10·1	88	92	50	2.10	89	·164	·237	42	1.15	89	·41	·59	·77	·86	·94	·92	1·32
Average.	9.53	83	02	43	1.43	89	·185	·256	32	12.35	89	·40	·56	·74	·83	·90	·94	..
June 1892	9·46	88	90	56	1.59	86	·22	·32	32	12.51	87	·48	·62	·78	·87	·93	·99	4·60
1893	9.25	88	94	27	1.28	91	·19	·29	29	11.54	92	·46	·60	·75	·87	·87	·94	2·97
1894	9.46	88	94	36	1.31	92	·18	·27	28	12.11	93	·45	·62	·81	·84	·86	·92	..
1895	9.54	88	92	44	1.35	90	·16	·23	30	12.20	91	·36	·48	·62	·72	·84	·90	·90
1896	9.48	88	93	52	1.49	92	·223	·329	12	12.9	91	·42	·58	·73	·83	..	·85	·97
1897	9.51	88	93	40	1.30	02	·173	·26	10	11.54	92	·36	·54	·71	·84	..	·92	1·27
Average.	9.45	88	93	42	1.39	90	·191	·283	23	12.13	91	·42	·57	·73	·83	·88	·92	..
July 1892	10.3	88	90	37	1.29	88	·21	·29	41	12.38	88	·52	·71	·88	·01	·93	1·00	4·66
1893	9.37	88	94	48	1.59	91	·19	·27	23	12.25	92	·40	·55	·71	·81	..	·86	..
1894	9.40	88	04	35	1.28	92	·18	·27	24	12.0	92	·47	·63	·73	·80	·86	·03	..
1895	9.47	88	92	43	1.33	90	·17	·25	22	12.4	90	·39	·58	·78	·87	·83	·95	·95
1896	9.51	88	93	52	1.45	91	·203	·304	16	12.12	91	·40	·60	·77	·80	·98	·03	1·01
1897	0 51	88	04	51	1.21	91	·169	·28	16	12.28	91	·37	·50	·66	·80	·88	·92	1·15
Average.	9.48	88	93	44	1.36	90	·187	·277	24	12.18	·91	·42	·59	·77	·83	·89	·93	..
Aug. 1891	0.36	88	93	39	1.43	90	·25	·35	20	..	..	·48	·63	·76	·83	·88	·93	3·25
1892	9.58	88	91	37	1.23	87	·21	·39	41	12.31	89	·53	·68	·84	·84	..	·88	4·47
1893	9.48	88	94	42	1.43	92	·18	·26	27	12·28	02	·45	·62	·77	·86	..	·90	..
1894	9.53	88	94	27	1.19	92	·17	·23	34	12.14	91	·39	·54	·70	·82	·84	·90	..
1895	9 39	88	94	34	1.20	91	·18	·27	20	11.58	92	·39	·54	·73	·77	·84	·83	·89
1896	9.37	88	93	47	1.41	91	·178	·23	27	12.15	91	·38	·55	·73	·77	·87	·09	·95
1897	9.46	88	94	42	1.35	93	·164	·26	8	11.49	93	·39	·55	·72	·85	·89	·01	1·15
Average.	9.45	88	93	38	1.32	91	·190	·271	27	12.12	91	·43	·59	·75	·82	·86	·91	..
Sept. 1891	9.33	88	94	53	1.43	91	·23	·36	26	12.7	91	·53	·63	·75	·82	·93	·90	3·94
1892	9.58	88	90	35	1.22	87	·20	·26	42	12.30	88	·48	·67	·87	·87	..	·91	4·69
1893	10.0	88	94	41	1.39	02	·18	·27	31	12.37	02	·42	·60	·75	·86	·88	·91	..
1894	9.55	88	94	30	1.20	91	·19	·23	27	12.9	91	·39	·53	·69	·78	·84	·90	..
1895	9.35	88	94	43	1.36	91	·20	30	16	11.46	91	·42	·59	·77	·86	·89	·92	·92
1896	9.41	88	94	58	1.58	92	·201	·318	17	12.19	92	·43	·03	·81	·86	·89	·93	·92
1897	10.7	88	95	37	1.25	93	·178	·27	10	12.3	93	·35	·52	·70	·82	·88	·93	·90
Average.	0.50	88	03	42	1.35	91	·197	·287	24	12.13	01	·40	·59	·76	·84	·88	·92	..
Oct. 1891	10 0	88	92	60	1.54	90	·22	·35	33	12.47	90	·52	·51	·72	·87	·94	1·01	3·20
1892	10.19	88	90	39	1.27	86	·19	·24	40	12.51	87	·42	·55	·70	·79	·83	·90	4·10
1893	9.54	88	92	36	1.28	90	·20	·27	26	12.18	92	·39	·59	·74	·87	·93	·94	..
1894	10.16	88	94	35	1.24	91	·18	·21	31	12.36	92	·37	·53	·69	·81	·86	·94	..
1895	9.54	88	94	46	1.30	91	·18	·26	39	12.29	91	·44	·59	·74	·89	·92	·93	·03
1896	10.24	89	94	49	1.52	91	·199	·271	30	12.59	91	38	·57	·74	·78	·94	·99	·90
1897	10.10	88	05	40	1.25	93	·197	·28	7	12.3	03	·35	·49	·67	·81	·89	·93	·87
Average.	10.8	88	03	43	1.35	90	·105	·273	29	12.39	91	·41	·55	·71	·83	·90	·95	..

