XXX. *On the Changes in Composition of the Milk of a Cow, according to its Exercise and Food.* By LYON PLAYFAIR, Ph.D., Honorary Member of the Royal Agricultural Society of England.

Read 17th January, 1843.

AS the principal object of this paper is to draw the attention of practical men to the conditions which effect a change in their dairy produce, it has been written in a more elementary form than would have been done, had its purpose merely been to communicate facts to scientific chemists. The object of the Chemical Society is to examine the applications of chemistry to practice, as well as to assist in the advancement of the abstract science. Many difficulties occur in the pursuits of a dairy farmer, which render his occupation precarious. Such difficulties arise entirely from an ignorance of the scientific relations of the practice in which he is engaged. I have endeavoured in the following paper to point out the causes which so often effect changes in the nature of his produce.

Boussingault and Lebel* instituted some experiments, with the view of proving that the composition of milk remains constant, when the food given to the cow contains the same amount of nitrogen: and their analyses established this fact, as far as regarded the casein in the milk; although its other ingredients varied very considerably, according to the nature of the food. The mean of eight analyses described in the first part of their memoir, gives the following composition for the milk of a cow:—

Casein	3·2
Butter	4·1
Sugar	5·1
Ashes	0·2
Water	87·4

The method employed by these chemists in their analyses did not differ from that used by Peligot in his examination of the milk of the ass†.

It consisted in treating the solid residue of a known weight of milk with æther, and afterwards with water. The loss in weight, after washing with æther, was estimated as butter,

* *Ann. de Chim. et de Phys.* lxxi. 65.

† *Ibid.* lxii. 432.

while that experienced by a similar treatment with water indicated the quantity of sugar; the dried insoluble residue being casein. The latter was incinerated, in order to obtain the ashes of the milk.

There is an error in this method of analysis, which seems to have escaped the attention of Boussingault and Lebel. It consists in the neglect of the inorganic matters dissolved by the water. In washing with water the mixture of casein and sugar, all the soluble salts of the milk are dissolved. The insoluble salts remain in the residual casein, and these alone were obtained by its incineration, whilst those dissolved by the water were neglected. Consequently, in the analyses of Boussingault, the quantity of sugar in the milk is always too high, and that of the inorganic ingredients too low.

The method of analysis employed in this paper was, with a few modifications, the same as the above. A weighed portion of milk, to which a few drops of acetic acid had previously been added, was evaporated to dryness at the heat of boiling water (212°). The solid residue was digested with æther, thrown upon a weighed filter, and well washed with hot æther. The mixture of sugar and casein remaining on the filter being again dried at 212° , indicated by its loss in weight the quantity of butter dissolved by the æther. The æthereal solution itself was evaporated to dryness, and consisted of butter with colouring matter, more or less intense, according to the character of the food. The mixture of casein and sugar was washed with hot water, and the casein remaining on the filter, after being dried at 212° , was weighed, then incinerated, its ashes determined and deducted from the weight of the casein. The solution of sugar, being evaporated by a heat of 212° , yielded a residue consisting of sugar of milk and of the soluble salts of the milk. This residue, after being weighed, was incinerated and its ashes determined. These, deducted from the weight of the residue, yielded the amount of sugar, and added to the ashes of the casein, indicated the total amount of inorganic ingredients in the milk. The ashes of the filter were of course subtracted.

The cow which was made the subject of the following experiments is of the breed of short horns. I am not aware of the number of days since she was delivered of her last calf. When the experiments were instituted, she was in good milking condition. In order to estimate the average amount of her milk, I measured it for several days previous to the experiments. During this time she subsisted upon after-grass; the meadow being about half a mile distant from the cow-house.

		Morning's milk.		Evening's milk.
October 5	.....	5 quarts	.....	4½ quarts
... 6	.....	5	.....	4
... 7	.....	4½	.....	5
... 8	.....	5	.....	4
... 9	.....	5½	.....	4

The weather was fine for the period of the year; but the nights being rather cold, on the evening of the 7th I directed that the cow should be driven to the house, and remain there during the night. In the morning it was put out to grass, but brought back in the evening. On the evening of the 9th I commenced the analyses, and followed them up in consecutive days. In every case the specimen of milk analysed was taken from the milk-pail, after the cow had been thoroughly milked, and the milk well stirred. This precaution was necessary, because the separation of the cream from the milk takes place in part in the udder of the cow. Hence the milk last drawn from the udder contains much more cream than that first obtained*.

