I. MILK—ITS MILK SUGAR, CONDUCTIVITY AND DEPRESSION OF FREEZING POINT.

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In this paper the results of the application of measurements of the electrical conductivity, percentage of milk sugar and depression of freezing point will be discussed chiefly from the standpoint of the physiology of milk.

In fact the measurements were obtained rather as the basis from which to draw certain deductions and interpretations, than as data for the identification and characterisation of different milks.

This latter work has already been accomplished and it is only necessary to give a brief survey of it in so far as it bears upon the subject matter of this paper.

Depression of freezing point.

The average depression of freezing point of cows' milk as found by 10 independent workers [Koepppe, Sommerfeld, 1909, p. 147] lies between 0.552° and 0.572° . In a recent paper Pins [1912] gives results of a large number of determinations of the depression of freezing point of the milk of 40 different cows, in which he finds that the largest proportion of the values obtained lie between 0.556° and 0.560° .

In the milk of sick animals higher values are often obtained [Schnorf, 1905, Pins, 1912].

The constancy of the depression of freezing point in normal milk is insisted upon by Guiraud and Lasserre [1904]. Parmentier [1903] points to the constancy of Δ even in milk from inflamed quarters of the udder. Schnorf [1905] draws attention to the constancy of the conditions determining the osmotic pressure of the milks from different quarters of the udder, and notes that the two fore-quarters and two hind-quarters go together.

H. Dreser [1892], in discussing the osmotic condition of different body fluids, lays stress on the closeness of the depression of freezing point of milk ($\Delta = 0.57$) to that of the blood ($\Delta = 0.58$ to 0.59). This osmotic equilibrium between the blood and milk is again emphasised by J. Winter [1895].

Rennet coagulation of milk has no effect on the depression of freezing point according to Hotz [1902] but boiling the milk slightly diminishes it.

The depression of freezing point of human milk shows greater individual variations than that of cows' milk, and Koeppe believes this to be due to variations in the salt content of the food. Strauss [1900] however denies that alterations in the food affect the depression of freezing point of the milk.

The following values have been given for human milk:

Koeppe	$\Delta 0.495$ to 0.630
Barthe [1904]	$\Delta 0.590$ to 0.610
Villejean [1905]	$\Delta 0.535$ to 0.615
Grassi [1906]	$\Delta 0.540$ to 0.740

Electrical conductivity.

In contrast with the relative constancy of the depression of freezing point of the milk of mammals, the specific conductivity shows greater variations, although under normal conditions the value for the conductivity in any one species does not vary to any large extent.

The following averages are given by different authors:

Cows' milk.

Koeppe [Sommerfeld, 1909, p. 149]	K at $25^{\circ} \text{C.} = 0.0043 - 0.0056$
Lehnert [1897] and Koeppe [1898]	" " $= 0.00487 - 0.00551$
Binaghi [1910]	" " $= 0.00494 - 0.00517$
Schnorf [1905]	" " $= 0.00485$

Goats' milk.

Binaghi [1910]	" " $= 0.00470 - 0.00499$
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Human milk.

K at $18^{\circ} \text{C.} = 0.00149 - 0.00843$

Friedrich Petersen [1904], examining cows' milk, notes that the first drawn portions have a lower electrical resistance (higher conductivity) than the last drawn portions.

He notes that the resistance diminishes (i.e. conductivity increases) at the end of lactation. Also, in colostrum the resistance is less. He finds no proportionality between specific gravity and electrical resistance or total solids and resistance, but mentions a general proportionality to the ash though there is no direct relationship.

H. Hotz [1902] notes that milk whey has a higher conductivity than milk itself, due to removal of the caseinogen. C. Schnorf in his book

mentions a rise of 10–17% in the conductivity when the caseinogen is removed by rennet. The caseinogen mechanically obstructs the carriage of electricity by the moving ions.

Differences in the conductivity of milk from different quarters are assigned to different amounts of non-electrolytes.

In small milk yields the conductivity is higher, and he notes the high conductivity of colostrum except in the very early stages, where the large amount of protein depresses the conductivity.

He also mentions the uniformly high values obtained for the conductivity in udder inflammations.

A paper by Bugarsky and Tangl [1898] will be referred to later on in connection with the effect of protein upon conductivity. They find 1 gram of protein per litre to depress the conductivity 0.25%. The experiments were conducted:

(a) By dialysing blood serum for two months till free from salts, and using this serum concentrated as a means of adding different amounts of protein to 0.8% salt solution.

(b) By dialysing 15 to 25 c.c. blood serum against 150 to 250 c.c. water until equilibrium was established and then noting the higher conductivity of the fluid outside the dialysing tube as compared with that inside the tube, and estimating the percentage of protein in the latter fluid.

Milk sugar.

The sugar from the milk of the cow, sheep, goat, mare, ass, dog and woman is lactose [Déniges, Bonmartini, Sommerfeld, 1909, p. 193]. The existence of a different sugar has from time to time been assumed owing to discrepancies between the reduction and polarimetric methods of estimation.

Scheibe [1901] has however shown that making due allowance for errors in both methods the results obtained do not differ. Consequently the conclusions of Schmöger, V. Raumer and Spath, and Landolph [Sommerfeld, 1909, p. 194] that another sugar is present in addition to lactose are unfounded. That the milk sugar is diminished in amount in milk from inflamed quarters of the udder is well known [J. Bongert, Sommerfeld, 1909, p. 555].

METHODS EMPLOYED.

Depression of freezing point. The Beckmann apparatus was used with an additional outer jacket and a mechanical stirrer. The determinations were made upon milk samples from which the greater part of the fat had been

removed by centrifugalisation. The experimental work was carried out as advised in a paper by Dekhuyzen.

Electrical conductivity. Kohlrausch's method was employed. It is very simple and can be very quickly carried out. For these reasons it is specially suited to the examination of milk.

The Wheatstone's bridge consisted of a wire wound on a cylindrical drum, with a sliding contact, operated by revolving the drum. The electrodes of the conductivity cell were replatinised at intervals and the cell standardised from time to time with a specially prepared solution of potassium chloride. All determinations were made at exactly 25°C. For all the measurements to be quoted in the present paper the cream was separated from the milk before the determinations were made.

Milk Sugar. The method selected was to determine the optical rotation of the filtrate after precipitating the milk proteins with Wiley's acid mercuric nitrate solution. This solution is made by dissolving mercury in twice its weight of nitric acid of specific gravity 1.42 and adding an equal volume of water after solution is completed.

In the case of cows' milk 3 c.c. of the reagent are necessary per 100 c.c. of milk, but in the milk of smaller animals with 7% protein or more 6 or 7 c.c. are necessary. It had to be assumed that the volume of precipitate formed was equivalent to the volume of Wiley's reagent added. Undoubtedly this assumption was not always correct and therefore slight experimental errors are present in the estimations, and milks from different species of animals do not show strictly comparable sugar determinations. This criticism does not, however, apply to the milks of the same animal, and here the sugar estimations are relatively to one another highly accurate.

Milk samples always had the fat removed before being used, and in the case of small amounts of milk very rich in protein (cat and dog) the samples were diluted with an equal volume of water before being precipitated by the Wiley's reagent. A Schmidt and Haensch triple field polarimeter was the instrument employed for taking the rotations.

