A STUDY OF THE LACTOSE, FAT AND PROTEIN CONTENT OF WOMEN'S MILK *

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While the limits and variations in the fat and protein content of human milk are well established, considerable uncertainty still exists regarding the question of the amount of lactose in this fluid,¹ a state of affairs largely due to the fact that while reliable and relatively simple methods for the determination of fat and protein have been in use for many years, the question of the technic of sugar determinations in milk is still unsettled. On account of the relatively large quantities of material required when lactose in milk is to be determined either by the polariscope or by one of the copper reduction methods, it is a more or less general custom, when the amount of material is limited, to calculate lactose by difference after having first determined the total solids, ash, protein and fat, a procedure which throws all the errors of the analysis on the sugar.

Last year Folin and Denis² described two methods for the determination of lactose in milk, one a colorimetric procedure based on the reduction of picric acid when treated with sodium carbonate and lactose at the temperature of boiling water, the other a titration method based on the reduction of copper in phosphate solution as described by Folin and McEllroy.³ These methods have the advantage over most of the procedures now in use, first that by means of them it is possible to obtain results of a considerable degree of accuracy in a relatively short time, and second that only 1 or 2 c.c. of human milk is needed for duplicate determinations.

During the past year we have been engaged by the help of the titration method in the collection of data regarding the lactose content of human milk, and for the sake of completeness have included determinations of the fat and protein.

When the samples of milk were sufficiently large, fat was determined by means of the Babcock method; when the amount of material was limited the analyses were made by Bloor's⁴ nephelometric method which requires only 1 c.c. of milk for duplicate determinations.

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1. Holt, Courtney and Fales: *Am. J. Dis. Child.* **10**:229 (Oct.) 1915.

2. Folin & Denis: *J. Biol. Chem.* **33**:521 (March) 1918.

3. Folin & McEllroy: *loc. cit.*, 513.

4. Bloor: *J. Am. Chem. Soc.* **36**:1301, 1914.

Protein was calculated from the total nitrogen values obtained by means of the Kjeldahl-Gunning method, the factor 6.25 being employed.

The experimental work of these investigations was divided into four lines and consisted, first, of a study of the composition of milk at different stages of lactation, the results of which are presented in Table 1; second, of a study of the composition of milk at the beginning and at the end of a single nursing, the results of which are presented in Table 2; third, of a study of the composition of milk taken practically simultaneously from the right and left breasts, the results of which are presented in Table 3, and fourth, of a study of the variations in composition of milk taken at three-hour periods during the course of a single day.

The samples of milk were obtained from the Wet-Nurse Directory, the Boston Eye and Ear Infirmary, the Children's Medical Out-Patient Department of the Massachusetts General Hospital, and from private practice. They were either drawn or expressed from a single breast at a time. The following technic was found to be most satisfactory: draw or express one ounce of milk before the infant is allowed to nurse, then allow the baby to nurse the usual length of time, but never longer than twenty minutes; finally draw or express one ounce of milk after the infant has finished. In this manner samples of the "fore milk" and a sample of the "strippings" are obtained. The figures which are reported later show how essential this is and how faulty conclusions may be drawn from the analysis of milk obtained in an improper manner.

Table 1 gives figures averaged from two samples of milk, one taken before nursing and the other immediately after nursing, except in a few instances, noted in the remarks.

It was found that the amount of lactose was low in colostrum, as has already been described by other investigators. In one instance in which the mother had pneumonia, it was necessary to pump her breasts for six days. The total amount of milk diminished until only one ounce could be obtained on the last day. When the baby was five days old the milk contained 5.8 per cent. sugar; when six days old, the milk contained 5.1 per cent. sugar, and when eleven days old, the milk contained 4.55 per cent. sugar (numbers 75, 76, 77). This sequence of events was probably due to the drying up of the milk rather than to the pneumonia, and is suggestive of what may be expected at the time of weaning. Further investigations are necessary to settle this point. The average amount of lactose in sixty samples was 7.19 per cent. There was a general tendency for the concentration of lactose to increase throughout the period of lactation. During the first ten weeks, two thirds of the samples of milk contained less than 7 per cent.