TABLE 2.—RESULTS OF OBSERVATIONS.—AVERAGE FOR EACH MONTH OF EACH YEAR, 1891—97.

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1896, Cossington; 1897, Ashton).

	47	48	49		50	51	52	53	54	55	56		57		58		59		60
	Salt Added.		Temperature of Dairy.		Relating to Curd.			Relating to Cheeses.											
											Temperature of Cheese Room.				Hygrometer Reading.				
											Morning.		Evening.		Morning.		Evening.		
Month and Year.	Weight.	Percentage.	Minimum.	Maximum.	Temperature in Vat.	Weight when Vatted.	Time of Vatting.	Acidity of Liquid from Press.	Weight taken to Cheese Room.	Loss in Press.	Min.	Max.	Min.	Max.	Dry.	Wet.	Dry.	Wet.	Weight of Cheese when sold.
	lbs oz				° F.	lbs.	p.m.	Per cent.	lbs.	lbs.									lbs.
Apr. 1892	1 11	2·15	54	60	67	77	6.58	1·08	71	6	48	56	49	58	52	49	56	53	68
1803	2 3	2·07	59	68	76	106	4.34	1·08	98	8	60	63	60	63	62	59	64	61	91
1894	2 1	2·12	57	62	72	109	5.18	1·05	101	8	52	57	53	58	55	53	57	55	96
1895	2 13	2·07	58	60	72	132	4.32	1·11	124	8	..	..	..	..	65	62	67	65	116
1896	2 14	2·10	62	65	76	134	3.43	1·01	126	8	54	58	55	58	55	52	58	54	118
1897	1 14	2·11	62	67	74	89	2.27	1·08	84	5	57	74	58	67	58	55	58	55	78
Average.	2 4	2·10	59	04	73	108	4.35	1·07	101	7	54	62	55	61	58	55	60	57	95
May 1892	2 5	2·07	61	06	72	110	7.31	1·18	102	8	56	64	55	64	58	56	62	59	94
1893	3 2	2·06	63	70	76	155	4.57	1·02	141	14	04	60	64	66	65	62	67	64	131
1894	3 5	2·04	59	64	75	162	4.0	1·08	148	14	55	60	57	64	59	56	63	60	140
1895	3 13	2·07	61	66	75	183	4.15	1·12	171	12	63	66	63	67	63	61	66	63	160
1806	3 6	2·16	64	70	77	175	4.39	1·01	164	11	62	66	62	66	63	60	66	63	157
1897	2 14	2·19	60	65	76	132	4.41	·98	123	9	58	65	59	65	60	57	66	62	112
Average.	3 2	2·10	61	67	75	153	5.0	1 06	142	11	60	64	60	65	61	59	65	62	132
June 1892	2 11	2·05	63	66	75	132	5.37	1·16	122	10	60	64	60	64	62	60	64	61	113
1893	3 4	2 13	65	72	78	151	3.41	1·01	138	13	66	68	66	68	67	64	69	66	129
1894	3 4	2·11	63	67	77	153	3.52	·99	141	12	60	65	61	66	61	60	66	64	132
1895	3 12	2·14	65	69	76	170	4.57	1·09	164	12	65	70	66	70	66	62	70	66	152
1896	3 10	2·16	67	72	79	167	3.40	·96	155	12	65	68	66	68	66	64	68	66	145
1897	2 15	2·22	65	71	79	133	3.8	·98	124	9	63	65	64	65	64	62	65	64	113
Average.	3 4	2·13	65	69	77	152	4 9	1·03	141	11	63	67	64	67	64	62	67	65	131
