ELECTRICAL CONDUCTIVITY AND CHLORIDE CONTENT OF WOMEN'S MILK

PART 2 : THE EFFECT OF FACTORS RELATING TO LACTATION

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In Part I it was shown that the electrical conductivity of human milk is positively correlated with its chloride content. It was thought desirable to investigate in some detail the effect on both conductivity and chloride content of various factors connected with the time and mode of obtaining milk. Comparisons have been made between (1) fore-milk (milk taken just before a child is fed) and after-milk (milk taken just after a breast feed), (2) milk samples taken in the early morning, at mid-day, and in the evening, (3) milk samples taken at various stages of lactation, i.e., in the first, second, third, fourth, and fifth months of lactation, and (4) milk samples taken from right and left breasts respectively.

Comparison of Fore-milk and After-milk

From each of 62 women a specimen of milk was taken before and another taken after a breast feed, and the electrical conductivity and chloride content of each of 124 specimens was determined as soon as possible after taking the sample. Of the 62 women, some had an adequate milk supply, but in others there were signs that the lactation was inadequate. Their infants failed to gain weight and received less than 2 oz. of breast milk per lb. body weight each day. The average of the values for electrical conductivity of the 62 specimens of after-milk was $231.1 \times 10^{-5} \pm 7.38 \times 10^{-5}$ ohm⁻¹ cm.⁻¹, whilst the corresponding figure for fore-milk was $219.4 \times 10^{-5} \pm 8.29 \times 10^{-5}$ ohm⁻¹ cm.⁻¹. The average chloride contents for the two series of milks were 67.7 ± 5.12 mg. and 75.2 ± 6.13 mg. per 100 ml. respectively. It will be seen that the values are lower in the fore-milk than in the after-milk. Using the standard errors, we find that the differences are not significant. This method of comparison, however, does not allow for the fact that the fore-milk and after-milk observations have been made on the same series of women. We have, therefore, taken the differences between the values of the two samples of milk obtained from each woman and applied tests to ascertain whether the mean of these differences differs significantly from

zero. The result is that the average of the differences of the conductivity values between fore-milk and after-milk does differ significantly from zero ($t=3.1$), but for the chloride content the result is just significant ($t=2.1$). Hence, it may be concluded that the tendency for after-milk to have higher electrical conductivity and chloride values than fore-milk is a real one. Similar observations were made by Sisson and Denis (1921), Macy, Nims, Brown, and Hunscher (1931) and Ishii (1937), but their results were not statistically analysed. These authors were agreed that the values for after-milk could be either greater or smaller than those for fore-milk. Thus, when making investigations into either the electrical conductivity or chloride content of milk, all milk samples should be taken either before a breast-feed or after a breast-feed, unless the daily milk yield can be obtained for examination.

Comparison of Morning, Mid-day, and Evening Milk

Samples of milk from two series of women were examined. The first series consisted of 219 women of whom 131 had sufficient milk for their infants and 88 had not. The second series contained 123 women of whom 81 had an adequate, and 42 an inadequate, milk supply. In the first series, two specimens were taken from each woman, both from the same breast, one before a morning feed at 6 a.m., and the second before the noon or 2 p.m. feed. In the second series, three specimens were taken from each woman, all from the same breast, one before the early morning, the second before the mid-day, and the third before the evening feed (the latter at 10 p.m.).

The observations on the electrical conductivity and chloride values of the milks are contained in Tables 1A and 1B. Average values are given for the first month of lactation and for the second to fifth months, the women in each of these groups being divided into two sub-groups, those with adequate and those with inadequate lactation. Both electrical conductivity and chloride values tend to be lowest at early morning, and highest at mid-day.

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TABLE 1A
AVERAGE ELECTRICAL CONDUCTIVITY VALUES OF MILK SAMPLES TAKEN IN THE FIRST AND SECOND TO FIFTH MONTHS OF LACTATION

Type of Lactation	Time of Withdrawing Sample	Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$		Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$	
		Series I		Series II	
		1st Month	2nd-5th Month	1st Month	2nd-5th Month
Adequate	Morning ..	214.0 $\pm$ 4.06 (65)*	180.8 $\pm$ 1.97 (63)	216.4 $\pm$ 5.27 (39)	181.7 $\pm$ 3.58 (42)
	Mid-day ..	214.4 $\pm$ 3.96 (65)	189.2 $\pm$ 4.13 (63)	224.0 $\pm$ 5.14 (39)	182.6 $\pm$ 3.35 (42)
	Evening ..			231.4 $\pm$ 6.90 (39)	185.1 $\pm$ 2.95 (42)
Inadequate	Morning ..	304.4 $\pm$ 11.35 (57)	293.0 $\pm$ 21.81 (31)	263.3 $\pm$ 14.22 (15)	259.7 $\pm$ 15.96 (27)
	Mid-day ..	313.2 $\pm$ 14.14 (57)	306.7 $\pm$ 22.68 (31)	303.1 $\pm$ 20.41 (15)	267.8 $\pm$ 17.01 (27)
	Evening ..			288.5 $\pm$ 13.65 (15)	257.3 $\pm$ 16.43 (27)

* The number of observations from which each mean and standard error of mean have been calculated is indicated by the figure in brackets.

