

THE EFFECT OF INANITION UPON THE YIELD AND COMPOSITION OF COWS' MILK¹

By O. R. OVERMAN and K. E. WRIGHT, *Department of Dairy Husbandry, University of Illinois*

INTRODUCTION

Very little work has been reported on the effect of inanition upon the yield and composition of milk. Only one record was found in the literature of an inanition period as long as 48 hours. Several investigators report upon the effects of underfeeding. Lami (2)² starved a cow for 36 hours and at the end of the starvation period found increases in the percentages of total solids (13.6 to 14.3 per cent) and in nitrogenous matter and ash (4.2 to 6.25 per cent.) He found a slight reduction in fat (4.4 to 4.15 per cent) and a decided reduction in lactose (5 to 3.9 per cent).

Eckles and Palmer (1) studied the influence of underfeeding upon the milk of a number of cows. They found that high fat tests uniformly accompanied underfeeding, that there was no uniform effect on the percentages of the other milk components, and that the percentage of fat was not affected in any of the experiments.

Porcher (4) states that starvation for two days showed no appreciable injury to the milk.

Ragsdale and Swett (5) showed that a sudden reduction of the total amount of feed to one-half the normal amount increased the percentage of fat and decreased the amount of milk produced.

Taylor and Husband (6), in their study of the effect of variations in the nature of the diet upon the percentage composition of the milk of the goat, state that (1) the percentages of protein, fat, and ash vary inversely and the percentage of lactose varies directly as the daily volume, the greatest variation being shown by the fat and the least by the inorganic elements; (2) there is an inverse relationship between the percentage of lactose and the percentages of all the other constituents of the milk, this being particularly apparent in the case of the fat. They suggest that the quantity of lactose elaborated by the mammary glands controls the daily volume of the milk, and that, therefore, the rate of its elaboration controls the rate of milk secretion.

The present study was undertaken to learn the effect of total absence of feed upon the yield and the composition of the milk produced.

DESCRIPTION OF ANIMALS USED

Three cows, Nos. 1, 11, and 742, were used in this investigation. These cows, while in the experimental herd of the dairy department at the University of Illinois, gave a positive reaction to the tuberculin test and were isolated from the herd until slaughtered.

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² Reference is made by number (italic) to "Literature cited," p. 644.

Cow No. 1, born October 4, 1923, was predominantly Holstein, probably less than one-quarter Guernsey. She calved March 10, 1926, and was in her first lactation during this investigation. She was bred May 27, 1926.

Cow No. 11, born May 12, 1921, was a high-grade Holstein. She calved December 11, 1925, and was in her third lactation. She was due to calve February 27, 1927. Cows Nos. 1 and 11 were condemned for slaughter August 11, 1926, following a positive reaction to the tuberculin test. The latest previous test, January 26, 1926, had given negative results.

Cow No. 742, born December 10, 1922, was a second generation Guernsey-Holstein cross. She calved January 13, 1927, for her second lactation. She was condemned February 15, 1927, following a positive reaction to the tuberculin test. The latest previous test, December 15, 1926, was negative.

The cows were in good flesh at the beginning of the investigation and were apparently in good physical condition. Post-mortem examinations by competent veterinary clinicians showed very slight glandular lesions and that tuberculosis was present only in its early stage.

EXPERIMENTAL PROCEDURE

The cows were given their customary feed and care during a 10-day preliminary period and were milked regularly twice each day at about 6 a. m. and 6 p. m. During this period three composite samples of milk were taken for each cow. The first sample represented all the milk produced during the first four days. The second and third samples each represented all the milk produced in successive three-day periods. Following the preliminary period the cows were given water but no feed. The inanition period continued five days for cow No. 11 and six days for cows Nos. 1 and 742. The treatment of the animals, except for the absence of feed, was precisely the same as during the preliminary period.