THE INVERSE PROPORTIONALITY OF MILK SUGAR AND SALTS.

The substances in milk which are chiefly responsible for its osmotic pressure are the milk sugar and soluble salts. The osmotic pressure of milk is, however, dictated by the osmotic condition of the blood, or in other words the conditions governing the osmotic pressure of the milk (as measured by the depression of freezing point) are to be sought in a fluid of fairly uniform

composition, whose osmotic condition is kept constant by the action of the kidneys.

This explains the constancy of the depression of freezing point in milk, and it follows that the substances in milk chiefly responsible for this physical manifestation cannot vary independently, but must be inter-related.

If the milk sugar is high the salts must be low, otherwise the osmotic pressure would be unusually high, and conversely, if the milk sugar is low the salts must be high or the osmotic pressure would be lower than normal.

Tables giving collected analyses of the milk of different species of animals, such as the following table quoted from Droop Richmond's *Dairy Chemistry*, do, as a rough generalisation, show an inverse proportionality between milk sugar and salts.

Animal	Sugar	Ash
Cow	4.75	0.75
Goat	4.22	0.76
Ewe	4.28	0.97
Buffalo	4.7	0.90
Woman	6.8	0.20
Mare	6.89	0.30
Ass	6.50	0.46
Mule	4.80	0.38
Bitch	3.09	0.73
Cat	4.91	0.58
Rabbit	1.95	2.56
Llama	5.60	0.80

That the relationship is not exhibited in a closer degree than is shown by these tables is due to the fact that the analyses of ash give no information as to the relative amounts of soluble and insoluble salts. In cows' milk, for example, much of the calcium phosphate (probably two-thirds of it) is in a state of colloidal suspension. This practically contributes nothing to the osmotic pressure and so should be deducted from the ash analyses to derive an estimate of the soluble salts. It is not, then, the total ash or salt content of the milk which is to vary inversely to the milk sugar, but the soluble ash, which alone appreciably contributes to the osmotic pressure.

The insoluble salts may be regarded as inert and it may be pointed out that their presence is probably a device of nature to get beyond the limitations imposed by the necessity of adjusting the osmotic pressure of the milk upon that of the blood. Colloidal calcium phosphate permits of a high calcium content of cows' milk without unduly reducing other soluble constituents such as the sugar and salts of sodium and potassium.

Undoubtedly also the limitation of an adjusted osmotic pressure has led to the fixing of a disaccharide as the sugar of the milk, which weight for

weight has only half the osmotic effect of the monosaccharide, dextrose, present in the blood.

The sugar and soluble ash then should vary inversely in any two milks whose salts are the same in character and whose osmotic pressures are equal.

Now in the case of soluble salts their osmotic effects are dependent upon their ionisation, and as the electrical conductivity of a salt solution is dependent upon the same factor, we have in the conductivity of milk a very close indication of the osmotic value of the soluble milk salts.

Putting this reasoning to the test of experiment it ought to be shown that conductivity and milk sugar vary inversely.

There are of course disturbing factors, some of which will be discussed later, but whereas it is only a very rough generalisation that ash and sugar are reciprocating, it can be shown that the inverse relationship between sugar and electrical conductivity is practically a law.

It is seen best of all in milk from one animal taken at the same milking, but from different teats. In the case of a cow it is possible to obtain four different milks from the four distinct quarters of the udder. If obtained at the one milking they will have within the limits of experimental error the same depressions of freezing point.

Here are the figures for the milk sugar and conductivity as estimated in the milk after separation of the fat.

TABLE I.

Connection between the conductivity of milk and the percentage of lactose.

Milk from the four different quarters of the cow's udder.

	Quarter	K	Percentage of lactose
Series I	Left anterior	0·00596	5·41
	Right „	0·00613	5·30
	Left posterior	0·00630	5·20
	Right „	0·00641	5·13
Series II	Left anterior	0·00500	5·70
	Right „	0·00502	5·68
	Left posterior	0·00506	5·61
	Right „	0·00512	5·58
Series III	Left anterior	0·00527	5·74
	Right „		
	Left posterior	0·00531	5·68
	Right „		
Series IV	Left anterior	0·00544	5·73
	Right „	0·00545	5·64
	Left posterior	0·00557	5·55
	Right „	0·00555	5·59

It is seen that milk sugar and conductivity vary inversely, that in every series the milk from the anterior quarters has more milk sugar than the milk from the posterior quarters but a lower conductivity.

The same relationship is also shown in the case of human milk.

TABLE II.

Human milk.

Individual	K	Percentage lactose	Remarks
A	0.00259	6.85	Left breast.
	0.00263	6.24	Right „
B	0.00290	5.18	Left „
	0.00262	5.41	Right „

Note. These samples of milk were obtained from women who for forty-eight hours previously had practised nursing their baby from both breasts. Two breast pumps were used and applied simultaneously one on each breast. We found that the practice at the Women's Hospital, Melbourne (from which institution most of our milk samples were obtained), was to nurse from only one breast at a time, saving the other breast for the next meal. This quite prevented samples taken simultaneously from right and left breasts showing the reciprocity of the above table, for the milk in each breast is not then secreted under comparable conditions of the blood.

In subsequent tables (see pp. 11, 12, 13) showing the composition of the milk of various species of animal, the sow, ass, mare, llama and goat, the inverse proportionality between conductivity and sugar is generally in evidence.

It has been our universal experience (which is in agreement with that of Guiraud and Lasserre, Parmentier and others) that the depression of freezing point of abnormal milk is not different from that of normal milk. One mammary gland may be giving a pathological fluid without the slightest resemblance to true milk yet with an identical depression of freezing point to the normal milk from the other gland (goat) or other quarters of the udder (cow).

In comparing the milk from an abnormal and normal quarter in the same animal the inverse proportionality of conductivity and sugar should be very apparent.

The method employed to disturb the secretion of one of the quarters was to return normal milk, guarding carefully against outside bacterial infection, and taking precautions to maintain the re-injected milk at body temperature.

Table III gives the results of two such experiments, and the figures showing the gradual recovery of the experimental quarter bear out the inverse relationship of milk sugar content and conductivity value very forcibly.

From the records below it will be seen that the pathological milk shows at first a high conductivity and a very low percentage of milk sugar, but as recovery of the quarter takes place, the conductivity gradually becomes lower, and the sugar percentage rises again towards its normal figure.

In Experiment II the ash in a sample of milk from the affected left anterior quarter was compared with the ash from the corresponding normal quarter—the right anterior quarter.

It will be seen that though the total ash is only slightly higher in the pathological milk, the difference between the proportions of soluble and insoluble ash is most marked as compared with the distribution in the ash of normal milk.

TABLE III.

Experiment I. 23/2/12.

On Friday morning February 23, 1912, 300 c.c. of milk were milked from the left anterior quarter of the cow's udder.

A silver teat cannula was then inserted and another 400 c.c. drawn off into a bulb condenser as receiving vessel. Water at 40° was flowing through the outer jacket of the condenser. The cannula was connected to the condenser by spiral flexible metal tubing wrapped in cotton wool. The whole apparatus had been carefully sterilised prior to use in an autoclave.