1st day. The cow, fed in the meadow upon after-grass during the day, was driven home to the cow-house in the evening. The milk then obtained amounted to four quarts. A portion of this was subjected to analysis.

Specific gravity of milk, 1034.

11·128 grammes of milk gave—	In 100 parts.
Casein	·611 5·4
Butter	·404 3·7
Sugar of milk . .	·429 3·8
Ashes	·068 0·6
Water	9·616 86·5
	11·128 100·0

During the day the cow had considerable exercise. Before being milked, it had half a mile to walk from the meadow. The nourishment in after-grass being small compared with fresh grass, the animal had to eat a greater quantity than it otherwise might have done, and consequently had to traverse more ground in order to procure it. The exercise which it thus received, by increasing the number of its respirations, must have occasioned a greater supply of oxygen to the system. This oxygen, as we shall afterwards show, unites with the butter and consumes it; consequently less butter is

* Schübler says that the milk last drawn contains three times as much cream as that first procured.

Dr. Anderson (Dickson's Practical Agriculture, vol. ii. p. 999) found the cream in the last cup of milk drawn from the udder, compared with that of the first cup, in the proportion of 16 to 1.

contained in the milk of the cow than would have been the case had its pasture been rich grass.

But, after being removed into the shed, less oxygen was respired, and the warmth of the house was equivalent to a certain amount of unazotised food*. The animal received nothing to eat during the night, and therefore the milk of the morning must have been derived from the after-grass consumed during the day. This milk measured four and a half quarts.

Specific gravity, 1032.

15·280 grammes yielded—	In 100 parts.
Casein 0·610	3·9
Butter 0·864	5·6
Sugar of milk. . 0·468	3·0
Ashes 0·091	0·5
Water 13·247	87·0
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	15·280 100·0

The butter, as we might have expected, is in larger proportion than in the previous analysis. The amount of casein is smaller.

We shall defer the consideration of the causes which produce a variation in the quantities of the latter constituent.

2nd day. The object of this day's experiment was to discover whether an increase of butter would be procured by feeding the cow with after-grass in the stall. It refused, however, to eat this food, and being removed from its companions, struggled for several hours to regain its liberty. To render it tranquil, a companion was introduced into the same stall, and it was then induced to consume 28 lbs. of good hay and $2\frac{1}{2}$ lbs. of oatmeal. The milk of the evening measured $3\frac{1}{2}$ quarts.

Specific gravity, 1031.

22·684 grammes yielded—	In 100 parts.
Casein 1·124	4·9
Butter 1·150	5·1
Sugar 0·867	3·8
Ashes 0·137	0·5
Water 19·406	85·7
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	22·684 100·0

The milk of the morning amounted to 4 quarts; but, owing to an accident, was not analysed.

3rd day.—A. The cow was kept in the shed, and consumed 28 lbs. of hay, $2\frac{1}{2}$ lbs. of oatmeal, and 8 lbs. of bean-flour. The milk of the evening amounted to 4 quarts = 10·34 lbs.

* In this paper we take for granted that the leading features of Liebig's *Animal Physiology* are acknowledged as true.

Specific gravity, 1034.

23·160 grammes gave—		In 100 parts.
Casein . . .	1·262	5·4
Butter . . .	0·905	3·9
Sugar of milk	1·112	4·8
Ashes . . .	0·136	0·5
Water . . .	19·745	85·4
	<u>23·160</u>	<u>100·0</u>

B. The quantity of milk obtained in the morning amounted to $4\frac{1}{2}$ quarts = 11·61 lbs.

Specific gravity, 1032.

19·445 grammes of milk gave—		In 100 parts.
Casein . . .	0·758	3·9
Butter . . .	0·888	4·6
Sugar . . .	0·877	4·5
Ashes . . .	0·129	0·7
Water . . .	16·793	86·3
	<u>19·445</u>	<u>100·0</u>

4th day.—A. The cow, kept in the stall as before, received this day 24 lbs. of potatoes (steamed), 14 lbs. of hay, and 8 lbs. of bean-flour. She gave in the evening 5 quarts of milk = 12·9 lbs.

Specific gravity, 1033.