The data have been submitted to statistical examination by the method of the analysis of variance with the following results. Dealing first with electrical conductivity, we find that in the first series of observations, there is a significant variation between the average values for conductivity of milk taken at the three times throughout the day in the case of women with adequate milk supply during the first month of lactation. For the corresponding women with inadequate lactation, the variation throughout the day is not statistically significant. However, in the second series investigated, the variation of the conductivity throughout the day is significant during the first month of lactation for mothers with an inadequate, as well as for those with an adequate, milk supply. During the second to fifth months of lactation, the variation of the electrical conductivity throughout the day is not significant either in the first or second series of observations; this holds both for mothers with an adequate and those with an inadequate milk supply.

Similar results are found in respect of chloride content.

The main result which emerges is that during the first month of lactation, the electrical conductivity and chloride value of women's milk tends to be higher at mid-day and to fall again towards evening. This result is more definite in the case of women with an adequate milk supply; for those with an inadequate milk supply, it is confirmed by the second set of observations, but not by the first where the random fluctuations obscure the significance of the observed differences. During the second to fifth months of lactation, there is no significant variation in the average value for early morning, mid-day, and evening milk specimens.

Previous investigators, who have recorded chloride values for milk specimens taken throughout the day, fail to agree on the time of day when the highest values are obtained (Sisson and Denis, 1921; Macy *et al.*, 1931; and Ishii, 1937).

TABLE 1B
AVERAGE CHLORIDE CONTENT OF MILK SAMPLES TAKEN IN THE FIRST AND IN THE SECOND TO FIFTH MONTHS OF LACTATION

Type of Lactation	Time of Withdrawing Sample	Average Chloride (mg. % calculated as NaCl.)		Average Chloride (mg. % calculated as NaCl.)	
		Series I		Series II	
		1st Month	2nd-5th Month	1st Month	2nd-5th Month
Adequate	Morning ..	65.0 $\pm$ 2.39 (66)*	44.7 $\pm$ 1.06 (65)	76.6 $\pm$ 4.79 (39)	49.9 $\pm$ 2.80 (42)
	Mid-day ..	71.0 $\pm$ 2.64 (66)	49.7 $\pm$ 2.63 (65)	78.3 $\pm$ 3.42 (39)	51.8 $\pm$ 2.53 (42)
	Evening ..			87.0 $\pm$ 6.27 (39)	50.9 $\pm$ 2.45 (42)
Inadequate	Morning ..	131.6 $\pm$ 8.89 (57)	126.0 $\pm$ 16.13 (31)	109.3 $\pm$ 10.19 (15)	112.3 $\pm$ 12.20 (27)
	Mid-day ..	149.2 $\pm$ 9.05 (57)	134.0 $\pm$ 15.49 (31)	141.4 $\pm$ 16.31 (15)	116.2 $\pm$ 13.45 (27)
	Evening ..			129.9 $\pm$ 11.67 (15)	109.7 $\pm$ 10.67 (27)

* The number of observations from which each mean and standard error of mean have been calculated is indicated by the figure in brackets

TABLE 2A
AVERAGE ELECTRICAL CONDUCTIVITY OF MILK SAMPLES TAKEN FROM WOMEN WITH ADEQUATE LACTATION

Time of Withdrawal of Sample	Series	Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$			Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$			
		2 weeks	3 weeks	4 weeks	2 months	3 months	4 months	5 months
Morning	I	222 (44)*	205 (13)	188 (8)	183 (28)	180 (18)	176 (7)	179 (10)
	II	222 (32)	197 (5)	172 (2)	193 (8)	202 (2)	188 (8)	174 (24)
Mid-day	I	225 (44)	207 (13)	204 (8)	188 (28)	194 (18)	189 (7)	183 (10)
	II	230 (32)	206 (5)	167 (2)	202 (8)	201 (2)	182 (8)	174 (24)
Evening	II	239 (32)	206 (5)	168 (2)	202 (8)	197 (2)	181 (8)	180 (24)

* The number of observations from which each mean has been calculated is indicated by the figure in brackets.

The Effect of the Stage of Lactation

The women investigated were divided into seven groups depending on the length of time for which they had been lactating; the groups included women who had been lactating two, three, and four weeks, and two, three, four, and five months respectively. The results of the conductivity and chloride content measurements are summarized in Tables 2A, 3A, 2B, and 3B. It will be observed that in Tables 2A, 3A, 2B, and 3B the groups are sub-divided to give values separately for mothers with adequate and inadequate lactation and also for milk samples taken in the morning, at mid-day, and in the evening.