TABLE 1.—ANALYSES OF BREAST MILK AT DIFFERENT STAGES OF LACTATION

No.	Lactose per Cent.	Fat per Cent.	Protein per Cent.	Age of Child	Age of Mother Years	Number of Preg- nancies	Remarks
172	3.2	....	....	2 days	..	.....	Colostrum
173	7.5	0.8	....	4 days	..	.....	Has never nursed
176	6.7	3.8	2.1	5 days	..	.....	Milk deep yellow color.
75	5.8	....	....	5 days	23	First	Changing from colostrum Mother has pneumonia. Baby not nursing
76	5.1	1.5	3.7	6 days	..	.....	Same as 75
77	4.85	1.81	2.01	11 days	..	.....	Same as 76
22-23	6.6	1.5	1.57	14 days	..	.....	
151-2	7.05	3.3	1.30	17 days	26	.....	
147	7.46	2.43	1.59	17 days	24	Third	
149	6.97	3.16	1.83	17 days	..	.....	Seven months premature
72	7.18	1.5	1.97	18 days	20	First	
90	6.45	1.66	1.96	21 days	21	First	Sample taken before nursing
16-17	6.40	5.8	1.18	21 days	16	Second	Baby gaining normally
20	6.73	9.9	1.18	21 days	16	Second	Baby gaining normally
36-7	6.8	1.8	1.40	21 days	20	First	
38	6.93	3.8	1.48	21 days	18	First	Fat and protein sample
47	7.10	6.4	1.48	21 days	..	.....	Sample before nursing
56	7.20	9.5	1.44	21 days	..	.....	Sample before nursing
131	7.07	4.20	1.58	25 days	23	First	
129	7.20	4.00	2.25	26 days	25	Second	
154	6.94	1.81	1.50	25 days	26	First	
42	6.88	4.65	....	4 weeks	..	.....	Child has eczema of face
142	7.20	2.6	1.27	4 weeks	..	.....	Unknown whether before or after nursing or mixed milk
40	6.96	6.0	1.16	4 weeks	16	Second	Baby gaining, satisfied. Di- gestion good
43	6.68	7.4	1.05	4 weeks	16	Second	Was given 75 grams lactose 3 hours before nursing
45	6.73	6.0	1.35	4 weeks	18	First	Was given 75 grams lactose 3 hours before nursing
58	6.73	9.2	1.42	4 weeks	18	Second	
60	5.49	6.4	2.23	4 weeks	18	First	Fat and protein from a sin- gle sample taken before nursing
156	6.80	3.1	1.63	4 weeks	19	First	
162	6.87	2.18	1.35	4 weeks	21	Third	
145	6.90	3.80	1.48	5 weeks	29	Third	
33	7.05	8.8	1.83	5 weeks	..	Second	Mother producing more milk than baby can take and drawing 12-14 ounces
81	7.00	6.3	1.63	5 weeks	18	Second	
83	6.47	7.05	1.80	5 weeks	22	First	Protein from before nurs- ing, sample only
102	8.20	....	1.56	5 weeks	23	Third	
128	7.2	2.2	1.14	5 weeks	25	First	Single sample taken before nursing
91	6.53	6.36	1.46	6 weeks	16	First	
160	6.04	2.25	1.41	6 weeks	35	Third	
88	6.45	4.9	1.74	7 weeks	21	First	
124	7.8	0.8	1.43	8 weeks	..	.....	Single sample taken before nursing
31	7.43	3.4	1.26	9 weeks	..	Second	
24	6.74	....	....	9 weeks	33	First	
28	6.75	5.0	1.57	9 weeks	38	First	Not quite enough milk for baby
93	6.30	9.9	1.67	9 weeks	22	First	
32	6.94	3.8	1.80	11 weeks	..	Second	Baby weaned because of pneumonia. Milk drawn
136	7.70	5.3	1.18	13 weeks	17	First	
79	7.10	1.64	1.37	18 weeks	28	First	Baby has eczema
135	7.30	0.79	1.05	18 weeks	21	First	Single sample before nursing
153	7.20	3.3	1.05	20 weeks	..	Third	Single sample before nursing
108	8.1	3.0	1.18	22 weeks	..	Second	Baby well. Stools regular with soft curd
117	7.80	2.7	1.22	22 weeks	..	.....	Single sample before nurs- ing. Baby has bronchitis and diarrhea
14	6.45	....	....	25 weeks	..	.....	Mother has diabetes; urine contains 6.95% sugar
158	7.20	2.40	1.22	26 weeks	35	Third	
4	6.98	....	....	28 weeks	30	First	
7	7.36	....	....	28 weeks	20	First	
8	6.06	....	....	28 weeks	26	Third	
220	7.6	4.00	1.16	29 weeks	35	Third	Normal mother and infant
12	6.76	....	....	30 weeks	24	First	
116	8.10	2.2	1.00	30 weeks	..	.....	Single sample before nurs- ing. Baby well
104	8.00	....	1.14	32 weeks	23	First	Fat in sample after nursing, 8.4%. Baby had one nor- mal stool a day
110	7.70	....	1.00	34 weeks	..	Third	One normal stool a day
133	7.30	9.3	1.06	39 weeks	..	.....	Normal baby with normal stools