TABLE 1.—Composition of milk from cow No. 1 preceding and during the inanition period

Date (1926)	Milk yield	Total solids	Fat	Protein	Lactose (gravity)	Ash	Specific gravity	Total solids	Fat	Protein	Lactose	Ash
	<i>Lbs.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>		<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>
Oct. 25 ^a -----	^b 13.4	12.63	4.03	3.27	4.40	0.706	1.0342	1.6924	0.5400	0.4382	0.5896	0.09460
Oct. 28 ^a -----	^d 13.3	12.94	4.22	3.24	Lost.	.708	1.0356	1.7210	.5613	.4309	Lost.	.09416
Oct. 31 ^a -----	^d 13.5	12.94	4.14	3.32	4.47	.716	1.0297	1.7469	.5589	.4482	.6035	.09666
Oct. 31, p. m.-----	13.1	12.72	4.02	3.30	4.35	.712	1.0305	1.6663	.5266	.4323	.5099	.09327
Nov. 1, a. m.-----	10.6	12.64	4.02	3.24	4.30	.738	1.0293	1.3398	.4261	.3434	.4558	.07823
Nov. 1, p. m.-----	4.4	16.28	7.53	3.85	3.80	.803	1.0277	.7163	.3312	.1694	.1672	.03533
Nov. 2, a. m.-----	3.3	18.04	8.70	3.50	3.10	.930	1.0283	.5953	.2871	.1155	.1023	.03069
Nov. 2, p. m.-----	2.0	23.12	13.34	4.97	2.60	1.063	1.0290	.4624	.2668	.0994	.0520	.02126
Nov. 3, a. m.-----	1.5	23.79	13.94	5.62	2.04	1.197	1.0286	.3569	.2091	.0843	.0306	.01796
Nov. 3, p. m.-----	.7	25.41	15.17	5.72	1.60	1.207	1.0271	.1779	.1062	.0400	.0112	.00845
Nov. 4, a. m.-----	.9	26.14	14.36	6.80	1.50	1.115	1.0286	.2353	.1292	.0612	.0135	.01004
Nov. 4, p. m.-----	.7	24.18	13.77	6.23	1.77	1.112	1.0271	.1693	.0964	.0436	.0124	.00778
Nov. 5, a. m.-----	.7	26.22	14.91	6.41	1.83	1.114	1.0250	.1835	.1044	.0449	.0128	.00780
Nov. 5, p. m.-----	.5	28.83	18.23	6.96	1.55	1.097	1.0275	.1442	.0912	.0348	.0078	.00548
Nov. 6, a. m.-----	.9	30.17	19.15	7.09	1.70	1.078	.0265	.2715	.1724	.0638	.0153	.00970

^a A composite sample made by taking proportional amounts from the milk produced at each milking for 4 days.

^b Average milk yield per milking for 4 days.

^c Composite samples made by taking proportional amounts from the milk produced at each milking for 3 days.

^d Average milk yield per milking for 3 days.

All samples were analyzed for percentages of total solids, fat, total protein, lactose, and ash. The methods of analysis employed by the Association of Official Agricultural Chemists were used, except that about 5 gm. of sample were employed for the fat determination by the Roese-Gottlieb method, and about 10 gm. of sample and 3 c. c. of strong nitric acid were used in the ash determination. The lactose was determined by the reduction method, the cuprous oxide being weighed directly. The specific gravities were taken at 20° C. with a chainomatic specific gravity balance.

The results obtained, including milk yields, percentages of total solids, fat, protein, lactose, and ash, and the yields of the components of the milk, are given in Tables 1, 2, and 3, and are graphically represented in Figures 1, 2, 3, and 4.