By raising the condenser approximately 350 c.c. of the 400 c.c. withdrawn were made to flow gently back into the same quarter of the udder, the cannula never having been withdrawn.

This operation is a sure method of obtaining a temporary upset in the quarter of the udder so handled, the other quarters remaining unaffected.

	Quarter	K	Percentage of lactose
23/2/12 (morning)	Left anterior	0·00557	5·52
	Right posterior	0·00566	5·52
23/2/12 (afternoon)	Left anterior	0·01259	0·65
	Right anterior	0·00581	5·65
	Left posterior	0·00589	5·57
	Right posterior	0·00592	5·62
24/2/12 (afternoon)	Left anterior	0·00718	
25/2/12 (morning)	Left anterior	0·00707	4·13
	Right anterior	0·00567	5·37
26/2/12 (morning)	Left anterior	0·00635	4·40
	Mixed sample from the 3 other quarters	0·00531	5·30
27/2/12 (morning)	Left anterior	0·00612	5·41
	Right anterior	0·00525	5·90
	Left posterior	0·00542	5·85
	Right posterior	0·00539	5·87
28/2/12 (morning)	Left anterior	0·00579	5·11
	Mixed sample from the 3 other quarters	0·00539	5·33

Note. The experimental quarter is indicated by heavy type.

Experiment II. 5/3/12.

On Tuesday morning March 5th, 1912, about 200 c.c. of milk were milked from the left anterior quarter and then 300 c.c. were withdrawn through a sterilised teat cannula into a bulb condenser as in Experiment I.

Of these 300 c.c. approximately 250 c.c. were returned. The whole proceeding was neatly and cleanly carried out. The disturbance which followed was profound.

	Quarter	K	% Lactose	Δ	% Sol. ash	% Insol. ash
5/3/12 (evening)	Left anterior	0·0114	1·50	0·580	0·615	0·44
	Right anterior	0·00569	5·40	0·575	0·285	0·625
6/3/12 (morning)	Not enough milk obtainable from left anterior quarter to take either conductivity or rotation.					
7/3/12 (morning)	Left anterior	0·00734	2·86	—	—	—
	Right anterior	0·00535	5·72	—	—	—
8/3/12 (morning)	Left anterior	0·00699	4·18	0·545	0·352	0·585
	Right anterior	0·00535	5·36	0·543	0·250	0·617
	Left posterior	0·00536	5·32	0·540	—	—
	Right posterior	0·00536	—	0·545	—	—
9/3/12 (morning)	Left anterior	0·00616	4·81	—	—	—
	Right anterior	0·00520	5·44	—	—	—
11/3/12 (morning)	Left anterior	0·00551	5·28	—	—	—
	Right anterior	0·00521	5·48	—	—	—

In the first set of analyses (5/3/12 evening), when the conductivity of the milk from the left anterior quarter was very high, the amount of soluble ash was very much greater than normal and the amount of insoluble ash considerably less than normal.

The same differences between the pathological and normal milks are still apparent on the morning of 8/3/12 but in a less degree, indicating the return of the left anterior quarter of the udder to a normal condition. It is interesting to note that in a pathological milk there may be the paradox of a diminished percentage of sugar and ash with an unaltered depression of freezing point. In the ordinary determinations of ash however, no distinction is made between the soluble and insoluble portions and moreover the heat employed in getting rid of the carbon causes the volatilisation of some of the chlorides.

The inverse proportionality between milk sugar and electrical conductivity may be shown by comparing the milks of different animals, and the manner in which the results obtained conform to theoretical considerations is, in view of the many disturbing factors, exceedingly satisfactory. The experimental difficulties are to be placed first, for many of the animals being unused to handling about the udders, had to be educated to give milk. Generally it meant establishing a habit, whereby the young were separated from the parent, and only admitted at stated times for their feed. When milk samples were required the young were allowed to start the flow of

milk, and then removed. In many cases this meant a wet teat, and with the sow the young pigs leave the teats covered with a very slimy mucous.

With the smaller animals it was particularly difficult to get samples large enough for the determinations of freezing point and milk sugar content, and the cat, bitch and kangaroo had to be kept apart from their young for longer periods than could be called natural.

As already mentioned actual methods of analysis were difficult to keep free from small errors in the determination of milk sugar, chiefly on account of the varying protein contents of the milk.

Also the large amounts of protein in the milks of the smaller animals would undoubtedly depress the conductivity values, as will be shown later in discussing the influence of colloids on the conductivity of milk.

But apart from experimental difficulties and errors of analysis, there is the added complication that the milks of different animals and even of the same animal have a varying depression of freezing point. Strictly to compare two different milks with a view to showing that the milk with the higher milk sugar percentage will have the lower conductivity, it is necessary that both should have the same osmotic pressure, i.e. the same depression of freezing point.

Again many milk samples we obtained were abnormal, for the most part because the milk was still in the colostrum period or because the lactation was practically at an end.

The analyses of these samples have been discarded and the averages of the other analyses we have made taken for each individual species.

In some cases, e.g. sow, llama, kangaroo, ass, only one animal was available, but we have only used the results of our own analyses because we know that the conductivity, milk sugar and depression of freezing point determinations were all carried through on the one sample.

Collecting together the averages representing milk sugar and conductivity the following table is obtained:—

TABLE IV.

Animal	K in ascending values	K corrected	Milk sugar % in descending values	Animal
Mare	0·00208	0·00231	7·52	Mare
Ass	0·00247	0·00276	7·37	Ass
Woman	0·00252	0·00281	6·40	Woman
Sow	0·00375	0·00477	6·11	Sow
Goat	0·00499	0·00595	6·05	Goat
Cow	0·00503	0·00587	5·72	Cow
Cat	0·00537	0·00712	5·24	Cat
Bitch	0·00538	0·00742	5·17	Bitch

The only two milks out of order and therefore omitted from this table are those of the llama and kangaroo. Their non-agreement can be accounted for by abnormal depressions of freezing point.

Thus, for the llama $\Delta = 0.600^\circ$ which is exceptionally high ;
for the kangaroo $\Delta = 0.515^\circ$ which is lower than with other animals.

The corresponding values for these animals are

	K	K corrected	Milk sugar
Llama	0.00395	0.00465	6.95
Kangaroo	0.00494	—	2.66

The corrections for K have been made by taking the average figures for the percentage of protein in the milks of the various species of animals concerned as published by Droop Richmond in his *Dairy Chemistry*, p. 323, and adding 2.76 % of the conductivity for each 1 % protein in the milk.

The corrections practically leave the table unaffected. They might justify actually reversing the positions of cow and goat in the left-hand list, just as they justify placing the llama ahead of the sow. With the corrected K , the llama is most definitely brought more into line with the generalisation established by the table and is far from being a glaring exception, such as the kangaroo remains¹.

It is apparent from the figures that the reciprocal relation between milk sugar and conductivity holds closely in a survey of the milk of different animals in spite of the disturbing factors previously discussed.

The following tables give our analyses for milks of the different animals we have investigated and from these tables the averages used in Table IV were compiled.