TABLE 1.—ANALYSES OF BREAST MILK AT DIFFERENT STAGES OF LACTATION—(Continued)

No.	Lactose per Cent.	Fat per Cent.	Protein per Cent.	Age of Child	Age of Mother, Years	Number of Pregnancies	Remarks
106	8.35	4.13	1.09	40 weeks	..	Third	Baby 17 pounds. General condition fair; two yellow stools a day
114	8.09	5.33	1.22	40 weeks	..	Sixth	Stools normal
118	7.70	3.9	1.20	43 weeks	..	.....	Baby under weight has bronchitis and green stools
120	7.25	4.25	1.15	49 weeks	..	.....	From 2 to 3 well digested soft yellow stools a day

TABLE 2.—ANALYSIS OF MILK AT THE BEGINNING AND AT THE END OF A SINGLE NURSING

No.	Before			After			Age of Child	Age of Mother, Years	Number of Pregnancies
	Lactose, per Cent.	Fat, per Cent.	Protein, per Cent.	Lactose, per Cent.	Fat, per Cent.	Protein, per Cent.			
16, 17	6.09	5.3	1.18	6.72	6.4	1.18	3 weeks	18	Second
20, 21	6.82	8.9	1.18	6.64	10.9	1.22	3 weeks	18	Second
22, 23	6.62	1.5	1.57	6.77	5.2	1.57	2 weeks	18	First
24, 25	7.23	....	....	6.25	....	....	9 weeks	33	First
28, 29	6.86	5.0	1.57	6.64	13.4	1.57	9 weeks	38	First
30a, 30	7.2	0.58	1.40	6.00	7.40	....	....	....	....
34, 35	5.45	6.70	1.84	6.64	7.10	1.57	17 days	18	First
36, 37	6.97	1.8	1.40	6.64	....	....	3 weeks	20	First
38, 39	7.04	3.8	1.48	6.82	....	....	3 weeks	18	First
40, 41	6.79	7.1	1.13	7.13	4.9	1.18	4 weeks	16	Second
43, 44	6.94	7.4	1.05	6.43	7.4	1.05	4 weeks	16	Second
45, 46	7.03	4.0	1.65	6.98	8.0	....	4 weeks	18	First
47, 48	7.10	6.4	1.48	4.88	16.0	....	3 weeks	18	First
49a, b	7.18	2.4	1.44	7.62	8.0	1.52	27 weeks	....	....
56, 57	7.20	9.5	1.44	6.57	....	....	3 weeks	18	First
58, 59	6.82	7.4	1.53	6.64	11.0	1.31	4 weeks	18	Second
60, 61	5.16	6.4	2.23	5.82	....	....	4 weeks	18	First
62, 63	5.82	5.6	1.97	5.96	5.2	2.2	....	....	....
67, 68	6.4	2.4	1.83	6.47	3.8	1.92	....	....	....
70, 71	7.58	2.5	1.66	7.40	4.4	1.57	26 weeks	26	Second
72, 73	7.28	1.6	1.97	7.08	1.4	1.98	18 days	20	Second
79, 80	7.50	2.06	1.44	6.7	1.22	1.31	18 weeks	28	First
81, 82	7.0	5.60	1.57	7.0	7.10	1.70	5 weeks	18	Second
83, 84	6.55	5.6	1.80	6.4	9.1	....	5 weeks	22	First
88, 89	6.65	3.2	1.79	6.26	6.6	1.70	7 weeks	21	First
91, 92	6.90	4.52	1.35	6.16	8.00	1.57	6 weeks	16	First
93, 94	6.53	6.48	1.70	6.06	13.3	1.63	9 weeks	22	First
95, 96	6.66	2.48	1.26	6.30	5.40	1.31	....	....	....
97, 98	6.87	2.76	0.96	6.62	....	0.96	....	....	....
99, 100	8.80	1.5	1.22	8.40	2.9	1.18	....	....	....
102, 103	8.20	....	1.43	8.10	....	1.69	5 weeks	23	Third
104, 105	8.00	....	1.14	7.90	8.4	1.10	32 weeks	23	First
106, 107	8.50	3.50	1.09	8.20	4.76	0.89	40 weeks	..	Third
108, 109	8.00	3.20	1.18	8.20	2.70	....	22 weeks	..	Second
110, 111	7.80	....	1.00	7.50	1.09	....	34 weeks	..	Third
112, 113	8.00	4.20	1.35	7.70	7.24	1.44	....	....	....
114, 115	8.09	0.66	....	8.09	10.0	1.22	40 weeks	..	Sixth