TABLE 2.—*Composition of milk from cow No. 11 preceding and during the inanition period*

Date (1926)	Milk yield		Total solids	Fat	Protein	Lactose (gravity)	Ash	Specific gravity	Total solids	Fat	Protein	Lactose	Ash
	Lbs.	P. ct.											
Oct. 25 ^a	12.9	12.83	3.93	3.48	4.45	0.748	1.0351	1.6551	0.5070	0.4489	0.5741	0.08649	
Oct. 28 ^c	^d 13.3	12.86	3.46	3.41	Lost.	.731	1.0348	1.7104	.4602	.4535	Lost.	.08722	
Oct. 31 ^c	^d 13.9	12.90	3.84	3.49	4.56	.740	1.0301	1.7931	.5338	.4851	.6358	.10286	
Oct. 31, p. m.	13.3	12.70	3.75	3.53	4.50	.729	1.0331	1.6891	.4988	.4695	.5985	.09696	
Nov. 1, a. m.	11.8	13.04	4.00	3.47	4.45	.698	1.0298	1.5387	.4720	.4095	.5251	.08236	
Nov. 1, p. m.	6.7	14.49	5.28	3.50	4.15	.756	1.0311	.9708	.3538	.2845	.2781	.05065	
Nov. 2, a. m.	4.8	16.92	7.22	4.30	3.68	.893	1.0290	.8122	.3466	.2064	.1766	.04286	
Nov. 2, p. m.	3.1	21.08	10.09	5.77	2.82	1.129	1.0341	.6535	.3128	.1789	.0874	.03500	
Nov. 3, a. m.	2.6	21.98	10.67	6.14	2.77	1.220	1.0351	.5715	.2774	.1596	.0720	.03172	
Nov. 3, p. m.	2.5	21.38	10.67	6.37	2.62	1.177	1.0335	.5345	.2518	.1593	.0655	.02942	
Nov. 4, a. m.	2.2	23.49	11.80	6.59	2.62	1.086	1.0306	.5168	.2596	.1450	.0576	.02389	
Nov. 4, p. m.	2.3	23.90	12.38	6.80	2.70	1.274	1.0342	.5497	.2847	.1564	.0621	.02930	
Nov. 5, a. m.	1.6	26.48	14.88	6.88	2.55	1.225	1.0294	.4237	.2381	.1101	.0408	.01960	

^a A composite sample made by taking proportional amounts from the milk produced at each milking for 4 days.

^b Average milk yield per milking for 4 days.

^c Composite samples made by taking proportional amounts from the milk produced at each milking for 3 days.

^d Average milk yield per milking for 2 days.

TABLE 3.—*Composition of milk from cow No. 742 preceding and during inanition period*

Date (1927)	Milk yield		Total solids	Fat	Protein	Lactose (gravity)	Ash	Specific gravity	Total solids	Fat	Protein	Lactose	Ash
	Lbs.	Pct.											
Feb. 21 ^a	20.5	14.19	5.27	3.06	4.64	0.717	1.0307	2.9090	1.0804	0.6273	0.9512	0.14698	
Mar. 1 ^c	^d 21.8	13.16	4.28	3.00	4.87	.688	1.0302	2.8689	.9330	.6540	1.0617	.14998	
Mar. 4 ^c	^d 22.6	12.96	4.18	2.93	4.80	.673	1.0298	2.9290	.9447	.6622	1.0848	.15210	
Mar. 4, p. m.	22.1	12.74	4.15	2.84	4.76	.642	1.0300	2.8155	.9172	.6276	1.0520	.14138	
Mar. 5, a. m.	22.9	13.22	4.69	2.73	4.55	.649	1.0259	3.0274	1.0740	0.6252	1.0420	.14862	
Mar. 5, p. m.	12.6	17.54	9.23	2.99	4.60	.726	1.0244	2.2100	1.1630*	.3767	.5796	.09148	
Mar. 6, a. m.	9.3	20.00	11.57	3.40	3.72	.804	1.0251	1.8600	1.0760	.3162	.3460	.07477	
Mar. 6, p. m.	8.0	18.22	9.56	3.18	3.80	.790	1.0247	1.4576	.7648	.2544	.3040	.06320	
Mar. 7, a. m.	7.6	18.22	9.72	3.30	3.78	.782	1.0219	1.3847	.7387	.2508	.2873	.05943	
Mar. 7, p. m.	7.1	17.32	8.74	3.35	3.72	.828	1.0274	1.2297	.6205	.2378	.2641	.05879	
Mar. 8, a. m.	4.8	19.17	10.28	3.53	3.66	.906	1.0245	.9202	.4934	.1694	.1757	.03439	
Mar. 8, p. m.	7.2	16.66	8.32	2.98	3.83	.762	1.0271	1.1995	.5990	.2146	.2758	.05486	
Mar. 9, a. m.	9.1	17.74	9.69	2.75	3.93	.676	1.0243	1.16143	.8818	.2502	.3576	.06152	
Mar. 9, p. m.	7.4	18.44	10.11	3.04	3.79	.781	1.0226	1.3646	.7481	.2250	.2805	.05779	
Mar. 10, a. m. ....	.5	19.06	10.18	3.34	4.07	.829	1.0214	.0953	.0509	.0167	.0204	.00414	