Date	No.	K	Percentage lactose	Depression of freezing point	Remarks
<i>Human Milk.</i>					
23/3/11	1	0.00327	—	—	Colostrum.
19/3/12	2	0.00391	8.48	—	"
25/3/12	3	0.00959	0.57-0.76	—	Pathological.
4/4/12	4	0.00321	5.5	—	Colostrum.
"	5	0.00214	6.78	—	Normal.
17/4/12	6	0.00234	6.23	—	"
27/4/12	7	0.00230	6.81	—	"
"	8	0.00221	6.81	—	
"	9	0.00229	7.20	0.560	
"	10	0.00223	6.45	0.550	
22/7/12	11	0.00216	6.66	—	
26/7/12	12	0.00207	6.80	—	
14/8/12	13	0.00243	6.50	—	
21/10/12	14	0.00274	5.14	—	
25/10/12	15	0.00264	5.79	—	
17/2/13	16	0.00300	5.70	0.545	
"	17	0.00313	5.18	0.530	
"	18	0.00256	5.63	0.550	

¹ This animal was in the later months of lactation, its young one spending most of its time out of the pouch.

Date	No.	K	Percentage lactose	Depression of freezing point	Remarks
17/2/13	19	0·00278	5·04	0·535	
24/2/13	20	0·00269	—	—	
"	21	0·00260	—	—	
"	22	0·00298	—	—	
"	23	0·00305	—	—	
6/3/13	24	0·00290	6·19	0·530	
"	25	0·00294	6·50	0·535	
"	26	0·00258	6·66	0·540	
"	27	0·00263	6·23	0·542	
Milk of the Mare.					
25/9/12	1	0·00982	2·33	0·589	12 months after foaling.
15/10/12	same	2	0·00395	6·55	0·561 2 days ditto.
4/12/12	animal	3	0·00214	7·49	0·560 2 months ditto.
6/1/13	4	0·00203	7·56	—	2 months ditto.
Milk of the Goat.					
15/5/12	1	0·00433	—	0·590	
"	2	0·00431	6·28	0·580	
16/5/12	3	0·00467	—	0·577	
18/5/12	4	0·00459	6·00	0·575	
16/7/12	5	0·00536	5·98	—	
14/5/13	6	0·00567	5·39	—	Right side.
14/5/13	7	0·00541	6·15	—	Left side.
"	8	0·00554	6·08	—	Mixed sample.
15/5/13	9	0·00493	6·19	0·590	"
16/5/13	10	0·00517	6·13	0·563	"
19/5/13	11	0·00497	6·21	0·564	"
Milk of the Ass. All samples obtained from the same animal.					
11/1/13	1	0·00249	7·35	0·513	
16/1/13	2	0·00246	7·38	0·535	
20/2/13	3	0·00794	4·28	0·564	Obviously pathological.
"	4	0·00888	—	—	
"	5	0·01136	2·09	0·564	
"	6	0·01138	1·25	—	
Milk of the Sow. All samples obtained from the same animal. Littered 1/1/13.					
9/1/13	1	0·00469	4·30	—	
10/1/13	2	0·00366	6·24	0·573	
14/1/13	3	0·00378	6·15	0·565	
16/1/13	4	0·00382	5·98	0·580	
Milk of the Llama. All samples obtained from the same animal, 4th-5th month of lactation.					
21/1/13	1	0·00324	7·51	0·605	
20/2/13	2	0·00445	6·70	0·602	
"	3	0·00417	6·96	0·589	
Milk of the Cat. Both samples obtained from same animal.					
15/3/12	1	0·00557	5·33	—	Both samples were small in amount & obtained with difficulty. Fat was separated before any determination was made.
22/3/12	2	0·00518	5·14	—	

Date	No.	K	Percentage lactose	Depression of freezing point	Remarks
<i>Milk of Bitch.</i>					
3/4/12	1	0·00611	6·2	—	All samples obtained with much difficulty.
16/7/12	2	0·00425	not obtainable	—	
20/7/12	3	0·00465	4·15	—	
27/8/12	4	0·00421	—	0·573	
<i>Milk of Kangaroo.</i> Both samples from one animal. Late stage of lactation.					
27/1/13	1	0·00409	2·28	0·520	Very small sample.
8/2/13	2	0·00494	2·66	0·515	Good sample.

FIRST AND LAST PORTIONS OF MILK.

It is generally known that differences exist between the first milk drawn off from the mammary gland and the last milk. The latter for instance is very rich in fat, the former poor in fat. One of the many suggestions put forward to account for this is that the first and last milks are secreted under different conditions. This explanation has probably a great deal of truth in it, for not only is there the marked variation in fat content, but the early and late portions may show differences in depression of freezing point, milk sugar, and conductivity. The fact that late samples from the mammary gland in cows' milk generally have a greater depression of freezing point than the early samples was noted by Pins.

With regard to the electrical conductivity, it is sometimes higher in the first portions milked and sometimes in the last portions. In the case of full milk from the cow the conductivity of the last portions is invariably lower owing to the larger fat content of the end milk. But if the milk be separated before measuring the conductivity then definite exceptions to the above rule are found.

The following table gives the results obtained with a single cow and with first and last portions of milk from different quarters of the udder.

TABLE V.

Conductivity of first and last portions of milk, or strippings, of cow.

	Quarter	K (first portion)	K (last portion)
Series I	Left anterior	0·00548	0·00554
	Left posterior	0·00543	0·00548
Series II	Left anterior	0·00611	0·00582
	Right „	0·00621	0·00606
	Left posterior	0·00629	0·00631
	Right „	0·00636	0·00647
Series III	Right anterior	0·00508	0·00514
	Left posterior	0·00514	0·00512
	Right „	0·00522	0·00520
Series IV	Left anterior	0·00496	0·00496
	Right „	0·00493	0·00505

The samples taken were approximately 100 c.c. in volume. The anterior quarters were yielding about 900—1100 c.c. the posterior quarters 1200—1400 c.c. of milk.

With human milk the conductivity in the later samples was invariably higher than in the earlier samples.

TABLE VI.

Human milk.

Individual	Early sample	Late sample
A	0.00300	0.00313
B	0.00256	0.00278
C	0.00298	0.00305
D	0.00269	0.00260
E	0.00290	0.00294
F	0.00258	0.00263

The milk sugar also varies between first and last samples as shown in Table VII.

TABLE VII.

In the cow	First portion	Last portion
Left anterior quarter	5.53 % sugar	5.29 % sugar
Right „ „	5.38 „	5.04 „
Left posterior „	5.35 „	5.27 „
Right „ „	5.22 „	5.04 „

These differences in the depression of freezing point, conductivity and milk sugar content of first and last samples of milk taken from a single quarter, or gland, all bear out the assumption that the first and last portions are secreted under different conditions. In fact everything points to:

(1) A steady slight secretion between the intervals of milking or suckling, and

(2) a reflex further secretion produced as the result of the stimuli applied to the teat and gland.

In the cow (1) is relatively important and the animal comes to the milking shed with a great deal of milk already secreted. In other animals (1) is almost absent and only after the efforts of the young is the milk flow established as a result of a nervous reflex. We may mention the cat, bitch, sow and llama in this connection.