In general, the values for both electrical conductivity and chloride content are higher for samples taken in the second, third, and fourth week of lactation than for those taken in the second, third, fourth and fifth month of lactation. This is brought out in Tables 1A and 1B, which afford a comparison of average values for the first month as a whole with those for the second, third, fourth, and fifth months taken together.

The application of the analysis of variance to these

data showed that in the mothers with adequate lactation, the difference between values for the first month and those for the other months was statistically significant, but was insignificant for mothers with inadequate lactation. This is true both in respect of electrical conductivity and chloride content and holds for specimens taken either in the early morning, at mid-day, or in the evening. On the other hand, no significant variation was found, even for mothers with adequate lactation, during the second, third, fourth, and fifth months of lactation either in respect of electrical conductivity or chloride content.

It will be noted that the study differs from that involving the sampling of milk at different times of day, because in the latter each woman gave three specimens which were compared, whereas in the present comparison, the women, say in the fifth month of lactation, were in general, different from those in the second week of lactation. In the statistical analysis, this difference in the structure of the experiments was taken into account. Naturally, when the individuals examined are different in the two groups, the degree of

TABLE 2B
AVERAGE CHLORIDE CONTENT OF MILK SAMPLES TAKEN FROM WOMEN WITH ADEQUATE LACTATION

Time of Withdrawal of Sample	Series	Average Chloride (mg. % calculated as NaCl.)			Average Chloride (mg. % calculated as NaCl.)			
		2 Weeks	3 Weeks	4 Weeks	2 Months	3 Months	4 Months	5 Months
Morning	I	68.0 (45)*	62.0 (13)	52.0 (8)	44.0 (29)	46.0 (18)	43.0 (7)	46.0 (11)
	II	81.6 (32)	57.8 (5)	45.5 (2)	48.4 (8)	65.0 (2)	55.5 (8)	47.5 (24)
Mid-day	I	76.0 (45)	64.0 (13)	67.0 (8)	46.0 (29)	56.0 (18)	50.0 (7)	49.0 (11)
	II	83.7 (32)	57.8 (5)	43.0 (2)	56.2 (8)	67.5 (2)	55.4 (8)	47.8 (24)
Evening	II	93.3 (32)	61.4 (5)	50.0 (2)	52.6 (8)	60.0 (2)	50.2 (8)	48.0 (24)

* The number of observations from which each mean has been calculated is indicated by the figure in brackets.

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TABLE 3A

AVERAGE ELECTRICAL CONDUCTIVITY OF MILK SAMPLES TAKEN FROM WOMEN WITH INADEQUATE LACTATION

Time of Withdrawal of Samples	Series	Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$			Average Conductivity $\times 10^5 \text{ ohm}^{-1} \text{ cm.}^{-1}$			
		2 Weeks	3 Weeks	4 Weeks	2 Months	3 Months	4 Months	5 Months
Morning	I	311 (38)*	294 (15)	278 (4)	337 (15)	259 (6)	258 (8)	202 (2)
	II	301 (2)	252 (5)	261 (8)	268 (13)	258 (9)	216 (2)	260 (3)
Mid-day	I	314 (38)	312 (15)	314 (4)	361 (15)	264 (6)	261 (8)	210 (2)
	II	278 (2)	297 (5)	314 (8)	285 (13)	244 (9)	281 (2)	259 (3)
Evening	II	288 (2)	275 (5)	297 (8)	270 (13)	239 (9)	237 (2)	274 (3)

* The number of observations from which each mean has been calculated is indicated by the figures in brackets.

variation to be expected is greater and so any real difference has less chance of showing itself. It is, therefore, advantageous to have the individuals in the two groups either the same or paired to resemble each other closely. This, however, was not practicable. It is possible that, had the numbers been larger, the electrical conductivity and chloride content of milk at the later stages of lactation might have proved to be significantly lower than the values at the earlier stage for women with inadequate as well as for those with adequate lactation.

The fall in chloride content of women's milk after the first month of lactation is in agreement with the findings of Holt, Courtney, and Fales (1915). Other observers however (Sisson and Denis, 1922; Widdows, Lowenfeld, Bond, Shiskin, and Taylor, 1935; and Ishii, 1937) did not observe any appreciable change in the chloride content of milk taken from women in the second week to fifth months of lactation.