118, 119	7.70	4.20	1.09	7.70	3.6	1.31	43 weeks	....	....
120, 121	7.00	1.5	1.22	7.50	8.0	1.09	49 weeks	....	....
129, 130	7.20	2.9	2.30	7.10	5.1	2.20	26 days	25	Second
131, 132	7.10	4.20	1.66	7.00	4.10	1.50	25 days	23	First
133, 134	7.30	5.50	1.06	7.30	13.1	1.05	39 weeks	....	....
138, 139	7.30	2.9	1.13	6.60	5.5	1.30	....	....	....
145, 146	7.00	3.0	1.44	6.80	4.5	1.53	10 weeks	26	Third
147, 148	7.72	1.66	1.61	7.20	3.20	1.57	3 weeks	24	Third
149, 150	7.08	2.64	1.83	6.86	3.68	1.89	3 weeks	..	First
151, 152	7.20	0.10	0.87	6.90	3.30	1.30	2 weeks	26	Third
154, 155	7.08	1.60	1.40	6.80	2.02	1.40	25 days	20	First
156, 157	6.80	2.60	1.57	6.80	3.60	1.70	4 weeks	19	First
158, 159	7.20	2.00	1.22	7.20	2.80	1.22	26 weeks	35	Third
160, 161	6.30	1.70	1.61	5.78	4.00	1.80	2 weeks	24	First
162, 163	6.54	1.90	1.40	7.20	2.40	1.31	4 weeks	21	Third
180, 181	7.50	8.40	1.60	7.20	8.40	1.70	....	....	....
182, 183	6.90	1.70	1.60	6.70	4.60	1.90	....	....	....
184, 185	7.50	1.39	1.35	....	3.68	1.22	....	....	....
222, 223	7.50	....	1.35	7.50	....	1.35	....	....	....

lactose. After the tenth week there were four times as many samples which contained between 7 and 8 per cent. as contained less than 7 per cent., and many others which contained over 8 per cent. of lactose. The weakest milk after the colostrum period contained 5.49 per cent. of lactose and the richest 8.35 per cent.

The percentage of fat in the milk of different women varied within wide limits, the lowest mixed milk being 1.5 per cent. and the highest 9.9 per cent. The average amount of fat in the mixed samples was 3 per cent., which is the same as that found in 119 Russian women by Skvortzov,⁵ and lower than the 4.5 per cent. found by Engel⁶ in ten German wet-nurses. If our wet-nurses only are taken, the average of thirty-five samples is 4.18 per cent. of fat. There does not seem to be any relation between the stage of lactation and the amount of fat in the milk. It seems more probable that the percentage of fat depends more on how completely the breasts are drained and how much of the late milk gets into the sample.

The protein is highest, as would be expected, during the colostrum period. There is a general tendency for the amount of protein to diminish as lactation progresses. It is usually over 1.5 per cent. up to the fourth week and after the twelfth week it averages below 1.2 per cent., the lowest being 1 per cent. So far as we were able to determine with incomplete records, there is no relation between the character of the stools and the amount of total protein.

Table 2 shows the variation in the composition of the milk from the beginning to the end of nursing. There is, as a rule, more lactose at the beginning of nursing than at the end; the difference rarely exceeds 1 per cent.

