STUDIES OF SOME OF THE PHYSICAL AND CHEMICAL PROPERTIES OF COLOSTRUM

by

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INTRODUCTION

Recent work at this Agricultural Experiment Station concerned with the composition of the colostrum of the dairy cow has been reported in a series of five publications. In the earliest of these papers, Parrish et al. (17) showed that the tocopherol levels were higher in the colostrum than in later milk. A short time later, Parrish et al. (19) reported that the total protein content of colostrum was not definitely related to prepartal diets containing low and high concentrations of protein, although the non-protein nitrogen content of the mammary secretions was increased by the high protein diet.

Parrish et al. (15) also pointed out that the vitamin A concentrations in colostrum and transition milk were increased by high intakes of vitamin A concentrates during the prepartal period and, if the concentrates were fed at high levels, the concentrations of carotenoids in the colostrum were lowered. In another contribution to this series, Parrish et al. (18) reported that the increased levels of vitamin A in colostrum and early milk were not dependent on the form or combination of the vitamin A and/or tocopherols fed the animals prior to the date of parturition. The most recent report (Parrish et al. 20) indicated that the specific gravity, total solids, solids-not-fat, total proteins and ash decreased during the transition period, whereas the lactose content increased during this period. The fat content was highly variable. The authors concluded that proteins contributed a greater percentage to the total energy of the colostrum than to that of milk, while lactose and fat contributed a greater percentage of energy to milk than to the first colostrum.

Colostrum has been found to contain globulins similar to the immune globulins found in bovine serum. The immunological aspects of colostrum have been summarized in an excellent review by Smith (25).

The composition of colostrum and transition milk has been investigated by several other workers. Dann (6), a pioneer in studies of the vitamin A content of colostrum, examined the colostrum of fourteen Shorthorn dairy cows and found the vitamin A content of the secretion was ten to 100 times higher than later milk. Stewart and McCallum (28) studied the colostrum of 100 dairy cows and observed wide variations in the vitamin A content. These workers suggested the vitamin A content of the early secretion might be effected by the length of the non-lactation period. During the transition period, the vitamin A levels were found to fall rapidly until normal levels were reached on the 3rd day postpartum (Sutton et al. 29), as also reported by Parrish et al. (15).

Spielman et al. (27) studied the relationship of the prepartum diet to the vitamin A and carotene content of bovine colostrum. Supplementation of the ration with carotene increased the amounts of this constituent in colostrum but did not effect the concentrations of vitamin A in the secretion. These authors also found that supplementation of the ration with vitamin A increased the levels of this vitamin in colostrum. Regardless of the form of vitamin A in the ration, the ester form of the vitamin was predominant in the early secretion (Parrish et al. 16, and Spielman et al. 27).

Seasonal trends were detected in the vitamin D content of colostrum by Eaton et al. (7), the values obtained in the latter part of the pasture season being materially higher than those values obtained near the end of the spring pasture grazing period.

Pearson et al. (21) reported that thiamine and riboflavin were present in relatively large amounts in colostrum and, as in the case of the fat soluble factors, the amounts of these constituents decreased after the first milkings. These results were similar to those reported by Sutton et al. (29) who found colostrum was approximately three times as rich in riboflavin as milk collected on the 10th day postpartum. Pearson et al. (21) also found that the nicotinic acid content of the mammary secretion remained constant during the transition period; whereas the pantothenic acid content increased.

Immediately following parturition, the choline content of colostrum was found to be comparatively high but decreased rapidly with subsequent milkings (Waugh et al. 33).

Lawrence et al. (11) suggested a correlation between the biotin and pantothenic acid content of early milk. The amounts of both constituents increased during the transition period.

Anantakrishnan et al. (1) found that the fatty acid composition of colostrum differed from that of typical butterfat. Oleic acid was found to decrease and the low molecular weight acids were found to increase during the transition period. Earlier investigations by Baldwin and Longenecker (2) were contrary to this.

Kuiken and Pearson (10) and Sarkar et al. (22), in studies of the essential amino acid composition, found significantly higher concentrations of valine, arginine, threonine and tryptophan in colostrum than in milk, whereas the reverse was true for leucine, isoleucine, phenylalanine and methionine.