17·820 grammes of milk gave—		In 100 parts.
Casein . . .	0·707	3·9
Butter . . .	1·190	6·7
Sugar of milk	0·815	4·6
Ashes . . .	0·104	0·6
Water . . .	15·004	84·2
	<u>17·820</u>	<u>100·0</u>

B. The milk of the morning amounted to 4 quarts = 10·32 lbs.

Specific gravity, 1032.

19·641 grammes of milk yielded—		In 100 parts.
Casein . . .	0·535	2·7
Butter . . .	0·978	4·9
Sugar of milk	0·991	5·0
Ashes . . .	0·116	0·5
Water . . .	17·021	86·9
	<u>19·641</u>	<u>100·0</u>

5th day.—A. The cow, kept as before, consumed 14 lbs. of hay and 30 lbs. of potatoes (steamed). She gave in the evening $5\frac{1}{8}$ quarts of milk = 13·18 lbs.

Specific gravity, 1030.	
18·141 grammes of milk yielded—	In 100 parts.
Casein . . . 0·716	3·9
Butter . . . 0·845	4·6
Sugar of milk 0·713	3·9
Ashes . . . 0·099	0·5
Water . . . 15·768	87·1
18·141	100·0

B. The milk of the morning amounted to $4\frac{3}{4}$ quarts
= 12·20 lbs.

Specific gravity, 1030.	
16·740 grammes yielded—	In 100 parts.
Casein . . . 0·600	3·5
Butter . . . 0·835	4·9
Sugar . . . 0·648	3·8
Ashes . . . 0·082	0·5
Water . . . 14·575	87·3
16·740	100·0

Before proceeding to the consideration of these experiments, it is necessary that we should examine the composition of the various kinds of food given to the cow. The cow received, during the course of the experiments, grass, oatmeal, hay, beans, and potatoes. The following analysis exhibits the composition of these various substances.

	Hay.	Oats.	Beans.	Potatoes.
	Boussingault.	Boussingault.	Playfair.	Boussingault.
Carbon . .	38·47	41·57	38·24	12·30
Hydrogen . .	4·20	5·25	5·84	1·74
Oxygen . .	32·51	30·10	33·10	12·04
Nitrogen . .	1·26	1·80	5·00	0·32
Ashes . .	7·56	3·28	3·71	1·40
Water . .	16·00	18·00	14·11	72·20

In a specimen of beans analysed by Boussingault, only 4 per cent. of nitrogen was found. But in the bean-flour, which I used in the experiments, there was as much as 5 per cent. It is obvious that if we multiply the quantity of nitrogen by $6\frac{1}{3}$, the product will be the amount of casein or albumen in the various kinds of food; and further, by deducting this, together with the water and ashes, the remainder must indicate the quantity of unazotised matter.

Albumen or casein. Unazotised matter.	
Hay . .	7·81
Oats . .	11·16
Beans . .	31·00
Potatoes . .	1·98
	68·63
	67·56
	51·18
	24·42

Finally, according to Liebig, good hay contains 1·56 per cent. of a fatty or waxy substance. Braconnot found 0·70 per

cent. of a similar substance in beans. Vogel found 2 per cent. in oats, and Liebig 0·3 per cent. in potatoes.

Dumas, in an announcement to the French Academy, has lately advanced the theory, that the fat of animals is wholly derived from the fatty matter contained in their food. This opinion has been very ably combated by Liebig, who refers to an analysis of milk executed by Boussingault, and shows that much more butter was contained in it than could be accounted for by the fat in the food taken. As the theory of the formation of fat is of the first importance in the practice of dairy farming, we will shortly examine Dumas's theory with reference to the preceding experiments.

1. On the 2nd day the cow received 28 lbs. of hay, which contains 0·436 lb. of fat and $2\frac{1}{2}$ lbs. of oatmeal, containing 0·050 lb. of the same constituent. The cow produced (calculating according to its specific gravity) about 19 lbs. of milk, in which was 0·969 lb. of butter. But the food altogether contained only 0·486 lb. of fat, so that 0·483 lb. of butter must have been produced from other sources.

2. The food received by the cow on the 3rd day consisted of 28 lbs. of hay, $2\frac{1}{2}$ lbs. of oatmeal, and 8 lbs. of bean-flour.