July 1892	2 9	2·04	64	07	76	127	4.53	1·18	115	12	62	65	02	66	64	62	65	63	108
1893	2 12	2·09	68	77	81	131	4.45	·89	122	9	68	71	68	74	70	66	75	67	116
1894	2 13	2·08	04	69	77	141	4.0	1·02	131	10	63	66	63	67	65	63	66	65	124
1895	3 3	2·07	65	70	79	156	3.22	1·12	145	11	63	68	63	69	65	60	68	63	135
1896	3 3	2·09	67	73	79	153	3.56	1·00	142	11	64	68	65	68	64	65	69	67	137
1897	2 5	2·23	66	71	78	104	4.10	·93	98	6	65	66	65	67	05	63	67	65	90
Average.	2 13	2·10	66	71	79	135	4.11	1·02	125	10	64	67	64	68	65	63	68	65	118
Aug. 1891	2 3	2·09	..	..	75	104	4.47	1·07	99	5	62	66	62	06	62	60	64	61	91
1892	2 4	2·00	64	69	76	112	4.8	1·14	102	10	63	67	63	67	67	65	66	65	94
1893	3 3	2·14	69	77	81	149	4.14	·90	138	11	67	69	67	71	70	66	70	67	131
1894	2 9	2 00	64	68	75	128	5.6	1·04	118	10	02	64	62	65	63	62	65	64	112
1895	3 3	2·11	64	69	78	151	2.50	1·09	141	10	02	65	63	66	63	61	66	63	133
1896	2 12	2·05	66	73	77	134	5.0	·90	124	10	63	65	63	65	64	63	65	64	119
1897	2 1	2·20	67	72	80	91	2.13	·89	85	6	04	66	65	67	66	65	67	66	77
Average.	2 8	2·09	66	71	77	124	4.2	1·01	115	9	63	66	03	67	65	63	67	64	108
Sept. 1891	1 15	2·13	..	..	74	92	5.30	1·10	88	4	61	66	61	66	63	61	62	60	82
1892	2 0	1·99	61	64	75	99	3.33	1·07	91	8	58	60	58	61	60	58	61	60	85
1893	2 8	2·02	65	74	78	124	4.34	·94	115	9	66	69	66	68	68	65	68	64	109
1894	2 7	2·03	62	65	74	120	5.13	1·02	112	8	62	65	62	67	63	62	65	64	106
1895	2 13	2·06	64	68	78	136	3.39	·98	128	8	03	66	63	66	64	60	66	63	122
1896	2 0	2·16	66	71	78	97	3.45	1·01	90	7	61	62	61	62	62	61	63	62	83
1897	2 0	2·12	63	67	76	94	4.0	·83	90	4	59	62	60	63	61	60	63	62	84
Average.	2 4	2 07	63	68	76	109	4.25	·99	102	7	61	64	62	65	63	61	64	62	96
Oct. 1891	1 7	2·06	..	..	70	68	6.24	1·22	64	4	55	60	55	60	57	56	59	57	00
1892	1 8	2·09	01	67	72	72	5.34	1·11	68	4	55	62	55	62	58	55	61	59	62
1893	2 2	2·06	59	66	74	104	4.1	·95	97	7	58	60	58	61	60	57	60	58	91
1894	1 15	2·02	62	60	74	94	5.0	1·04	87	7	58	65	60	67	60	58	65	63	82
1895	2 2	2·06	61	61	74	104	5.40	1·01	97	7	58	63	58	00	59	57	60	57	92
1896	1 12	2·22	63	68	74	79	5.38	·90	71	5	57	58	56	58	58	57	59	58	70
1897	1 14	2·08	59	64	74	90	3.50	·81	87	3	55	59	55	58	50	55	58	57	82
Average.	1 10	2·08	61	63	73	87	5.15	1·01	82	5	56	61	57	01	58	50	60	58	77

TABLE 3.—RESULTS OF ANALYSES.—AVERAGE FOR EACH MONTH OF EACH YEAR 1891–97.