In analyses of the mineral content of colostrum and transition milk, Garrett and Overman (8) reported levels of calcium, magnesium, sodium, phosphorus and chloride decreased rapidly during the early milkings until a constant level was attained. According to Luecke et al. (14), early colostrum contained small but significant quantities of iron, cobalt and copper.

Van der Burg (30) has reported data on the pH and specific gravity of the first colostral secretion of a large number of cows. The colostrum was slightly acidic (average pH 6.22) and had a specific gravity higher than normal milk. The specific gravity in early milkings was found by Parrish et al. (20) to decrease rapidly until the 4th milking after which time the decrease was less rapid.

The buffering capacity of colostrum, as reported by Koestler (9), is greater than the buffering capacity of normal herd milk. The data, however, were limited.

Schuette and Huebner (24) published a small amount of information on the freezing point of the mammary secretion from parturition until the 11th day postpartum. A gradual rise in the freezing point was noted until the 5th day after which time the value remained nearly constant.

Although, as indicated by the review of the literature, colostrum has received considerable study, the published data on certain chemical and physical properties, pH, buffering capacity, reducing capacity and osmotic pressure, are limited. It was considered desirable to undertake a study of the foregoing properties since it was believed such data might be of value in obtaining a better understanding of the digestion and absorption of colostrum by the new-born calf.

EXPERIMENTAL

Feeding and Management of Dairy Cows

All cows included in the experiment were fed similar rations prior to parturition. Animals that calved before the middle of April were fed the same ration during the milk and colostrum collection period as they received before parturition. This was a typical winter barn ration consisting of: Atlas sorghum silage, alfalfa hay and a grain concentrate mixture (16 per cent protein). After the middle of April, the cows also received rye pasture starting on the 4th day postpartum.

Additional data on feeding and management of experimental animals is placed in the appendix (Table A1).

Collection of Samples

The cows were milked as completely as possible, either by machine or hand, shortly after parturition (within 4 hours). Subsequent samples were collected at regular morning and evening milking periods which were 12 hours apart. The calves were not allowed to nurse so that representative samples could be obtained. The mammary products were well mixed before sampling. When analyses could not be made immediately after collection, the colostrum was placed in the refrigerator at approximately 4° C. Analyses usually were made within 24 hours after the mammary secretion had been withdrawn, and the maximum time before analyses was 60 hours. The colostrum or milk from each cow was analyzed separately for the first four milkings and as composites for 5th and 6th, 7th and 8th, 15th and 16th, and 27th and 28th milkings.

Analytical Procedures

<u>pH</u>. A Beckman pH meter, Model G, equipped with external electrodes, was employed to determine the pH of the samples. After the instrument had been turned on a short interval, it was standardized with a standard buffer solution. The mammary products were placed in a water bath and heated to room temperature. After the samples were poured several times to insure proper mixing, a portion was placed in a beaker and the pH read on the instrument.

<u>Buffering Capacity</u>. One hundred ml of the thoroughly mixed colostrum or milk (adjusted to room temperature) was pipetted into a 400 ml beaker. In order to study the buffering action at pH's

lower than the initial pH of the sample, 0.100 N hydrochloric acid, standardized with pure sodium carbonate, was added in small aliquots to the beaker containing the sample. The mixture was stirred for one minute and the pH read after each addition of standard acid. Similarly, standardized base, 0.100 N sodium hydroxide, was used to titrate another 100 ml aliquot of the sample. Titration curves were prepared by plotting the pH against the milliliters of standard acid or standard base used in the titration of the mammary secretion.

Reducing Capacity. The total reducing capacity of colostrum and transition milk was determined by a modification of the method of Crowe et al. (4) for dried milk. In preliminary work, it was found that colostrum had a higher reducing capacity than the reconstituted milk which the aforementioned workers used in their investigations. Because of the high reducing capacity of colostrum, the following slightly modified procedure was used.