^a A composite sample made by taking proportional amounts from the milk produced at each milking for 4 days.

^b Average milk yield per milking for 4 days.

^c Composite samples made by taking proportional amounts from the milk produced at each milking for 3 days.

^d Average milk yield per milking for 3 days.

RESULTS

The milk yield and the content of the various components showed only the normal fluctuations during the preliminary feeding period. However, after the beginning of the inanition period, the yield of milk dropped very rapidly and marked changes in the composition were found. Cow No. 1 produced an average of 13.4 pounds of milk per milking during the preliminary period. After three days without feed her production had dropped to less than 1 pound per milking and varied from 0.5 to 0.9 of a pound each milking during

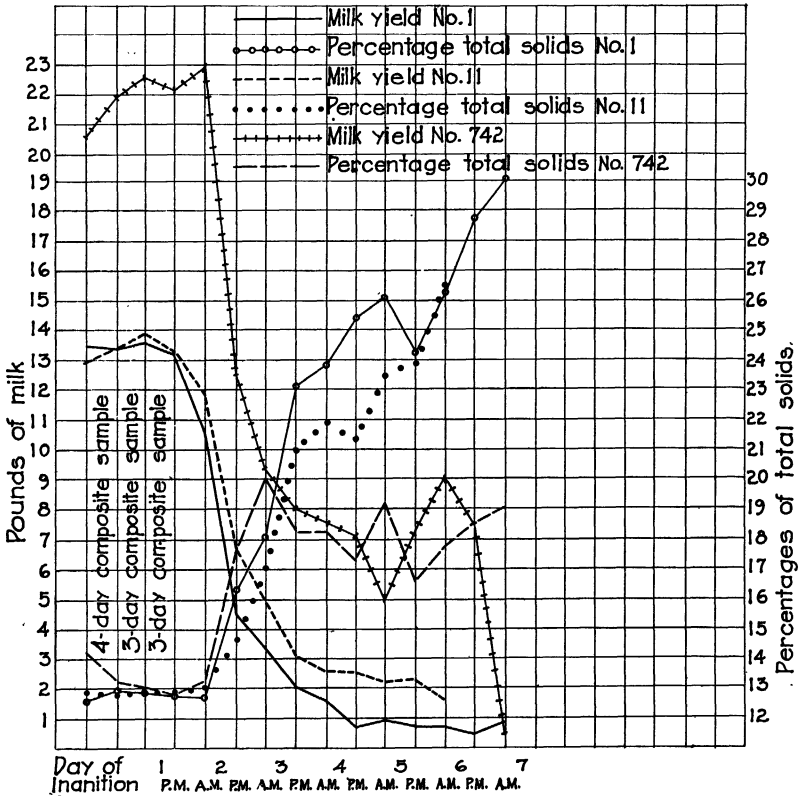


FIG. 1.—Milk yields and percentages of solids preceding and during inanition period

the remainder of the period. The percentage composition of her milk also changed very radically. The total solids increased from an average of 12.82 per cent during the preliminary period to 30.17 per cent for the last milking during inanition. The fat increased from an average of 4.12 to 19.15 per cent; the protein from an average of 3.28 to 7.09 per cent; the ash from an average of 0.710 to 1.207 per cent in the seventh milking during inanition. In the remaining five milkings the ash varied between 1.078 and 1.115 per cent. The lactose averaged 4.43 per cent for seven days of the preliminary period (this determination on the second composite sample was lost) and decreased to 1.6 per cent in the seventh milking of the inanition period. It varied from 1.50 to 1.83 per cent in the remaining five milkings.