28 lbs. of hay contain . . .	0·436 lb. of fat.
$2\frac{1}{2}$ lbs. of oatmeal contain . .	0·050 lb. of fat.
8 lbs. of beans contain . . .	0·056 lb. of fat.
In the food . . .	0·542 lb. of fat.

The milk of the evening amounted to 10·34 lbs., and contained 0·4 lb. of butter; that of the morning to 11·61 lbs., and contained 0·5 lb. of butter. The butter in the milk amounted, therefore, to 0·9 lb., of which only 0·542 lb. could possibly have been furnished by the food, assuming that the fat in the food could be converted into butter.

3. The cow received on the 4th day 14 lbs. of hay, 8 lbs. of beans, and 24 lbs. of potatoes.

14 lbs. of hay contain . . .	0·218 lb. of fat.
8 lbs. of beans contain . . .	0·056 lb. of fat.
24 lbs. of potatoes contain . .	0·072 lb. of fat.
	<hr/> 0·346

The evening's milk amounted to 12·9 lbs., and contained 0·86 lb. of butter; that of the morning to 10·32 lbs., and contained 0·50 lb. The cow, therefore, furnished during the day 1·36 lb. of butter. The fat in the food amounted only to 0·346 lb., and therefore 1·064 lb. must have been received from other sources.

4. On the 5th day the cow received 14 lbs. of hay and 30 lbs. of potatoes.

14 lbs. of hay contain . . .	0·218 lb. of fat.
30 lbs. of potatoes contain . .	0·090 lb. of fat.
	<u>0·308</u>

The milk of the evening amounted to 13·18 lbs., and contained 0·606 lb. of butter; that of the morning to 12·20 lbs., containing 0·597 lb. of butter. The cow, therefore, furnished 1·203 lb. of butter. The fat in the food amounted only to 0·308 lb. Hence 0·895 lb. of butter must have been produced from other sources.

From these calculations it must be obvious, that the butter in the milk could not have arisen solely from the fat contained in the food. Hence it must have been produced by a separation of oxygen from the elements of the unazotised ingredients of the food of the animal, in the manner pointed out by Liebig.

We remark striking variations in the quantity of butter in the preceding analysis, and a similar result occurred in the experiments of Boussingault. In the milk of the first day there is a small amount of butter. The cow had been exposed in the field during the day, and hence required a greater quantity of unazotised food to support the heat of its body than would have been necessary had it been protected from the cold. But in the evening it was removed into a warm and well-littered stall, where the warmth thus communicated was equivalent to a certain amount of food; and hence we find, that the milk of the morning was considerably richer in butter. It is uniformly found to be the case, that a stall-fed cow yields more butter in its milk than one fed in the field. Besides the warmth of the shed, less butter is consumed by the oxygen of the air. In the stall the respirations of an animal are much less frequent than in the field, and consequently less oxygen enters into its system. The great care of all dairy farmers is to prevent an excess of this gas from entering the body. Hence the practice of milking in the field those cows which are distant from home, and of driving home to be milked only such cows as are close to the shed. The exercise required in walking home causes an increased play of the respiratory system, and therefore increases the amount of oxygen inspired. This oxygen unites with part of the butter and consumes it. The greatest care is taken by all good dairymen to allow the cows to walk home at their own pace, and never to accelerate it. By this means only a small amount of oxygen enters the system. When a cow is harassed and runs to escape from the annoyance, its milk becomes very much heated, diminishes in volume and in richness, and speedily becomes sour. This is a fact well known to all dairymen. During running the cow respires a large quantity of oxygen. This unites with the butter, and the

heat evolved by its combustion elevates the temperature of the milk and evaporates part of its water. The acetous fermentation is also induced, and cannot be restrained. For this reason cows are not turned into the fields in very hot weather, when the flies are apt to annoy them and produce restiveness. During such weather, it is not an uncommon practice to feed the cows in the stall during the day and turn them out to grass at night. By this means they are kept tranquil, and prevented from respiring a large amount of oxygen. There cannot be any doubt that the practice of stall-feeding cows during winter or in cold weather must conduce very much to the formation of butter; but in summer, when the pastures are rich and near the dairy, the slight exercise which they receive increases their health, and with it their appetite. They are thus induced to eat more food than they would do in the stall, and they consequently receive a greater flow of milk. The loss experienced by the greater absorption of oxygen is more than compensated for by the increased appetite of the animal.