Five ml of colostrum or transition milk was added to a volumetric flask and diluted to 100 ml with distilled water. Five ml of Clark-Lubs buffer, pH 6.6, and five ml of one per cent potassium ferricyanide solution were added to a five ml aliquot of the diluted colostrum. After thorough mixing, the solution was held at 50° C. in a water bath for 20 minutes and then cooled in an ice bath to 20° C. or lower. Five ml of ten per cent trichloracetic acid was added to the cooled solution and mixed thoroughly. The solution was filtered through a No. 40 Whatman filter paper. Five ml of the filtrate was transferred to a colorimeter tube, and five ml of water and one ml of 0.5 per cent ferric chloride were added. The system was allowed to stand at room temperature for exactly 10 minutes. After this period of time had expired, readings of color development were taken on an Evelyn photoelectric colorimeter (equipped with a 660 mu filter) which had been previously set to read 100 per cent transmission with a reagent blank. The reagent blank was prepared similar to the unknown solution except that five ml of water was substituted for the diluted colostrum.

The results were expressed as grams of ferricyanide reduced. A calibration curve was prepared using pure potassium ferrocyanide. To prepare the curve, known concentrations of ferrocyanide were used instead of the diluted colostrum in the above procedure. Crowe et al. (4) had previously published a graph of these calibration data.

Osmotic Pressure. The method of Lillie (13), wherein collodion bags were used to measure osmotic pressure, was employed in these investigations. Each collodion bag was made by filling a 50 ml Erlenmeyer flask with collodion (U. S. P., Merck) and then pouring the collodion out of the flask while rotating it slowly for exactly 2 minutes. The flask, then empty except for a thin coating of collodion adhering to the inner surface, was dried for 2 minutes at room temperature. After this interval, the flask was placed under the faucet and tap water was allowed to run into it in a gentle stream for 5 minutes. Following this treatment the flask was rinsed with distilled water and the collodion membrane was removed.

Each bag was filled with a sample of the mammary product under study and closed by a rubber stopper containing a glass tube which served as a manometer. The bag was tied firmly to the stopper with a string. The bag containing the liquid and fitted with the manometer was placed in a beaker containing approximately 400 ml of water. The surface of the rubber stopper was adjusted to lie slightly above the surface of the water and the glass tube pushed into the stopper until the liquid rose 20 to 30 mm in the tube. This height, corresponding to the zero reading, was marked on the manometer. The apparatus was allowed to stand at room temperature until a maximum rise was reached after which the height of the liquid in the manometer decreased. The maximum was easily read since the fluid left a thin film of protein material on the inner surface of the tube. The difference in the maximum rise and the initial reading was recorded as the osmotic pressure of the solution.

Results

pH. The hydrogen ion concentration (Table 1) of the first colostral secretion was variable within the range from 6.00 to 6.61. The average pH of the first samples was 6.32. Considering secretions from the individual animals, the pH of the eight samples collected over the 2-week period of study did not follow a definite pattern; however, when the average results of all cows were compared, an increase was noted with increasing time after calving. The increment of increase was small, an average value of pH 6.50 being found in the samples collected on the 14th day.

Table 1. pH of colostrum and early milk.

Cow No.	No. of milking 1	2	3	4	5&6	7&8	15&16	27&28
133A	6.20	6.28	6.30	6.29	6.27	6.31	6.51	
143A	6.13	6.15	6.24	6.22	6.27	6.31	6.24	6.30
156A	6.37	6.47	6.49	6.67	6.50	6.55	6.59	6.60
157A	6.43	6.31	6.36	6.39	6.28	6.33	6.43	6.43
158A	6.18	6.12	6.11	6.08	6.08	6.13	6.35	6.41
167A	6.47	6.50	6.48	6.46	6.36	6.37	6.49	6.46
168A	6.26	6.33	6.28	6.16	6.37	6.23	6.46	6.47
169A	6.31	6.30	6.33	6.35	6.31	6.34	6.44	
258A	6.08	6.17	6.16	6.22	6.28	6.31	6.28	6.58
275A	6.61	6.34	6.42	6.43	6.40	6.44	6.49	
392A	6.42	6.46	6.48	6.39	6.58	6.64	6.58	6.71
303B	6.44	6.42	6.41	6.38	6.40			
324B	6.39	6.39	6.33	6.33	6.42	6.39	6.57	6.34
325B	6.45	6.43	6.36	6.36	6.36	6.38		6.56
328B	6.33	6.19	6.22	6.20	6.15	6.20	6.33	6.50
453A	6.51	6.59	6.62	6.45	6.57	6.60		
470A	6.00	6.11	6.09	6.09	6.16	6.21	6.40	6.56
489A	6.23	6.24	6.23	6.32	6.26	6.32	6.51	6.39
494A	6.26	6.39	6.46	6.40	6.39			
495A	6.27	6.27	6.31	6.31	6.34	6.32	6.52	6.64
Av.	6.32	6.32	6.33	6.33	6.34	6.35	6.45	6.50