In women an intermediate condition is usually met with, there being some milk present in the breast at the time of suckling. The greater portion however is usually secreted under the reflex, initiated by the child. A child may occasionally take the milk already secreted and then have to work for as long as 10 to 15 minutes to establish the reflex flow. In such cases there is the danger that the mother may remove her child from the breast without the reflex flow of milk having been established.

To strengthen the view that milk may be secreted under different conditions, examinations of milk, obtained before and after the putting of the child to the breast, were made with different women. We have to express our very sincerest thanks to Dr A. W. Robertson, Honorary Physician of the Women's Hospital, Melbourne, for his kindness in procuring us these samples. The samples were taken under the supervision of one of us, and in every case the strictest precautions were observed.

Invariably the putting of the child to the breast changed the character of the milk. Some of the figures for milk sugar and conductivity have already been quoted separately.

The results are collected together in the following table :

Human milk.

First and last portions contrasted.

Individual	<i>First portion (before child put to breast)</i>			<i>Last portion (after child put to breast)</i>		
	<i>K</i>	Percentage lactose	Δ	<i>K</i>	Percentage lactose	Δ
A	0.00300	5.70	0.545°	0.00313	5.18	0.530°
„	0.00256	5.63	0.550	0.00278	5.04	0.535
B	0.00269	—	—	0.00260	—	—
C	0.00298	—	—	0.00305	—	—
D	0.00290	6.19	0.530	0.00294	6.50	0.535
E	0.00258	6.66	0.540	0.00263	6.23	0.542

There is no rule as to the effect produced by putting the child to the breast. The depression of freezing point, milk sugar percentage and conductivity may either be diminished or increased.

It is certainly not merely a question of first and last portions as such, but of two milks secreted at different times. Being secreted at different times they would undoubtedly be influenced by the variations occurring in the blood, due to the meals, drinking and varying activity of the kidneys and glands of the skin.

The first and last portions with the child placed at the breast between the taking of samples is simply the best manner of showing the difference between the milk already secreted and that poured forth as the response to the stimulus of suckling.

In the following experiment the influence of the child is apparent though only the first samples were taken, April 26th, 1913—evening.

A sample of milk was taken from the left breast and the baby then applied to this breast. There resulted a reflex flow of milk in both breasts and milk came dripping away from the right nipple. A sample was now taken from the right breast.

Evening	{ <i>Right</i> (child being on left breast)	<i>K</i> = 0.00229	Sugar 7.20 %
	{ <i>Left</i> (before child applied)	<i>K</i> = 0.00230	„ 6.82 %

The next morning a sample was taken from the right breast, the child then put to this breast and a sample now taken from the left side.

Morning	<i>Right</i> (before child applied)	$K=0.00223$	Sugar 6.46 %
	<i>Left</i> (child being on right breast)	$K=0.00221$	„ 6.82 %

In this experiment right morning, and left evening, are comparable as the samples were taken before bringing the child to its mother. The bringing of the child and subsequent taking of samples from the left breast in the morning, and the right breast in the evening in both cases led to a milk with slightly lowered conductivity and definitely increased milk sugar from 6.46 % to 6.82 % in the morning and 6.82 % to 7.20 % in the evening.

In evaluating the figures in this experiment allowance must be made in comparing morning milk with evening milk, for the generally higher conductivity and milk sugar content of evening milk, as compared with morning milk. The following analyses of the milk from another woman are typical of these morning and evening differences.

Morning and evening samples of milk.

Series III. Human milk (one individual).

Morning				Evening			
	K	Percentage lactose	Δ		K	Percentage lactose	Δ
Right breast	0.00295	5.14	0.610°	Right breast	0.00333	5.35	0.700°
Left breast	0.00289	5.06	—	Left breast	0.00323	5.25	—

MORNING AND EVENING MILK.

Cows' milk. With regard to morning and evening samples of milk it seems impossible to state any definite rule, although a large number of determinations have been made, but as will be seen later, it is probable that external climatic conditions, as well as the food factor referred to previously, affect the conductivity.

In the first series taken, where the milk of a single cow was employed, six morning samples taken at varying intervals were contrasted with six evening samples taken on the same days.

In this series four times was the morning conductivity greater than the evening and twice the evening was greater than the morning.

In the next series on 15 different days, evening and morning samples of milk were obtained from the Willsmere Co. These samples were taken from large mixed quantities (150 to 500 qts.) of milk from a special dairy herd (Holstein) and, in this series, of the 30 samples examined, in two instances

morning and evening conductivity were identical, ten times the evening conductivity was greater, while three times the morning conductivity was greater though only pronouncedly so in one case.

Conductivity of morning and evening samples of milk.

	Date	K (morning)	K (evening)
Series I. 1 cow.	16/10/11	0·00611	0·00584
	18/10/11	0·00613	0·00641
	19/10/11	0·00652	0·00644
	24/11/11	0·00633	0·00628
	19/ 2/12	0·00516	0·00504
	21/ 2/12	0·00501	0·00527
	23/ 2/12	0·00509	0·00531
Series II. Willsmere samples, from 150 to 500 qts.	5/12/12	0·00554	0·00563
	6/12/12	0·00555	0·00554
	9/12/12	0·00562	0·00562
	10/12/12	0·00556	0·00562
	11/12/12	0·00554	0·00555
	12/12/12	0·00549	0·00557
	16/12/12	0·00568	0·00566
	18/12/12	0·00573	0·00559
	17/ 2/13	0·00587	0·00593
	18/ 2/13	0·00562	0·00593
	19/ 2/13	0·00568	0·00585
	20/ 2/13	0·00562	0·00573
	27/ 2/13	0·00555	0·00599
	3/ 3/13	0·00573	0·00582
	4/ 3/13	0·00575	0·00575

These irregularities in the electrical conductivities of morning and evening milk are to be sought in the conditions under which the animals live during the hot months of the year in Victoria.

They feed by night, as well as by day, upon grass which is burnt dry. They receive their chief water supply when brought to the sheds to be milked, and lastly, with a very changeable climate, a given night may be hotter than the following day.

A regular diurnal periodicity in the concentration of the animals' blood (and consequently in the concentration of their milk) is therefore hardly to be expected.

In contrast to this, women's milk appears to be regularly more concentrated in the evening. This may be assigned to the regular daily eating and activity which, following the night's abstinence and rest, produce a rise in the osmotic concentration of the blood.

THE DEPRESSION OF THE CONDUCTIVITY BY THE PROTEINS OF THE MILK.

The effect of colloids simultaneously present in solution in water with inorganic salts may be postulated as diminishing the conductivity which the salts alone in water would otherwise show.

In the case of milk, freed as far as possible from fat globules, the chief source of obstruction would undoubtedly be the colloidal particles of protein.

The richer a separated milk in protein the greater probably the depression of the conductivity, so that in comparing the milks of different species of animals, the conductivity of each could not necessarily be taken as a quantitative indication of soluble ionised salts without a correction being made.

For instance in mares' milk the protein averages about 1.5 % and probably has only a small influence on the conductivity of what may be termed the "protein free whey."

On the other hand there is every reason to think that in the milk of smaller animals such as the dog and cat, with their high protein content (quoted as high as 11.15 %), the conductivity of the protein free whey would be distinctly greater than that of the fat free milk.