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1896, Cossington; 1897, Ashton.)

Month and Year.	Composition of Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
April 1892	88·25	11·75	3·06	2·35	·40	5·28	·66	7·00	·31	·54	42·04	57·96	28·82	2·54
1893	88·11	11·89	3·09	2·43	·33	5·35	·69	6·89	·37	·55	40·81	59·19	29·43	2·15
1894	87·69	12·31	3·29	2·42	·41	5·52	·67	7·08	·24	·44	40·03	59·97	28·28	2·45
1895	87·35	12·65	3·70	2·43	·41	5·37	·74	7·40	·34	·48	41·40	58·60	32·27	2·13
1896	87·25	12·75	3·83	2·43	·39	5·46	·63	7·48	·32	·45	40·66	59·33	32·05	1·78
1897	87·26	12·74	3·87	2·45	·42	5·29	·71	7·23	·42	·46	42·01	57·99	30·00	2·08
Average ...	87·65	12·35	3·47	2·42	·40	5·38	·68	7·18	·33	·49	41·16	58·84	30·14	2·19
May 1892	87·96	12·04	3·12	2·55	·40	5·25	·72	6·95	·38	·55	42·48	57·52	29·49	2·49
1893	87·99	12·01	3·05	2·59	·37	5·32	·68	6·86	·33	·53	41·23	58·77	28·29	2·29
1894	87·48	12·51	3·35	2·73	·40	5·33	·70	7·05	·17	·46	40·28	59·72	27·53	2·59
1895	87·42	12·58	3·39	2·60	·41	5·45	·73	7·24	·25	·44	41·14	58·86	29·78	2·15
1896	87·22	12·78	3·70	2·64	·35	5·41	·67	7·21	·25	·43	40·72	59·28	30·64	2·05
1897	87·45	12·55	3·65	2·48	·38	5·33	·71	7·19	·44	·43	41·95	58·05	28·57	2·25
Average ...	87·59	12·41	3·38	2·60	·38	5·35	·70	7·08	·30	·48	41·30	58·70	29·05	2·30
June 1892	87·80	12·20	3·17	2·65	·39	5·26	·73	6·91	·35	·55	41·14	58·86	29·59	2·46
1893	87·97	12·03	3·08	2·65	·35	5·30	·65	6·77	·31	·55	40·54	59·46	29·68	2·28
1894	87·48	12·52	3·40	2·69	·40	5·31	·72	7·28	·21	·52	40·12	59·88	29·62	2·41
1895	87·44	12·56	3·51	2·58	·41	5·34	·72	7·20	·31	·42	40·95	59·05	29·70	2·14
1896	87·41	12·59	3·57	2·64	·36	5·36	·67	7·12	·21	·44	41·33	58·67	29·88	1·83
1897	87·63	12·37	3·50	2·43	·38	5·35	·71	7·08	·45	·52	42·58	57·42	28·12	2·26
Average ...	87·62	12·38	3·37	2·61	·38	5·32	·70	7·01	·31	·50	41·11	58·89	29·43	2·23
July 1892	87·80	12·20	3·21	2·66	·39	5·22	·72	6·87	·34	·55	41·82	58·18	29·17	2·34
1893	87·86	12·14	3·20	2·49	·34	5·43	·68	6·68	·38	·55	40·24	59·76	29·89	2·38
1894	87·48	12·52	3·47	2·64	·39	5·30	·72	7·15	·23	·49	40·38	59·62	31·45	2·28
1895	87·32	12·68	3·60	2·67	·40	5·29	·72	7·16	·28	·43	41·04	58·96	31·10	2·03
1896	87·39	12·61	3·66	2·58	·35	5·34	·69	7·17	·25	·49	42·07	57·93	30·87	2·01
1897	87·54	12·46	3·61	2·35	·37	5·41	·72	7·02	·51	·54	41·40	58·60	30·53	2·17
Average ...	87·57	12·43	3·46	2·56	·37	5·33	·71	7·01	·33	·51	41·16	58·84	30·50	2·20

TABLE 3.—RESULTS OF ANALYSES.—AVERAGE FOR EACH MONTH OF EACH YEAR 1891-97—*continued.*

(The locality of the Cheese School in each year was as follows:—1891, Vallis; 1892, Axbridge; 1893, Butleigh; 1894, Mark; 1895, Haselbury; 1896, Cossington: 1897, Ashton.)