In these experiments it will be remarked, that potatoes were favourable both to the flow of milk and formation of butter. This quite accords with practical experience. They abound in starch, and therefore furnish the substance from which butter is formed. The increase of butter in the milk of the fourth day is very striking; on this day 24 lbs. of potatoes formed part of the food. The butter is also in large quantity in the milk of the fifth day, though not so much so as in that of the fourth, though 6 lbs. of potatoes in excess were consumed. In these 6 lbs. of potatoes only $1\frac{1}{2}$ lb. of dry unazotised matter were furnished, which could not compensate for 8 lbs. of beans (containing 4 lbs. of dry unazotised matter) which had formed part of the diet of the preceding day. The result is, therefore, exactly as might have been anticipated. When the food contained much starch, the sugar of milk increased in quantity as well as the butter. The large amount of butter in the milk of the second day is singular, and makes us regret the accident which happened to the milk of the morning and prevented its analysis. A remark has often been made to me by practical men (how far it is true I know not), that the milk of the morning is generally richer than that of the evening. As far as the limited number of analyses here given warrants any conclusion, there would seem to be some accuracy in this observation. The cause that it should be so is apparent: during the day, when exercise is taken, the number of respirations is frequent, and a large amount of oxygen enters the system—this is unfavourable to the formation of butter; but at night, during sleep, the respirations

are slow, and the amount of oxygen respired is trifling. Such a condition must favour the separation of oxygen from starch to supply the deficiency.

All practical experience is against the theory of Dumas, regarding the formation of butter in milk, and of fat in cattle. In Scotland the system of stall-feeding cows is carried to a great extent. The Glasgow dairymen feed their cows in warm stalls, giving them malt refuse, a few pounds of beans, steamed turneps and potatoes, and as much pot ale (residuum after distillation, commonly called wash) as they will drink. The malt refuse consists of starch, gum, and a little saccharine matter, but it is not known to contain fat. This refuse is the principal food, and is very favourable to the production of butter, evidently from its great excess of unazotised matter. The beans furnish the nitrogenous matter, in which the other foods are deficient; and as they contain casein ready formed, they assist in the formation of the milk. Their value is fully appreciated by all Scotch dairymen, although their use is little known in this country. The pot ale contains sugar and alcohol, and therefore contributes to sustain the heat of the body. It thus enables the other food to be formed into butter. But its principal use seems to be in diluting the secretions. Pure water does not readily enter the blood; we know that it destroys the blood-globules. But acid water does not do so, and this pot ale is generally very acid. Hence it dilutes the secretions. The great object, therefore, in this kind of feeding, is to give the cows as much unazotised food as possible; and the food which is preferred, consists of those very kinds in which fat exists in the least proportion. Porter and beer are well known to be favourable to the production of butter in the milk both of women and of cows; yet these fluids do not contain fat. We are, therefore, justified in asserting that practice is opposed to the theory of Dumas, but highly favourable to that propounded by Liebig.

During stall-feeding we have it in our power to alter the composition of milk, even with respect to the casein. Thus in the second day the cow received in its food $2\frac{1}{2}$ lbs. of albumen, or of a substance of the same composition (28 lbs. of hay, $2\frac{1}{2}$ lbs. of oatmeal). It produced 19 lbs. of milk, in which was 0.93 lb. of cheese. The next day it received 5 lbs., or double the quantity, of albumen in its food, and the milk, which amounted to 22 lbs., contained 1 lb. of casein*. Still theory would have led us to anticipate a larger increase than actually took place. The circumstance which favoured the production of casein in the milk of the first day will afterwards be considered.

* Calculated according to the composition of the evening's milk, as that of the morning had not been analysed.

The cow received in the food given on the fourth day, 4 lbs. of casein and albumen (14 lbs. hay, 8 lbs. beans, 24 lbs. potatoes), and yielded 23·22 lbs. of milk, which contained 0·75 lb. of casein. The fifth day she received considerably less albumen in her food, viz. 1·7 lb. (14 lbs. hay and 30 lbs. potatoes), but the amount of casein in the milk, though in less per centage than before, was equal in amount to the other, from there being a greater flow of milk. The milk amounted to 25 lbs., of which about 0·94 lb. was casein. Here, although the food did not contain much casein, it was such as to induce a great flow of milk, and the casein must have been derived from the albumen of the blood. Had the cow been continued on this food, there cannot be a doubt that the quantity of casein in the milk must either have diminished, or the cow must have lost condition in giving this substance at the expense of its tissues.