The trend of the production and of the composition of the milk was the same for cow No. 11 as for cow No. 1. The milk yield decreased from an average of 13.3 pounds per milking during the preliminary period to 2.6 pounds at the end of three days' inanition, and decreased slowly through the remaining four milkings. The percentage of total solids increased from an average of 12.86 to 26.48 per cent; fat from 3.76 to 14.88 per cent; protein from 3.46 to 6.88 per cent; and ash from 0.740 to 1.274 per cent. The lactose

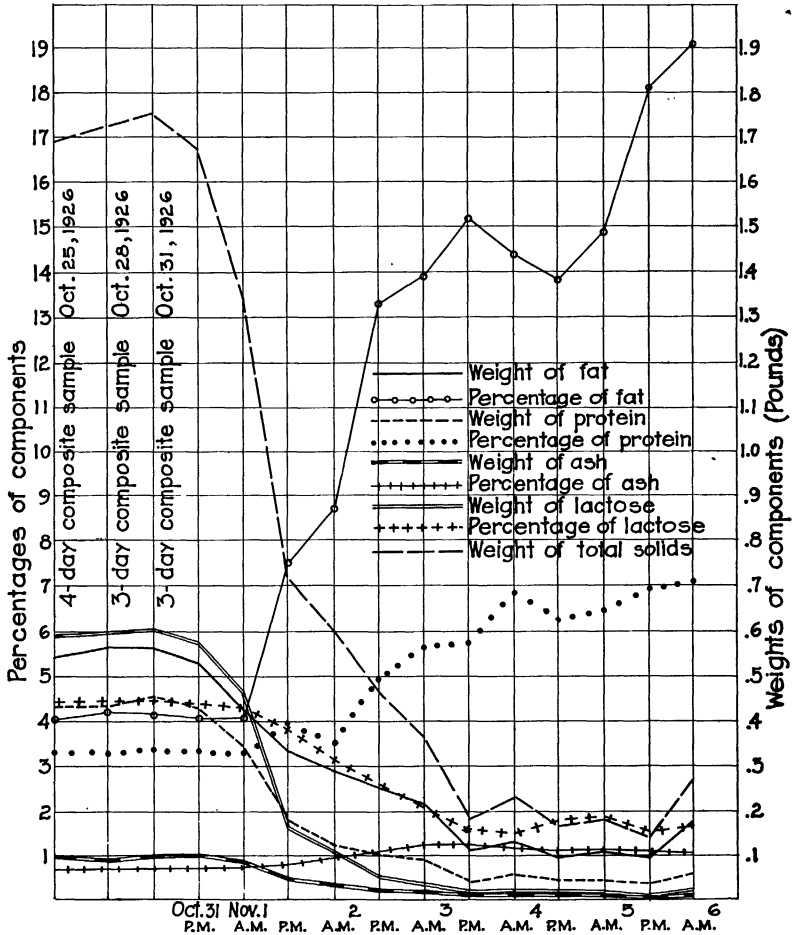


FIG. 2.—Percentages and yields of milk components for cow No. 1, preceding and during inanition period

averaged 4.50 per cent during 7 days of the preliminary 10-day period, and decreased to 2.55 per cent during inanition.

The analyses of the milk samples from cow No. 742 showed much less variation than for the other two cows. The milk yield decreased from an average of 21.5 pounds per milking during the preliminary period to 8 pounds at the end of three days' inanition, and fluctuated between 4.8 and 9.1 pounds during the next six milkings. During the last 12 hours of inanition only 0.5 pound of milk was produced, while during the preceding 12 hours the production was 7.4 pounds.