The colostrum of the Jersey breed exhibited the highest pH of the first milking, being on the average 6.41 (5 samples). Corresponding values for the Holstein, Guernsey, and Ayrshire breeds were 6.29 (8 samples), 6.25 (5 samples) and 6.35 (2 samples), respectively. Appreciable variations in pH were found in samples collected at the same period postpartum from cows of the same breed.

There was no direct correlation between pH and other properties studied.

Buffering Capacity. The titration curves of colostrum and transition milk, previously described (page 7), are shown in Figs. 1 to 20, inclusive. The buffering capacity of the first colostrum, except in one case, was higher than that exhibited by samples collected later in the transition period and, with few exceptions, the buffering action of the second milking was greater than any following. Further changes after the third milking were not consistent. The changes after this time were, however, not large. Colostrum and early milk had a greater buffering power in the pH range below the pH of the original sample than in pH's higher than that of the original sample.

The milliliters of acid required to lower the hydrogen ion concentration of the original sample to pH 5.00 was calculated (Table 2). These results, used as a comparative measure of buffer capacity, also showed that the first colostrum always had a higher buffering capacity than any samples collected later. The average values, graphically represented in Fig. 21, indicated a rapid

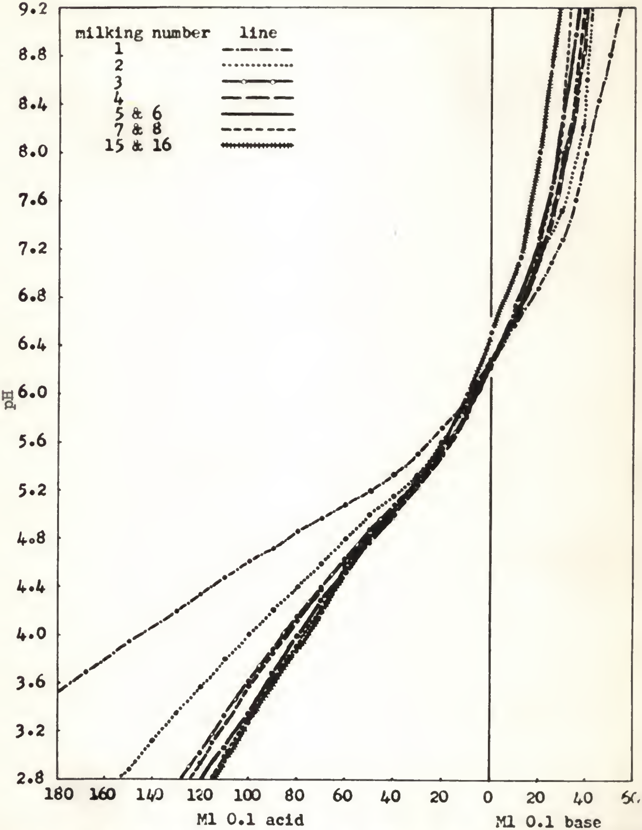

Fig. 1. Titration curves of 100 ml samples of colostrum and early milk from cow 133A.