The value of these experiments is certainly very much diminished by not being extended over a series of days on each kind of food. But in England, where the price of æther is so exorbitantly high, the expense of such experiments is a serious consideration for a private individual. As they were conducted under the same conditions with respect to temperature and exercise, an indication of the effects produced by the various foods must have been obtained, although the final effects have escaped detection.

Neglecting the second day, in which an abnormal increase of casein was produced by an accidental circumstance, we find the milk of the third day contained 5·4 per cent. of casein, that of the fourth 3·9 per cent., and of the fifth also 3·9 per cent. The food consumed on the third day contained a very large amount of casein, and this was immediately followed by an increased amount in the milk. Some peculiar cause favoured the flow of milk on the fifth day, in spite of the small quantity of albumen in the food; the milk derived its casein from other sources. The milk of the second day contained 4·9 per cent. of casein, while that of the fourth day possessed only 3·9 per cent. of the same constituent, although on that day the cow had received 4 lbs. of albumen in its food, and on the former day only one half or 2 lbs.

Such are the changes which constantly occur to the dairy farmer, and cause variations in the value of his milk, even when the conditions of feeding seem to be the same. It is for us to determine to what these seemingly discordant results are due.

In experiments such as these, we must remember that the animal body is not a mere chemical laboratory, in which a chemist may operate as he pleases. But there is a power,—

vitality,—superior to his, and it is only by its concurrence that the changes which he desires are effected.

Now, on the second day the animal struggled violently to regain its liberty, and consequently expended much matter in the production of force. It is difficult to conceive that any waste of tissues can take place, without an alteration in their chemical composition. Still we cannot deny (in the present state of our knowledge) that an alteration in form might effect a waste, as well as a change in composition. We know little or nothing of the nature of secretion. All we know is, that certain glands have the power of appropriating particular parts of the organism or of food, and of producing fluids, which either perform some new functions in the system, or are separated from it; but we are entirely ignorant how these secretions are produced. Scherer has indeed pointed out that albumen may be converted into casein by digestion with caustic potash; and it is possible that this may be the process employed to form it in the organism. On this view, we might suppose that the waste of the tissues operated indirectly in its production. By their waste their alkaline constituents are liberated, and might act upon the albumen of the blood by converting it into casein. Be this as it may, there are many facts which induce us to believe that the waste of the tissues does favour the production of casein in the milk. The milk of a cow, fed in the stall, is not only absolutely but relatively poorer in casein than one fed in the field, where exercise increases the transformation of its tissues. During parturition all the muscles are thrown into a violent state of action. As the labour in a cow continues for many hours, there must be a great waste of tissues in the production of the force necessary to occasion these muscular exertions. Such being the case, if our view be correct there ought to be in the milk of a cow, immediately after parturition, an abundance of casein: and every one knows that such milk is quite thick with cheese. We are indebted to Boussingault for an analysis of the milk of a cow before the calf had been allowed to suck. He found it to contain as much as 15 per cent. of casein, while the milk of the same cow analysed a few days after its calving contained only 3 per cent. of the same substance; therefore only one-fifth the quantity*. If then the waste of the tissues tends, directly or indirectly, to increase the amount of casein

* It might be objected to the view given, that the analysis of this milk indicates a very small amount of inorganic ingredients. Boussingault found only 0.3 per cent. To this it may be answered, that the alkalies which favoured the formation of casein are soluble, and therefore were neglected in Boussingault's analysis, by being included along with the sugar of milk. (*Ann. de Ch. et de Phys.* lxxi. p. 72.)

in the milk, then we are at no loss to understand why the milk of the second day should be unusually rich in casein.

Beans contain 31 per cent. of casein ready formed. Hence it is that they have been found so practically useful in aiding the formation of the milk.