The percentage of total solids increased from an average of 13.49 to a maximum of 19.06; and the fat increased from an average of 4.63 to a maximum of 11.57 per cent at the beginning of the third day of inanition and fluctuated between 8.32 and 10.28 per cent during the remainder of the inanition period. The protein averaged 3.01 per cent during the preliminary period and varied between 2.73 and 3.53 per cent during inanition, without showing any regular increase. The lactose decreased from an average of 4.76 per cent in the pre-

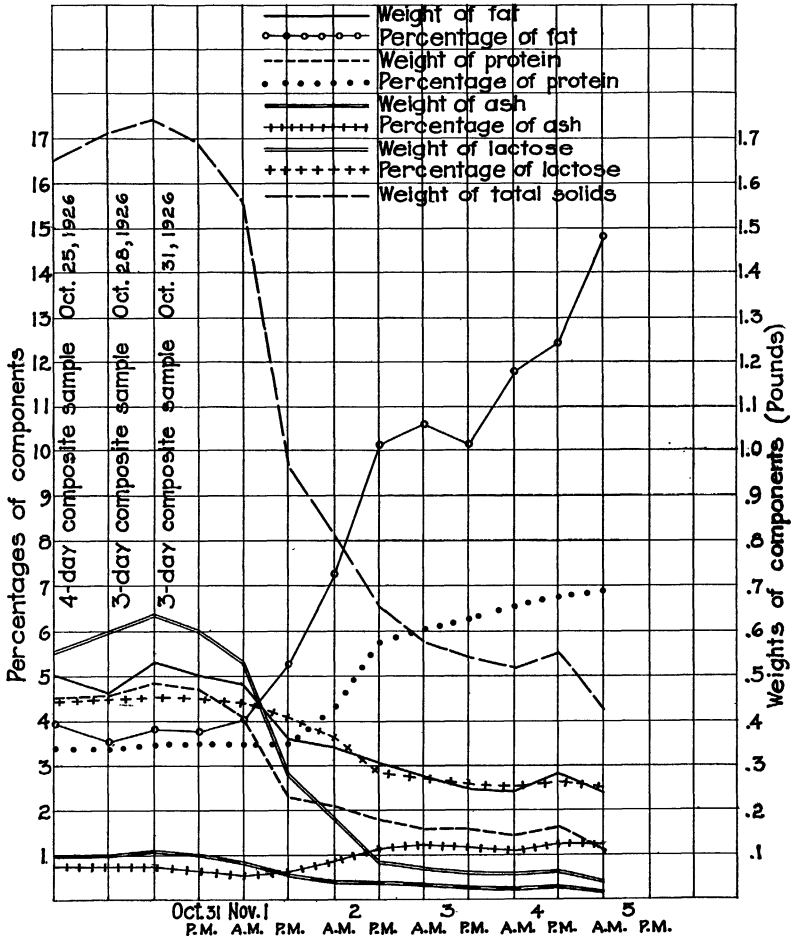


FIG. 3.—Percentages and yields of milk components for cow No. 11, preceding and during inanition period

liminary period to 3.66 per cent for the eighth milking during inanition, then increased slightly, varying from 3.79 to 4.07 per cent during the last four milkings. The value for the last milking (4.07 per cent) is, however, decidedly below the preliminary average for this cow. The ash content averaged 0.696 per cent during the preliminary period and for the most part was above this value during inanition, reaching for one milking a maximum of 0.906 per cent.

The specific gravity of the milk tended to be lower during inanition than during the normal feeding period.

DISCUSSION

The results obtained in this investigation show that inanition exerts a profound influence upon the yield and the composition of the milk of the dairy cow. As the milk production decreased the percentage content of all the components except lactose increased. The increases in percentages of fat were greatest for cow No. 1 and showed a maximum of 4.65 times the average during the preliminary 10-day feeding period. For cows Nos. 11 and 742, the increases were, respectively, 3.95 and 2.50 times the preliminary 10-day aver-