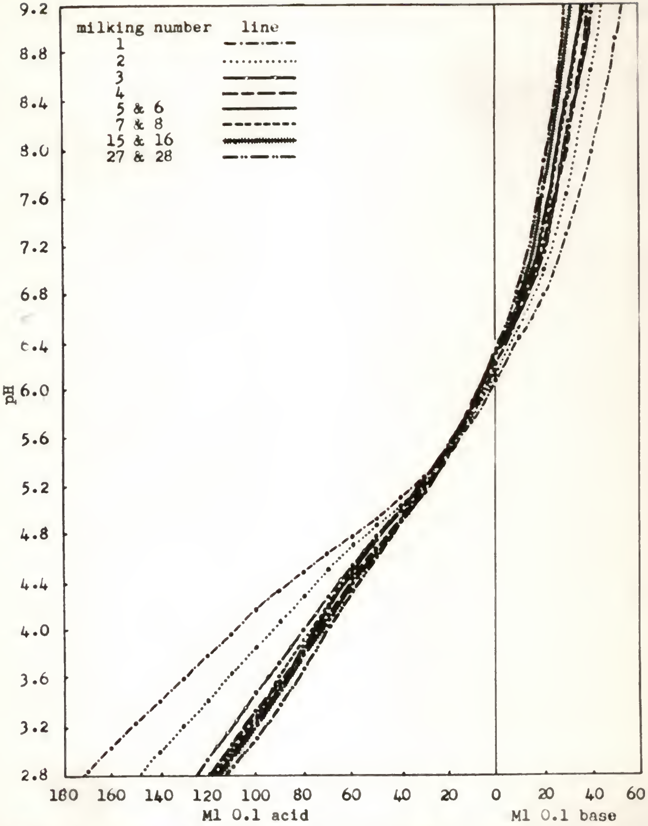

Fig. 2. Titration curves of 100 ml samples of colostrum and early milk from cow 143A.

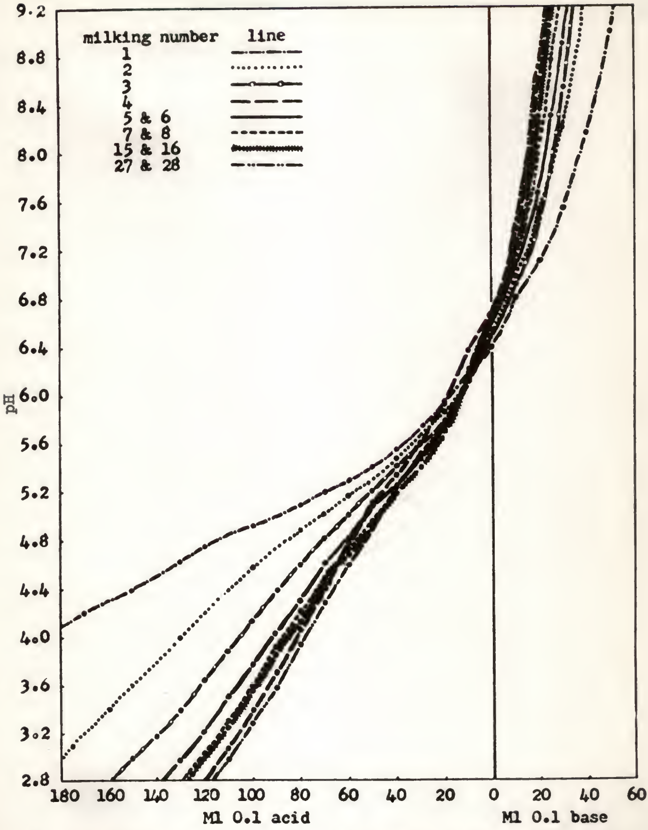

Fig. 3. Titration curves of 100 ml samples of colostrum and early milk from cow 156A.