The presence of the protein will diminish the power of the ions to transport electricity by reducing their available free paths; also perhaps the conductivity may be affected by the protein diminishing the ionisation of the salts.

In order to determine the extent to which the protein in cows' milk depresses the electrical conductivity, the following experimental methods were employed.

The milk was obtained directly from a cow on the premises and the cream separated from it as quickly as possible. One portion of the separated milk was weighed and then boiled for one hour in a large flask under a reflux condenser. After cooling, the milk was reweighed, and the very small loss of water made good by adding a special distilled water.

The boiled and raw milks were then placed in two large beakers and in each were suspended dialysing tubes of peritoneal membrane. Each tube contained a measured volume (not exceeding 50 c.c.) of specially distilled water ($K = 0.00007$).

Toluene was added to the milk in each beaker (in all the earlier experiments), and when the weather was warm the beakers were placed in an ice chest at a temperature of about 12° C. At intervals 5 c.c. samples were measured from the dialysing tubes and from the surrounding milk.

In accordance with physico-chemical laws, after a sufficient length of time,

equilibrium should be established between the milk outside the membrane and the water inside.

The membranes in all later experiments were the prepared peritoneal sacs from the appendices of sheep, known technically as "*Fischblasen-condom*" and here referred to as "peritoneal membranes." They were apparently perfect in action and much to be preferred to parchment for this purpose.

We quote however earlier results obtained with parchment as the effects observed are the same as with the peritoneal membranes.

Experiment 1. 26/10/11–28/10/11.

A. 630 c.c. *raw* separated milk plus 15 c.c. toluene: 25 c.c. pure distilled water dialysed against it for 2 days. Less than 5 c.c. of a yellow-green faintly opalescent fluid recovered from the *parchment* dialysing tube.

B. 630 c.c. *boiled* separated milk (1 hour's boiling) treated as in A. 5 c.c. clear yellow-green fluid recovered from the parchment.

A. <i>Raw milk.</i>		B. <i>Boiled milk.</i>	
Before dialysis	$K=0\cdot00518$	Before dialysis began	$K=0\cdot00514$
After "	$K=0\cdot00507$	After "	$K=0\cdot00503$
Water & salts from parchment	$K=0\cdot00570$	Water & salts	$K=0\cdot00577$

Experiment 2. 3 p.m. 27/2/13–8 p.m. 1/3/13.

A. 1250 c.c. fresh separated milk dialysed against two tubes of peritoneal membrane each containing 50 c.c. conductivity water. 15 c.c. toluene were added to milk as preservative. Vessel placed in ice chest at 12° C. Evaporation prevented by parchment cover placed on mouth of beaker.

B. 1300 c.c. fresh separated milk *boiled for one hour* under reflux condenser, then dialysed against two peritoneal tubes each containing 50 c.c. conductivity water.

Other details as in A. .

27/2/13. *Before dialysis.*

A. Raw milk and toluene	$K=0\cdot00500$
Conductivity water	$K=0\cdot00007$
B. Boiled milk and toluene	$K=0\cdot00498$
Conductivity water	$K=0\cdot00007$

Dialysis commenced 3 p.m. 27/2/13.

Date	Time	No.	Raw milk	Boiled milk	Dialysate	
					Tube 1	Tube 2
28/2/13	12 noon	A	$K=0\cdot00492$	—	$K=0\cdot00494$	$K=0\cdot00478$
		B	—	$K=0\cdot00496$	$K=0\cdot00460$	$K=0\cdot00440$
28/2/13	6.30 p.m.	A	$K=0\cdot00486$	—	$K=0\cdot00496$	$K=0\cdot00490$
		B	—	$K=0\cdot00486$	$K=0\cdot00484$	$K=0\cdot00470$
1/3/13	12 noon	A	$K=0\cdot00488$	—	$K=0\cdot00502$	$K=0\cdot00508$
		B	—	$K=0\cdot00492$	$K=0\cdot00498$	$K=0\cdot00494$
1/3/13	8 p.m.	A	$K=0\cdot00488$	—	$K=0\cdot00512$	$K=0\cdot00514$
		B	—	$K=0\cdot00486$	$K=0\cdot00514$	$K=0\cdot00512$

In both experiments quoted it was found that after two days' dialysis the conductivity of the liquid from the dialysing tubes was greater than that of the surrounding milk.

Boiling the milk has apparently no influence on the end equilibrium.

The second experiment suggested a slower course in the establishment of equilibrium in the case of boiled milk and it might be that some fixation of soluble dialysable salts had occurred as the result of the boiling, the change being slowly reversible. It was realised however that diffusion processes and the three occasions on which the milk was disturbed in taking samples, would be responsible for the rate of dialysis.

Consequently in the experiments which follow, performed in mid-winter, stirrers driven by an electrical motor kept the milk in continuous movement during the whole course of the dialysis. Further, the percentages of fat and proteins in the milk employed were directly estimated and gravimetric estimations of ash in the dialysate were made. As will be seen from the records which follow there is no reason to assign any special importance to the slower establishment of equilibrium to which attention was called in Experiment 2.

Experiment 3. 9/6/13.

1600 c.c. fresh separated milk (from one cow) and 5 c.c. toluene were dialysed against 50 c.c. conductivity water. The beaker containing the milk and the dialysing tube was placed in a water bath, which during the course of the experiment maintained an average temperature of 8° C. The milk was kept in constant movement by means of an electrical stirrer, and a filter paper, kept slightly moistened, was arranged over the top of the beaker to check evaporation.

An estimation of the fat by Babcock's method gave the content 0.025 % and from a Kjeldahl determination of the nitrogen the protein was found to be 4.35 %, after correcting for dialysable nitrogen and dilution by 35 c.c. water.

5 c.c. samples were removed at intervals from the milk and the dialysing tube.

Experiment set up 12.30 p.m. 9/6/13.

Date	Time	Milk	Dialysate
9/6/13	12.30 p.m.	$K=0.00747$	—
10/6/13	9.30 a.m.	$K=0.00736$	$K=0.00843$
10/6/13	4.30 p.m.	$K=0.00740$	$K=0.00843$
11/6/13	10.15 a.m.	$K=0.00740$	$K=0.00839$

In this experiment equilibrium appears to have been attained at 4.30 p.m. 10/6/13.

Averaging the figures with those obtained at 10.15 a.m. 11/6/13, gives

Milk	$K=0.00740$
Dialysate	$K=0.00841$

The differences between these figures, 0.00101, stated as percentage depression of the conductivity gives:—

$$\frac{0.00101}{0.00841} \times 100 \text{ or } 12.01 \%$$

This 12.01 % depression of the conductivity is produced by 4.35 protein in the milk, or 1 % protein is equivalent to a depression of 2.77 % of the conductivity.

Experiment 4 a.

The milk used in this experiment was obtained from a cow in the third month of lactation. Immediately after separation a portion of it was taken and boiled for 45 minutes, the remaining part being kept in the meantime at a fairly low temperature. The two beakers were subsequently placed in a water bath at 9° C. and the milk was stirred as in the previous experiment, but no toluene was added.