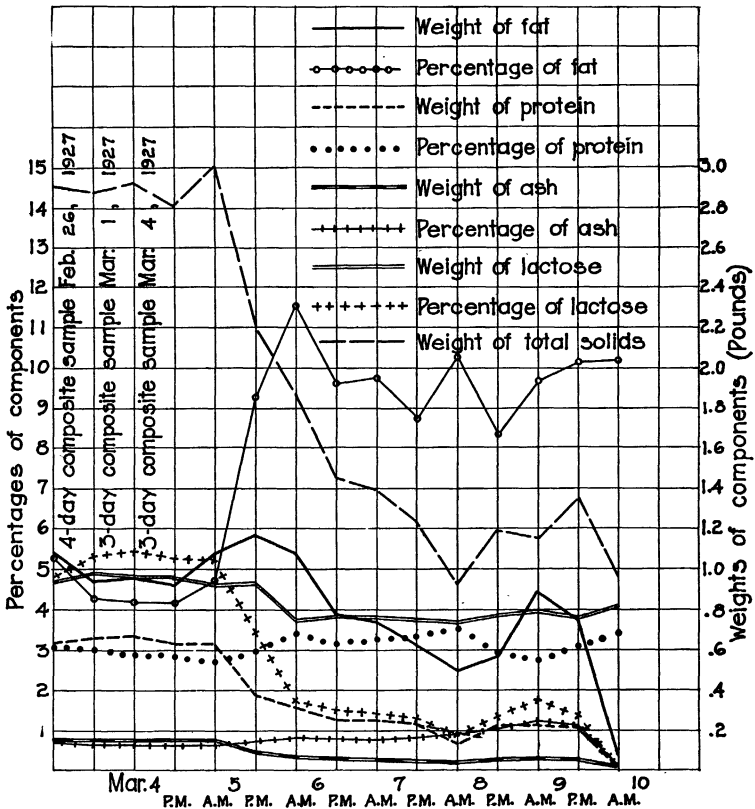


FIG. 4.—Percentages and yields of milk components for cow No. 742, preceding and during inanition period

age. The maximum percentage of total solids for cow No. 1 was 2.35 times the preliminary average. For cows Nos. 11 and 742, it was, respectively, 2.06 and 1.49 times the preliminary average. The maximum percentages of protein for the three cows were, respectively, 2.14, 1.99, and 1.17 times the preliminary average. The maximum percentages of ash were, respectively, 1.70, 1.72, and 1.30 times the preliminary average.

The lactose, however, decreased from an average of 4.43 per cent to a minimum which was 33.9 per cent of that value for cow No. 1. The corresponding values for cows Nos. 11 and 742, were, respectively, 56.7 and 76.9 per cent of the preliminary average.

These changes in composition of milk, which were caused by lack of feed, agree with the observations of other investigators cited in the introduction to this paper. The reduction in the percentage of lactose also supports the statement made from this laboratory that the lactose content of milk is especially sensitive to physiological disturbances (3). As the quantity of lactose produced by the cows studied in this investigation decreased much more rapidly than did the volume of milk, it appears that the suggestion of Taylor and Husband (6) does not apply to cows subjected to inanition, since they state that the quantity of lactose elaborated by the mammary glands controls the daily volume of the milk, and that, therefore, the rate of its elaboration controls the rate of milk secretion.

The reduction in the milk flow was less rapid and the variations in composition were less marked for cow No. 742 than for the other two cows. This may be explained by the fact that this cow had begun her lactation only a short time previous to the beginning of the investigation, while the other two cows were approaching the end of their lactations. This explanation is in accord with the belief of Eckles and Palmer (1, p. 69), that the milk flow of the cow is stimulated by two factors chemical and nervous. It is the opinion of these investigators that the chemical factor is more or less independent of the food supply and predominates for a period of time after parturition; and that the nervous factor is almost entirely dependent on the food supply and predominates or replaces the chemical stimulus after the lactation period has attained a certain stage.

SUMMARY

The composition of the milk of three cows subjected to inanition has been determined and has been compared with the composition of the milk of the same cows when kept under normal conditions just previous to the inanition period.

It has been shown (1) that as the period of inanition progresses the milk flow decreases, the percentages of total solids, fat, protein, and ash increase, while the specific gravity and the percentage of lactose decrease, and (2) that the changes are not so marked when inanition occurs early in the lactation period.

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