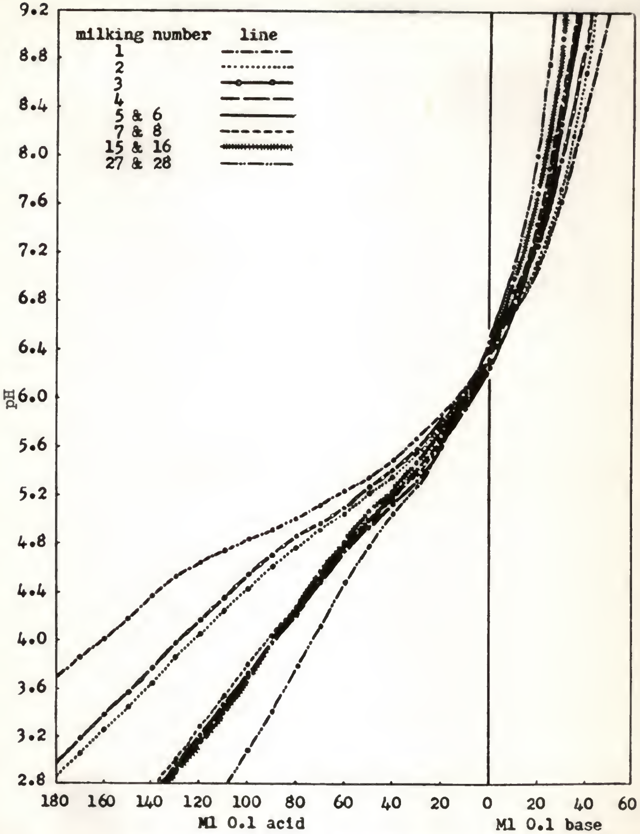

Fig. 4. Titration curves of 100 ml samples of colostrum and early milk from cow 157A.

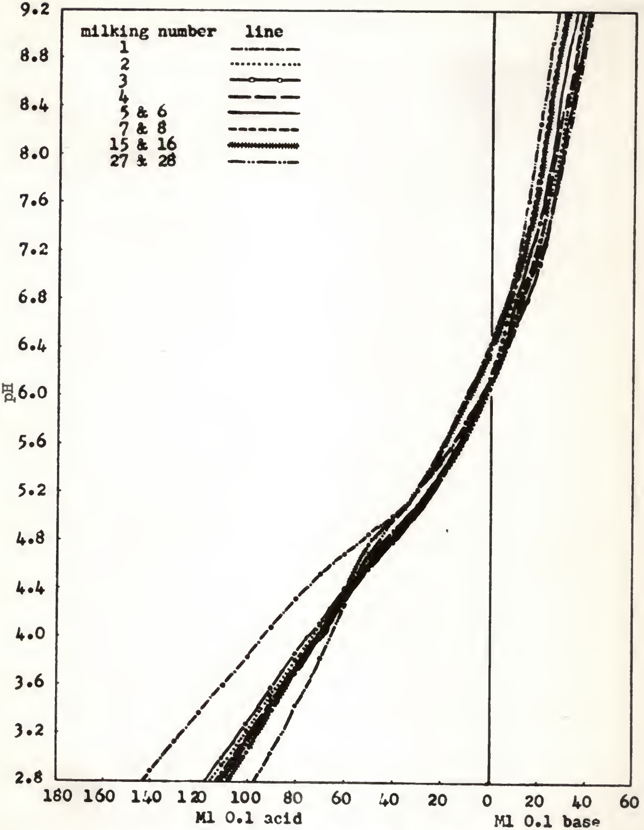

Fig. 5. Titration curves of 100 ml samples of colostrum and early milk from cow 158A.