A Babcock determination showed 0.1 % fat in the separated milk and a nitrogen estimation by Kjeldahl's method fixed the protein content at 3.07 % after correcting for dialysable nitrogen and dilution with 10 c.c. water.

A. 1100 c.c. fresh separated milk dialysed against 25 c.c. pure distilled water.

B. 1100 c.c. separated milk boiled for 45 minutes under reflux condenser, then dialysed against 25 c.c. pure distilled water.

Before dialysis.

13/6/13. 6 p.m.	A. Raw milk	$K=0.00491$
	B. Boiled milk	$K=0.00487$

Dialysis commenced 6 p.m. 13/6/13.

Date	Time	Raw			Boiled		
		No.	Milk	Dialysate	No.	Milk	Dialysate
13/6/13	10.45 p.m.	A	$K=0.00489$	$K=0.00496$	B	$K=0.00483$	$K=0.00508$
14/6/13	10.20 a.m.	A	$K=0.00484$	$K=0.00529$	B	$K=0.00485$	$K=0.00527$
14/6/13	4 p.m.	A	$K=0.00478$	$K=0.00526$	B	$K=0.00480$	$K=0.00523$

4 c.c. of each dialysate were taken and the amount of ash estimated. The ash of the dialysate from the raw milk amounted to 0.0175 g. and that from boiled milk to 0.0180 g.

In this experiment equilibrium is established at 10.20 a.m. 14/6/13.

Also there is no essential difference between the results for the raw and boiled milks. Consequently the average of the conductivities for the last four milks (two raw and two boiled) and for the last four dialysates may be used to calculate the depression due to the protein.

Average for milk	$K=0.00482$
Average for dialysates	$K=0.00526$

Hence conductivity is depressed 8.365% for 3.07% protein or 1% protein depresses the conductivity 2.73%.

Experiment 4 b. 20th and 21st July, 1913.

1000 c.c. separated milk (morning milk from several cows). Fat 0.25%; $K=0.00541$. No toluene added. Two dialysing tubes each with 20 c.c. conductivity water. Stirrer used throughout. Commenced 2 p.m. 20th July, 1913. Temperature 10.5°.

21/7/13. 11.30 a.m.	Milk	$K=0.00528$
	Dialysate I	$K=0.00577$
	II	$K=0.00579$
2.30 p.m.	Milk	$K=0.00528$
	Dialysate I	$K=0.00577$
	II	$K=0.00578$

Results of Kjeldahl determinations.

5 c.c. of milk at end of experiment = 18.9 c.c. $N/10$,

5 c.c. dialysate I at end of experiment = 0.6 c.c. $N/10$,

5 c.c. dialysate II at end of experiment = 0.9 c.c. $N/10$,

Blank determination = 0.00.

Hence 18 c.c. $N/10$ represents protein nitrogen of milk = 3.12% protein.

K is depressed 8.65% by this amount of protein or 1% protein depresses the conductivity 2.77%.

Experiment 5. 21/6/13.

The milk used in this experiment was bulk milk obtained from a dairy. The same experimental detail was observed as in the previous experiments, but in this case the separation of the cream from the milk was by no means complete. No toluene used.

A. 2000 c.c. fresh separated milk dialysed against 40 c.c. conductivity water.

B. 2000 c.c. fresh separated milk, boiled for one hour under reflux condenser then dialysed against 40 c.c. conductivity water

21/6/13. 12.30 p.m.

A. Raw milk $K=0\cdot00527$ B. Boiled milk $K=0\cdot00514$

Dialysis commenced 12.30 p.m.

Date	Time	Raw		Boiled	
		Milk	Dialysate	Milk	Dialysate
21/6/13	2 p.m.	A $K=0\cdot00522$	$K=0\cdot00447$	B $K=0\cdot00511$	$K=0\cdot00451$
21/6/13	4 p.m.	A $K=0\cdot00519$	$K=0\cdot00540$	B $K=0\cdot00509$	$K=0\cdot00564$
21/6/13	5 p.m.	A —	$K=0\cdot00563$	B —	$K=0\cdot00564$
21/6/13	7.30 p.m.	A $K=0\cdot00522$	$K=0\cdot00578$	B $K=0\cdot00512$	$K=0\cdot00570$

At the conclusion of the dialysis, 10 c.c. of each dialysate were taken and evaporated to dryness and ashed. The amount of ash from 10 c.c. of the dialysate from raw milk was 0.052 g. and exactly the same amount was given by the dialysate from the boiled milk.

The ash was then dissolved in dilute hydrochloric and 0.5 c.c. of a sodium acetate solution added; ammonia was added till the reaction was alkaline and then 1 c.c. saturated solution of ammonium oxalate. The mixture was kept at 100° for ten minutes, then the oxalate precipitate transferred to a filter paper and well washed with dilute acetic acid and distilled water. Paper and precipitate were dried at 100° and ashed over a low flame. The ashes at this stage weighed.

(1) From boiled milk dialysate 0.0187 g.

(2) From raw milk dialysate 0.0150 g.

In both cases the ash was moistened with 25% sulphuric acid, carefully dried and at first gently then strongly heated.

(1) From boiled milk dialysate 0.0165 g.

(2) From raw milk dialysate 0.0150 g.

Discussion of dialysis experiments.

The experiments all show the same qualitative results, but owing to absence of analyses for the milk as actually used in Experiments 1 and 2 and also to lack of evidence that equilibrium had definitely been reached, it is only the later experiments which can be used for obtaining an accurate quantitative evaluation of the depressant action of protein on the conductivity of milk.

It is most interesting to compare these values (average 2.76%) with those of Bugarsky and Tangl obtained for the proteins of blood serum (2.5% depression of conductivity per 1% protein).

We feel that we may claim for Experiment 4 *a* and *b* an almost perfect technique. Not even a preservative agent such as toluene was necessary.

Also Experiments 3 and 4a give uniform results with two totally different milks. In Experiment 3 milk very rich in protein was used from a cow at the end of lactation (8th month). In Experiment 4a the milk was from a cow in the third month of lactation. Experiment 5 was with market milk, which having previously creamed repeatedly clogged the separator. Owing to the large amount of fat present the experiment cannot be used to evaluate the depressant action of the protein upon the conductivity.

Analyses of ash show that the dialysates from raw and boiled milk not only contain the same amounts of ionised salts, as shown by their equal conductivities, but also the same amounts of total ash, and of calcium. Söldner's statement [1888] that boiling milk renders a great portion of the calcium insoluble, a statement which has often been used to explain the absence of rennet coagulation in boiled milk, is incorrect in the strict sense. No calcium which is in true molecular solution can become insoluble or results, such as those just quoted, would not be obtained. The chief effect of boiling milk is a physical alteration of the colloids. Probably an insoluble irreversible calcium caseinogenate is formed which mechanically fixes colloidal calcium phosphate.

Such an explanation will account for Söldner's observation that with boiled milk less calcium will pass a porous clay filter than is the case with raw milk.

DAILY FLUCTUATIONS IN CONDUCTIVITY OF MILK ASSOCIATED WITH VARYING CLIMATIC CONDITIONS.