The percentage of fat, on the other hand, is much greater at the end of the nursing than at the beginning. One example of extreme variation was found in samples 114 and 115 which showed, respectively, 0.66 per cent. fat before nursing, and 10 per cent. after nursing. As a rule, the differences before and after nursing are not so great, and there was usually less than 4 per cent. difference. An occasional sample was very rich both at the beginning and at the end of nursing, as, for example, Nos. 93 and 94, in which the fat was, respectively, 6.48 per cent. before nursing, and 13.3 per cent. after nursing. Occasionally, two samples, one taken before and one after nursing, showed very little change, and in the rare case the milk after nursing showed less fat than before nursing.

5. Skvortzov: *Russk. Vrach.* **11**:1392; *Ref. Chem. Abstr.* **7**: No. 18, 1913.

6. Engel: *Sommerfeld's Handb. d. Milchkunde*, Wiesbaden, 1909, p. 810.

The protein showed less difference in percentage than the fat. It rarely varied more than a few tenths between the beginning and end of nursing. Sometimes it was lower after nursing, and sometimes higher.

The above results emphasize the importance of analyses of milk both before and after nursing, and the uselessness of analyses made (as is too frequently the case) on the first ounce of milk drawn.

Table 3 shows the variation in the composition of the milks taken from the right and left breast of the same woman at about the same time. These figures show that although the milks tend to have the same composition from both breasts, they may be quite different as in Cases 122 and 123, and in Case Cases 18 and 19 where one breast was scarred by a breast abscess.

TABLE 3.—ANALYSIS OF MILK TAKEN SIMULTANEOUSLY FROM THE RIGHT AND LEFT BREAST

No.	Right Breast			Left Breast			Remarks
	Lactose, per Cent.	Fat, per Cent.	Protein, per Cent.	Lactose, per Cent.	Fat, per Cent.	Protein, per Cent.	
85, 87	7.50	2.30	1.60	6.65	6.8	1.60	Right breast taken before nursing; left breast entire quantity
65, 66	7.84	0.73	1.05	7.28	0.63	1.05	Both breasts before nursing
122, 123	7.40	12.0	1.43	7.00	3.80	1.84	Entire amount drawn from both breasts separately
126, 127	7.40	0.7	1.07	7.40	1.4	1.17	Samples taken before nursing
143, 144	7.28	3.5	1.79	7.08	2.4	1.70	
166, 164	7.50	1.6	1.26	7.50	1.5	1.22	Samples taken after nursing
167, 165	7.5	5.0	1.44	7.20	10.0	1.44	Same woman
168, 170	7.5	0.80	0.80	7.70	0.8	0.80	Same woman
169, 171	7.5	2.4	0.90	7.70	1.9	0.80	Same woman
174, 175	6.8	3.3	1.40	7.5	1.8	1.40	Whole of milk drawn, but it did not represent completely empty breasts
30b, 30c	7.2	0.58	1.40	7.2	1.9	1.50	Samples before nursing
18, 19	7.6	2.6	1.18	6.8	8.8	1.01	Right breast normal; left had breast abscess and is scarred

There was a tendency for the volume of the milk to diminish as the day went on, the smallest amount being obtained at 3 p. m. or later. There was very little variation in the amount of lactose and protein, and no rule can be devised from these cases. There were striking variations in the amount of fat, especially in Case 1, and there was a tendency for its concentration to be greater at noon or in the afternoon than at other times of day. There was no relation, however, between the percentage of fat found and the amount of milk drawn from the breast.