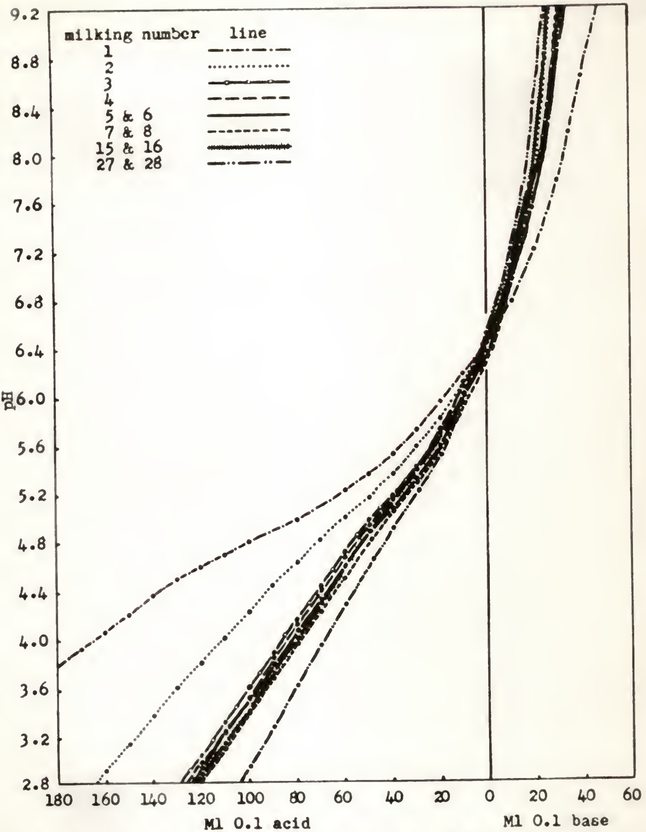

Fig. 6. Titration curves of 100 ml samples of colostrum and early milk from cow 167A.

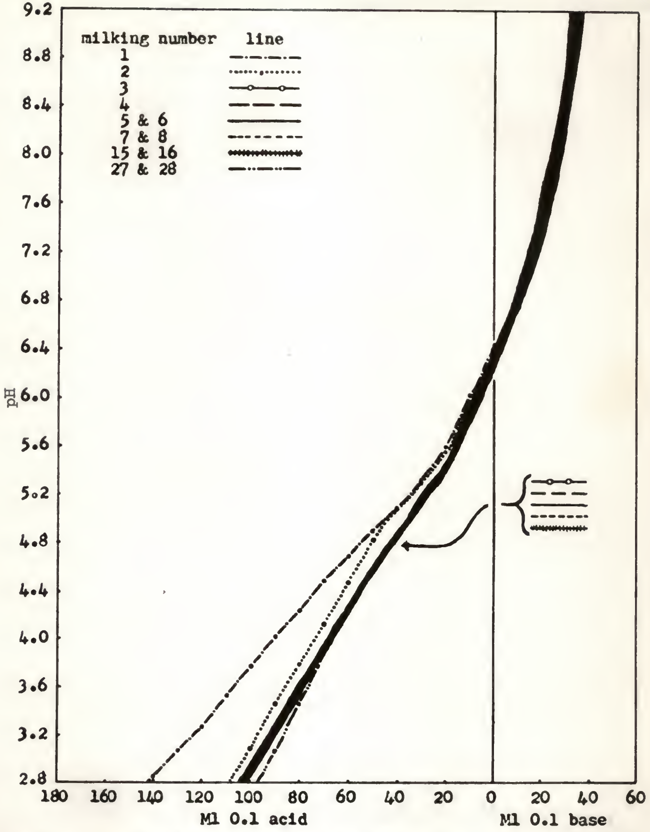

Fig. 7. Titration curves of 100 ml samples of colostrum and early milk from cow 168A.

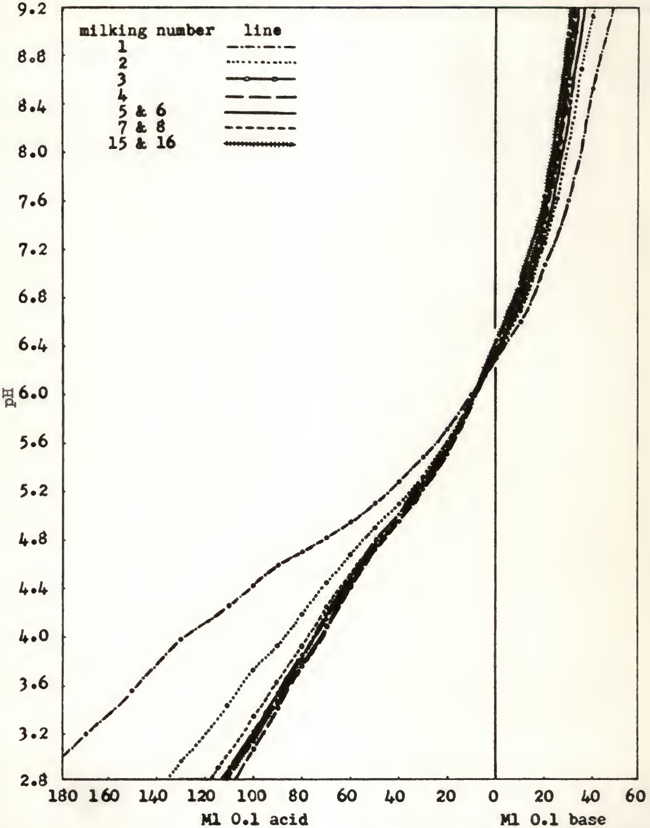

Fig. 8. Titration curves of 100 ml samples of colostrum and early milk from cow 169A.