During the summer months in Victoria rapid changes from hot dry weather to a period of coldness and rain are experienced from time to time, and the following observations which extended over portions of the months of November, December, February and March include well marked extremes of summer temperature.

The milk used in this series of conductivity determinations was a special supply from the Syme Model Farm, Gisborne, Victoria. This farm possesses modern refrigerating machinery. The milk is immediately put over the coolers and sent packed with ice by motor to Melbourne. The conductivity changes are therefore not due to bacterial changes in the milk but to climatic influences affecting the cows. As soon as the supply arrived at the Melbourne depot a composite sample from 3-10 cans, each containing 50 quarts, was carefully collected by the Dairy Expert of the Willsmere Certified Milk Company and our thanks are due to him and to the Company for obtaining these samples for us.

The weather reports quoted in the following table are abridged from the daily bulletins published in the *Argus*; the figures for humidity and the dry bulb temperature as recorded by the Melbourne Observatory were obtained from the same source.

Date	Weather report	Relative humidity %	Dry bulb temperature, °F.			K
			Max.	Min.	Mean	
27/11/12	Fine, warm, pleasant	57·3	77·4	43·2	60·3	0·00578
28/11/12	Hot, dry, north winds	37·6	83·6	53·7	68·6	0·00573
29/11/12	Small fall of rain, followed by fine, pleasant day, light cool winds	59·6	67·3	57·9	62·6	0·00562
1/12/12	Light steady rain, sultry conditions ...	74·3	73·9	61·1	67·5	0·00570
3/12/12	Tropical downpour, severe thunderstorm	74·3	75·0	49·0	62·0	0·00557
4/12/12	Dull cloudy morning, followed by fine pleasant day, light southerly wind	63·0	70·3	53·0	61·6	0·00554
5/12/12	Cloudy, sultry generally	49·0	84·7	51·7	68·2	0·00555
6/12/12	Thunderstorms, followed by squally showery weather	56·3	68·8	56·4	62·6	0·00554
8/12/12	Unsettled, showery, "unusual weather"	63·0	67·3	47·3	57·3	0·00562
9/12/12	Cloudy but fine at first, gradually becoming windy and threatening	60·6	67·7	54·2	60·9	0·00556
10/12/12	Weather very disturbed, stormy ...	61·3	62·3	50·7	56·5	0·00554
11/12/12	Cool, showery	61·0	57·6	44·2	50·9	0·00549
15/12/12	Weather becoming finer, max. temp. higher than any recorded since 6th Dec.	56·6	70·2	47·5	58·8	0·00568
17/12/12	Hot, slightly cloudy, light breezes ...	52·3	83·7	59·3	71·5	0·00573
12/ 2/13	Fine, light variable winds and little rain	61·0	82·8	55·2	69·0	0·00585
16/ 2/13	Close, sultry	74·6	74·8	64·5	69·6	0·00587
17/ 2/13	Fine, warm, sultry	57·3	85·0	60·8	72·9	0·00562
18/ 2/13	Fine, unpleasant strong westerly winds	43·6	78·0	60·3	69·1	0·00568
19/ 2/13	Fine, after a cloudy threatening morning	49·3	73·0	57·5	65·2	0·00562
20/ 2/13	Cloudy & dull at first, afterwards bright	59·3	66·6	57·4	62·0	0·00559
24/ 2/13	Northerly winds at first, followed by light sea breezes. Very hot	44·3	95·0	59·9	77·4	0·00573
26/ 2/13	Cloudy, sultry, thundery	69·0	71·0	62·0	66·5	0·00555
27/ 2/13	Bright, warm, sea breezes	68·3	84·0	60·0	72·0	0·00577
2/ 3/13	Fine, clear, hot	48·6	93·4	48·5	70·9	0·00573
3/ 3/13	Warm night followed by dull sultry day. Thunderstorm	51·6	95·3	70·2	82·6	0·00575
4/ 3/13	Oppressive weather, high humidity, small amount of rain	81·3	76·5	64·9	70·7	0·00551
6/ 3/13	Cold with squally southerly wind, at times showery	68·3	62·8	55·0	58·9	0·00562

By reference to the table it will be seen that on November 27, 28, 29 and December 1, warm weather was experienced and the average conductivity obtained for the milk during that time = 0·00570.

On December 3 there was a large fall of rain and a lowered conductivity recorded = 0·00557.

On December 5 a quick cold change followed a hot sultry day and from that date until December 11 there was a period of cold, showery stormy weather and the average conductivity during this time = 0·00555.

On December 15 and 17 the weather was becoming finer with rising temperatures and the mean conductivity for these two days = 0.00576.

On various days between February 15 and 19, both inclusive, fairly high temperatures were recorded and the average conductivity for 5 days = 0.00572.

On February 24 and 27 and March 2 and 3 the dry bulb temperatures were high and the average conductivity = 0.00574.

February 26 was cloudy and thundery with moderate temperatures and $K = 0.00555$.

The weather of March 4 was very oppressive with a high humidity and $K = 0.00551$.

By March 6 the weather was colder and squally and the conductivity was found = 0.00562.

It will thus be seen that as a generalisation it may be stated that hot dry weather causes the conductivity to become higher, while cold, wet or very humid weather has the reverse effect.

The value given for the relative humidity is the mean of three determinations made at 9 a.m., 3 p.m. and 9 p.m. respectively.

The maximum and minimum dry bulb temperatures are those recorded during twenty-four hours.

The conductivities quoted in the table are all for early morning samples of milk and placed against them are the climatic details of the *previous* day. The conductivities obtained ranged from 0.00549–0.00587.

SUMMARY.

(1) In milks secreted from different quarters of the cow's udder and from the right and left breasts in women, the electrical conductivity and percentage of milk sugar show a strict reciprocity provided that the secretion of the milk samples corresponds to the same period. In this case the milk samples are secreted against the osmotic pressure of the blood with its variation over that period. They will all have the same osmotic pressure and if in one sample the sugar is higher than in another, then the electrical conductivity will be lower.

(2) The reciprocity of milk sugar content and electrical conductivity is well seen in the milks from a pathological gland which is slowly recovering and becoming normal.

(3) In a comparison of the milks of different species of animals the reciprocity between milk sugar and electrical conductivity is evident.

(4) It is shown that the milk secreted under the stimulus of removal (milking or natural suckling) differs in character from that secreted previously. The contention is that the condition of the blood has not kept absolutely constant, and that the reflex milk is secreted against a slightly different blood from that against which the previously formed milk was secreted.

(5) Morning and evening samples of cows' milk have been compared. The evening milk generally has the higher conductivity but exceptions exist.

(6) The exact effect of the proteins of cows' milk in diminishing the electrical conductivity has been estimated, the value found being a diminution of 2.76% of the conductivity for every 1% of protein in the milk.

(7) The dialysis experiments employed for determining this effect showed no difference between raw fresh milk, and the same boiled for one hour. Also there was no evidence that boiling has any effect on soluble calcium salts in a state of ionisation.

(8) The effect of climatic changes upon a Holstein herd of cows has been studied. The generalisation holds that hot dry weather increases the electrical conductivity of the milk, whilst wet or cold weather diminishes it. The climatic conditions affect the cows and so indirectly their milk.

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