The conditions necessary for the production of casein in the milk, are different from those which are favourable to the formation of butter. When butter is the principal object desired, the cow cannot be put upon too rich pastures. But in all cheese districts, it is agreed that *poor* land is best adapted for cheese. Land is called poor, not when the grass is deficient in nitrogenous bodies, but in constituents destitute of nitrogen. The "equivalent," as farmers term it, is higher; that is, the cattle are compelled to eat a greater quantity of poor than of rich grass, in order to sustain animal heat. They have also to traverse more ground to procure their food; this causes an increased respiration of oxygen and waste of the tissues. Hence the appetite of the animal is increased, and a larger quantity of food is consumed. If the view already given be correct, the waste of the tissues aids in the supply of casein to the milk. One great object in cheese-farms is to induce the cows to eat a large quantity of food, and for this purpose, in large farms, they are tempted with new pastures every day. The Cheddar, Cheshire and Stilton cheeses contain a considerable quantity of butter. In a celebrated cheese-farm, a few miles from Bridgewater, where Cheddar cheese is made in great perfection, I found it to be the practice (a prevalent one, I believe) to drive the cows in the morning to the pastures on dry sandy soil, and in the evening to those situated on soft peaty soil. The grass of the sandy soil being poor, the cows traversed considerable ground in procuring it. They therefore eat a quantity more than they would have done on rich land, where there is little exertion required in taking the food. By this means a large quantity of cheese was procured in the milk. But during the night they were allowed to feed on rich pastures, fitted for the formation of butter, and as the darkness prevented them from wandering, little oxygen was respired to consume the butter formed, or to prevent its formation. The milk of the evening and morning being always mixed together in the preparation of the cheese, a proper proportion of both constituents was thus procured. In districts where inferior cheeses are manufactured, that is, in which the farmer depends upon his butter as much as upon his cheese, he is ignorant of the value of poor land. Thus it is that there is occasionally a contradiction amongst dairymen with respect to this point, though there is

none with those who depend wholly on their cheese, and care little for the butter, except as a means of enriching the former.

Chevallier's analysis of woman's milk (the only one of which I am aware) indicates a very small quantity of butter. As attention to diet and exercise must be very important to nurses, when we consider the trivial causes which produce a variation in the composition of milk, I was desirous of ascertaining whether the quantity of butter could be made greater than in the analysis given by Chevallier. Accordingly I selected a farmer's wife, a strong healthy female of twenty-eight years of age, who had been delivered of her third child. On the 19th day after her confinement she remained in bed, and thus diminished the amount of oxygen respired, and was then fed upon gruel (oatmeal and water). On the 21st sufficient milk for analysis was procured.

23·945 grammes yielded—

Casein	0·3695	1·54
Butter	1·0315	4·30
Sugar of milk . .	1·3770	5·75
Ashes	0·1270	0·53
Water	21·0400	87·88
	23·9450	100·00

The butter in this milk was therefore quite equal to that in the milk of a cow. As the diet thus influences the composition of the milk, may not the frequent occurrence of ricketty children in the higher classes of life be due to the circumstance of the mothers living principally upon white bread—bread, therefore, from which phosphates have been in a great measure removed? Had the woman been at her usual exercise, it must of course have diminished. The milk of a woman possesses a very sweet taste, and is remarkable for its great amount of sugar of milk. In this and in other respects it closely resembles that of the ass. The following analyses exhibit the composition of the milk of various animals :—

	Woman.		Ass.		Cow.		
	Henry and Chevallier*.	Playfair†.	Peligot‡.	Henry and Chevallier*.	Bous-singault§.	Henry and Chevallier*.	Playfair||.
Casein	1·52	1·54	1·95	1·82	3·2	4·48	4·0
Butter	3·55	4·30	1·29	0·11	4·1	3·13	4·6
Sugar of milk	6·50	5·75	6·29	6·08	5·1	4·77	3·8
Ashes	0·45	0·53	..	0·34	0·2	0·60	0·6
Water	87·98	87·88	90·47	91·65	87·4	87·02	87·0

* *Journal de Pharmacie*, xxv. 333 et 401.

† *Suprà*.

‡ *Ann. de Ch. et de Phys.* lxii. 432.

§ *Ann. de Ch. et de Phys.* lxxi. 65.

|| Average of analyses of the milk of a cow in the field.

Before concluding this paper, I take the opportunity of making a few remarks to *practical men* on the mode of preserving milk, as this is a subject on which questions have been often sent to me.