Comparison of Samples from Right and Left Breasts

Determinations have been made of the electrical

conductivity and chloride content of samples of the fore-milk taken from each of the right and left breasts of 152 women. The specimens were taken from women at different stages of lactation and from women with adequate and inadequate supply, but it is impractical to differentiate between the various types. Both electrical conductivity and chloride content values of the two samples taken from the same women often showed considerable differences. Thus the mean of the absolute value of the differences of the electrical conductivities was $30.2 \times 10^{-5} \text{ ohm}^{-1} \text{ cm.}^{-1}$, whilst that of the chloride content was 23.5 mg. per 100 ml. However, although in any one woman there might be a considerable difference between the values for the two breasts, there was no general tendency for the right breast to give either higher or lower values than the left breast. Thus the average electrical conductivity was $208.7 \times 10^{-5} \text{ ohm}^{-1} \text{ cm.}^{-1}$ for the samples from the right breast and $205.7 \times 10^{-5} \text{ ohm}^{-1} \text{ cm.}^{-1}$ for those from the left breast. The corresponding figures for the chloride contents were 64.3 mg. % and 64.4 mg. %. These differences of means are not statistically

TABLE 3B

AVERAGE CHLORIDE CONTENT OF MILK SAMPLES TAKEN FROM WOMEN WITH INADEQUATE LACTATION

Time of Withdrawal of Samples	Series	Average Chloride (mg. % calculated as NaCl.)			Average Chloride (mg. % calculated as NaCl.)			
		2 Weeks	3 Weeks	4 Weeks	2 Months	3 Months	4 Months	5 Months
Morning	I	137.0 (38)*	120.0 (15)	125.0 (4)	157.0 (15)	100.0 (6)	102.0 (8)	70.0 (2)
	II	118.5 (2)	93.8 (5)	116.6 (8)	122.5 (13)	104.1 (9)	75.5 (2)	116.5 (3)
Mid-day	I	140.0 (38)	133.0 (15)	145.0 (4)	175.0 (15)	104.0 (6)	96.0 (8)	73.0 (2)
	II	116.0 (2)	132.0 (5)	153.6 (8)	134.8 (13)	136.2 (9)	124.0 (2)	119.7 (3)
Evening	II	116.0 (2)	121.8 (5)	138.4 (8)	122.0 (13)	89.1 (9)	89.5 (2)	131.3 (3)

* The number of observations from which each mean has been calculated is indicated by the figure in brackets.

significant, nor is the mean of the differences between the values for right and left breasts significantly different from zero, for either the electrical conductivity or the chloride content.

These results are in conformity with those reported by Nozaki (1934) and Ishii (1937 and 1938) who found that, on the average, the chloride content of milk from the right breast was almost the same as that for milk from the left breast, but that the chloride content of the milk from the two breasts of any one woman may differ considerably. It is obvious, in view of these findings, that in using either the electrical conductivity or the chloride content of the milk to assess the probable value of a mother's milk, it is important to make observations on samples from both the right and left breasts.

Discussion

The work reported here reveals the importance of sampling milk for examination with sufficient care if the specimens are to be used to help in assessing the quality of the milk and the probable adequacy of the lactation. It has been shown that in mothers with adequate lactation, the electrical conductivity and chloride content of the milk tend to fall during the second to fourth week, after which they remain approximately constant. In the same mother, there appears to be a rise between early morning and mid-day and the milk from the two breasts may differ very considerably, although there is no general tendency for the milk from the right breast to give either higher or lower values than that from the left. In view of these variations, it is suggested that samples should be taken at least twice a day (before the morning and before the mid-day feed) and that, on each occasion, one sample should be taken from each breast. In assessing the quality of the milk, the values obtained should be compared with standards varying according to the period of lactation. It is suggested that from women with adequate lactation milk should give values which do not significantly exceed the average values shown in Tables 1A and 1B. Milk which gives values for electrical conductivity and chloride content substantially above these averages is to be regarded with suspicion.

Summary

A study has been made of the effect of various factors on the electrical conductivity and chloride content of women's milk. In general, the electrical conductivity and chloride content run closely parallel.

The electrical conductivity and chloride content of milk is generally somewhat greater in samples taken after a breast feed than in samples taken before a breast feed.

Samples of milk taken before the mid-day feed tend to have a higher electrical conductivity and chloride content than samples taken before the morning or evening feeds, but this difference is significant only in the first month of lactation.

The electrical conductivity and chloride content of samples of milk taken from women with adequate milk supply at various periods of lactation show a tendency to fall from the second to the fourth weeks, which is statistically significant, but from this point onwards there is, on the average, no significant variation. In women with inadequate lactation, who show greater variation in the electrical conductivity and chloride content, the variations at the different periods of lactation were not statistically significant.

On the average, milk samples taken from the right breasts of women do not differ significantly from samples taken from the left breasts, but in any one woman the difference in electrical conductivity and chloride content may be considerable. Samples of milk taken from only one breast may give misleading results.

The bearing of these findings on the procedure to be adopted in sampling milk in order to determine the adequacy of lactation is discussed.

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