TABLE 4.—ANALYSIS OF BREAST MILK TAKEN AT THREE HOUR PERIODS DURING THE COURSE OF A SINGLE DAY

Time	Lactose, per Cent.	Fat, per Cent.	Protein, per Cent.	Volume of Milk, C.c.	Remarks
Observation 1	....	....	....	...	Mrs. E. L.: Age of mother 22 years; age of infant 4 months; first pregnancy; normal infant; weight 15 pounds 11 ounces
Nov. 27, 1917					Breakfast: Cornmeal mush, corned beef hash, muffins, milk and cocoa
6 a.m.	7.30	4.0	1.18	180	Lunch, 10:30 a.m.: Cornmeal gruel with milk
9 a.m.	7.25	6.4	1.26	180	Dinner: Fish, potato, banana salad, ginger bread
12 m.	7.23	12.5	1.31	170	Lunch, 3:30 p.m.: Mellin's food and milk
3 p.m.	7.12	8.0	1.22	128	Supper: Scalloped corn, bread and butter, prunes, cocoa
6 p.m.	7.18	5.3	1.22	157	8 p.m.: Cocoa
10 p.m.	7.23	3.6	1.18	150	
Observation 2	....	....	....	...	Mrs. B. R. H.: Age of mother 23 years; baby born May 18, 1918; weight 12 pounds 15 ounces; gained 7 ounces in past week
July 11, 1918					Breakfast: Oatmeal, hash, potatoes, bread, butter and cocoa
6 a.m.	6.91	4.00	1.35	202	10:30 a.m.: Mellin's food with milk
9 a.m.	7.08	4.56	1.40	150	Dinner: Hamburg steak, rice, carrots, cottage pudding, cocoa
12 m.	7.08	5.32	1.40	120	3:30 p.m.: Cocoa
3 p.m.	7.08	6.02	1.44	130	Macaroni, bread and butter, stewed peaches, cocoa
6 p.m.	7.28	3.62	1.44	120	8:30 p.m.: Cocoa
9 p.m.	7.28	2.84	1.49	90	
Observation 3	....	....	....	...	Mrs. M. N.: Age of mother 20 years; baby born May 15, 1918; weight 10 pounds 9 ounces; gained 6 ounces in past week
July 11, 1918					Food same as in Observation 2
6 a.m.	7.08	4.73	1.26	90	
9 a.m.	6.91	3.92	1.35	60	
12 m.	6.91	3.36	1.31	150	
3 p.m.	7.08	3.72	1.35	50	
6 p.m.	7.08	4.60	1.49	90	
9 p.m.	7.08	2.80	1.23	75	
Observation 4	....	....	....	...	Mrs. M. H.: Age of mother 20 years; baby born April 1, 1918; weight 10 pounds 12½ ounces; gained 6 ounces in past week
July 11, 1918					Food same as in Observation 2
6 a.m.	6.91	2.00	1.22	135	
12 m.	6.81	3.72	1.18	172	
3 p.m.	6.91	3.68	1.05	75	
6 p.m.	6.91	4.20	1.09	105	
9 p.m.	6.80	2.48	1.05	75	
Observation 5	....	....	....	...	Mrs. S. McG.: Age of mother 23 years; baby born May 2, 1918; weight 8 pounds 12 ounces; gained 4 ounces in past week
July 11, 1918					Food same as in Observation 2
6 a.m.	7.08	2.40	1.67	120	
9 a.m.	7.08	3.00	1.40		
12 m.	7.20	4.00	1.31	90	
3 p.m.	7.08	3.48	1.40	120	
6 p.m.	7.08	3.48	1.26	75	
9 p.m.	7.09	2.40	1.35	84	
Observation 6	....	....	....	...	Mrs. R. M.: Age of mother 23 years; baby born Dec. 1, 1917; weight 15 pounds 3 ounces; gained 5 ounces in past week
July 11, 1918					Food same as in Observation 2
6 a.m.	7.18	2.76	1.05	202	
9 a.m.	7.00	4.56	1.12	158	
12 m.	6.90	4.56	1.00	120	
3 p.m.	7.20	3.80	1.05	90	
6 p.m.	7.20	3.74	1.00	150	
9 p.m.	7.20	2.85	1.18	120	

SUMMARY

1. Newer chemical methods make it possible to quantitate accurately the fat, lactose and protein from small samples of milk.

2. There is a rapid increase of lactose during the first few days when colostrum changes into milk, and a further increase as lactation progresses. The reverse is true of protein which after the first rapid decrease during the change from colostrum into milk tends to further decrease during the course of lactation. After the colostrum period there does not seem to be any relation between the stage of lactation and the amount of fat in the milk.

3. There is usually a higher percentage of lactose at the beginning of a single nursing than at the end. Although this difference may be one or more per cent., it is usually less. It is almost the rule for the percentage of fat to be much higher at the end of nursing than at the beginning. There is very little, if any, difference in the protein.

4. The milks taken simultaneously from both breasts of the same woman tend to have the same composition, but often vary in respect to the percentage of fat.

5. Toward the middle or later afternoon the volume of milk in a woman tends to diminish. The percentage of fat is as a rule higher at mid-day or mid-afternoon than at other times of day.