Milk consists of casein, of sugar of milk, and of certain salts dissolved in water, in which are suspended little globules of fat or butter. These globules are surrounded by a shell or skin, which is supposed (by Otto) to be coagulated casein. The soluble casein, being a nitrogenous body, is very apt to run into putrefaction. In summer it does not do so readily, because the temperature being elevated, the sugar of milk is converted apparently into grape sugar by the agency of lactic acid, then into alcohol, and the alcohol into acetic acid. These changes are induced by a primary action of oxygen upon the casein. This action is then imparted to the other constituents, the atoms of which being once set in motion, readily undergo the changes described. The acetic acid being formed by the agency of air on the alcohol, acts upon the soluble casein and coagulates it, or renders it insoluble. It is thus removed from the action of the oxygen of the air, and may be kept for some time without entering into putrefaction. Such are the changes which milk undergoes in summer, but they are quite different in winter.

In winter the first action is that of oxygen upon the casein. The temperature is not sufficiently elevated to cause vinous fermentation. The decay of the casein generally passes over to putrefaction, that is, the atoms are transformed more rapidly than they unite with oxygen. A putrid smell now arises.

Good butter cannot be made from milk which has undergone this change. The cause is, that butter always contains a certain quantity of casein which it is difficult to remove. When incipient putrefaction has taken place, it cannot be arrested by ordinary means, and imparts itself to the bodies with which it is in contact. It is for this reason that the greatest part of the butter manufactured in winter has a rank putrid taste.

The principal object in view in the preservation of milk in winter, is to prevent the commencement of this putrefaction. One method has been termed *scalding* the milk, and is generally used in dairies. It consists in heating the milk until the oxygen of the air acts upon the casein, and forms a pellicle on its surface. The milk should then be left to perfect repose. The pellicle excludes the air from the soluble casein. The partial oxidation by which the pellicle was produced, is effected at too high a temperature to enable the decay to pass into putrefaction. When this operation is skilfully performed,

the milk remains quite good for four or five days. But there is a risk of failure in this process, and it is only adapted for small dairies.

The best method, which I have seen used in practice with much success, seems to be to induce the acetous fermentation in the milk. For this purpose, the cream or milk, being placed in a proper vessel, should be surrounded with hot water. The heat which I find to answer best is from 100° to 110° . A cloth may be thrown over the whole to retain the heat, and as the water cools, it should be removed and replenished with hot water of the above temperature. In a few hours the cream acquires the smell and taste of vinegar. The changes which I have described above ensue. In large dairies a portion of this soured cream or milk may be added to fresh cream or milk, which should be kept in a room possessing a temperature of 60° . By adding this soured cream to the fresh milk, we furnish an acid, by which the sugar of milk is converted into grape sugar. The curd then acts upon the grape sugar, and converts it into alcohol. The latter by oxidation becomes acetic acid, and thus the whole mass of milk is rendered sour, the casein coagulated, and therefore protected from immediate putrefaction. The butter made from such soured milk is quite sweet and destitute of that rank taste which distinguishes our winter from summer butter. But if incipient putrefaction has once begun in the milk, all this will be of no avail, because it is communicated to the insoluble casein. Milk perfectly fresh must therefore be used. Fresh milk soured in this way will last for many days, and give risings of cream for a considerable time. This practice, as far as I am aware, is not a general one, though it is well worthy of adoption. In summer of course no such operation is requisite, as it is done at a sacrifice of the skimmed milk. One great cause of the putrefaction in milk is the want of absolute cleanliness in the dairy. If a drop of milk fall on the table, it should be dried and washed off with care, for its putrefaction causes the evolution of a putrid gas, and this *imparts* its state of putrefaction to the remainder of the milk.

With respect to making butter, scientific explanations can be of little use to practical men. The theory of churning is very simple. By agitation, the globules of butter are broken, and made to unite together into a mass. The introduction of air during churning, aided by the heat at which the cream or milk is, occasions the formation of lactic or acetic acid, and this coagulates the casein, and thus assists the separation of the butter. In summer, when the heat prevents the ready coherence of the butter, a quantity of cold spring water thrown

in, after the buttermilk has formed, often effects the desired end. The temperature is thus depressed, the butter rendered solid and more coherent, while the air contained in the water aids in the formation of acid and coagulation of the casein. The only thing, in a scientific point of view, to attend to after the separation of the butter, is to free it from buttermilk or casein. If the casein be suffered to remain, putrefaction ensues, and the butter acquires a rank putrid taste. Its separation is therefore of the first moment.

The cause of the superiority of certain foreign butter, which retains its flavour and taste for a considerable time, is more due to its freedom from casein than to any mystery in its mode of preparation.