Month and Year.	Composition of Milk.							Composition of Whey.			Composition of Curd.			
	Water.	Solids.	Fat.	Casein.	Albumin.	Sugar.	Ash.	Solids.	Fat.	Ash.	Water.	Solids.	Fat.	Ash.
Aug. 1891	87·39	12·61	3·87	2·76	·37	4·84	·77	6·94	·33	·60	40·91	59·09	28·58	2·06
1892	87·72	12·28	3·38	2·65	·37	5·20	·68	6·86	·32	·54	42·25	57·75	29·49	2·16
1893	87·86	12·14	3·19	2·77	·34	5·17	·67	6·59	·35	·55	41·02	58·98	28·76	2·32
1894	87·22	12·78	3·70	2·76	·40	5·17	·75	7·13	·32	·46	40·33	59·67	30·06	2·26
1895	87·18	12·82	3·80	2·68	·41	5·18	·75	7·13	·23	·43	41·14	58·86	31·17	2·13
1896	87·27	12·73	3·82	2·66	·36	5·18	·71	7·00	·34	·50	41·65	58·35	31·09	1·93
1897	87·46	12·54	3·66	2·38	·35	5·42	·73	7·05	·53	·54	41·42	58·58	30·57	2·17
Average ...	87·44	12·56	3·63	2·67	·37	5·17	·72	6·96	·34	·52	41·25	58·75	29·96	2·15
Sept. 1891	87·00	13·00	4·13	2·99	·41	4·69	·78	7·00	·34	·62	40·85	59·15	28·93	2·02
1892	87·44	12·56	3·57	2·87	·41	5·05	·66	6·78	·33	·53	42·17	57·83	29·49	2·14
1893	87·47	12·53	3·53	2·95	·36	5·01	·68	6·75	·39	·54	40·96	59·04	29·04	2·31
1894	86·95	13·05	3·93	2·83	·42	5·07	·80	7·21	·23	·47	40·94	59·06	29·81	2·20
1895	86·97	13·03	3·94	2·91	·42	5·00	·76	7·18	·27	·42	41·28	58·72	29·91	2·05
1896	86·81	13·19	4·31	2·71	·38	5·06	·73	7·03	·34	·54	40·57	59·43	32·85	1·88
1897	87·11	12·89	3·86	2·59	·38	5·34	·72	7·08	·43	·54	41·90	58·10	29·39	2·12
Average ...	87·11	12·89	3·90	2·83	·40	5·03	·73	7·00	·33	·52	41·24	58·76	29·92	2·10
Oct. 1891	86·19	13·81	4·75	3·21	·47	4·61	·77	6·91	·44	·61	40·43	59·57	27·01	1·78
1892	86·87	13·13	4·00	3·08	·51	4·84	·70	6·89	·34	·55	41·66	58·34	30·06	2·25
1893	86·51	13·49	4·30	3·14	·46	4·92	·67	6·76	·45	·55	40·88	59·12	29·87	2·34
1894	86·54	13·46	4·39	2·95	·44	4·85	·83	7·27	·21	·45	40·58	59·42	30·19	2·25
1895	86·30	13·70	4·55	2·92	·44	5·01	·78	7·21	·20	·43	41·05	58·95	31·05	2·12
1896	86·62	13·38	4·41	2·85	·40	5·02	·70	7·13	·33	·51	41·40	58·60	31·69	2·05
1897	86·78	13·22	4·18	2·71	·44	5·14	·75	7·13	·44	·51	41·30	58·70	29·41	2·10
Average ...	86·54	13·46	4·37	2·98	·45	4·92	·74	7·04	·34	·51	41·04	58·96	29·90	2·13

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