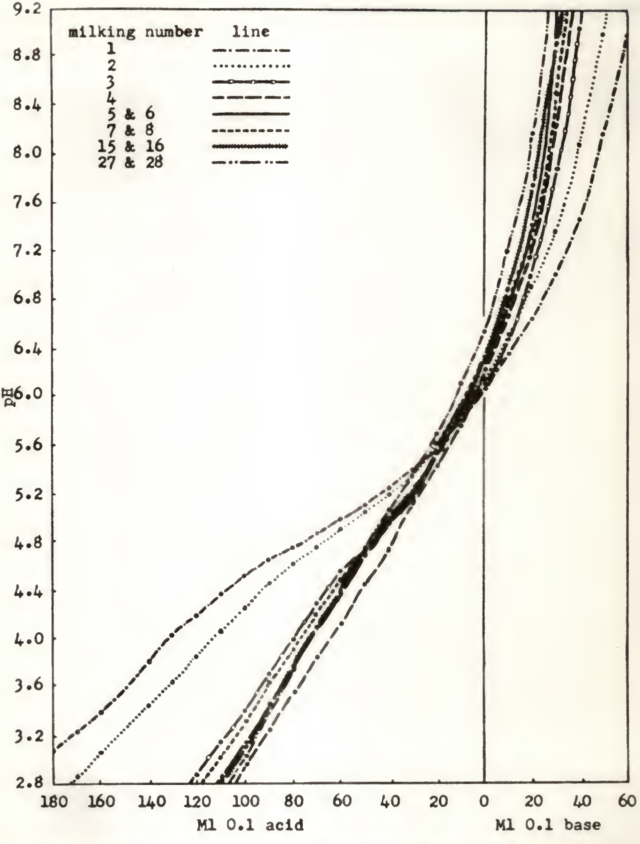

Fig. 9. Titration curves of 100 ml samples of colostrum and early milk from cow 258A.

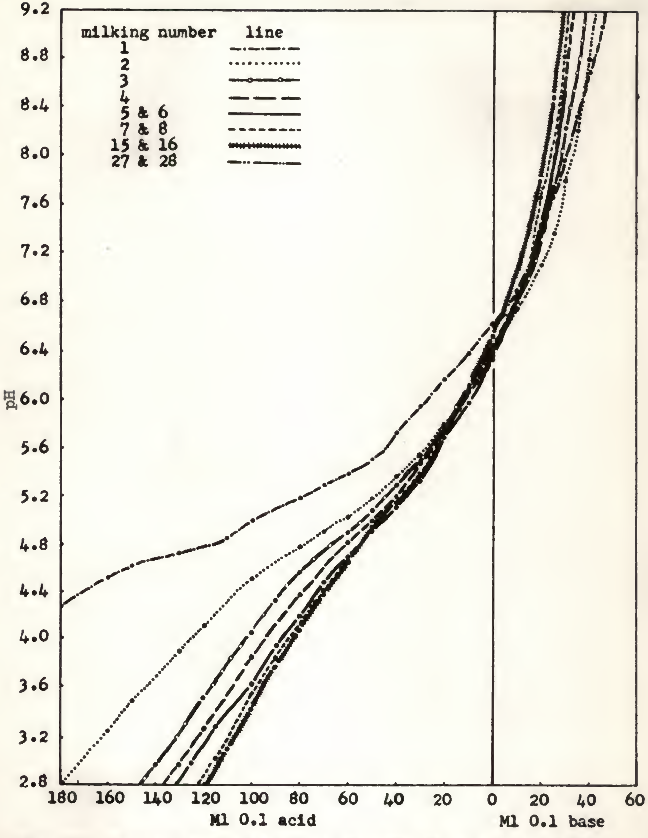

Fig. 10. Titration curves of 100 ml samples of colostrum and early milk from cow 275A.

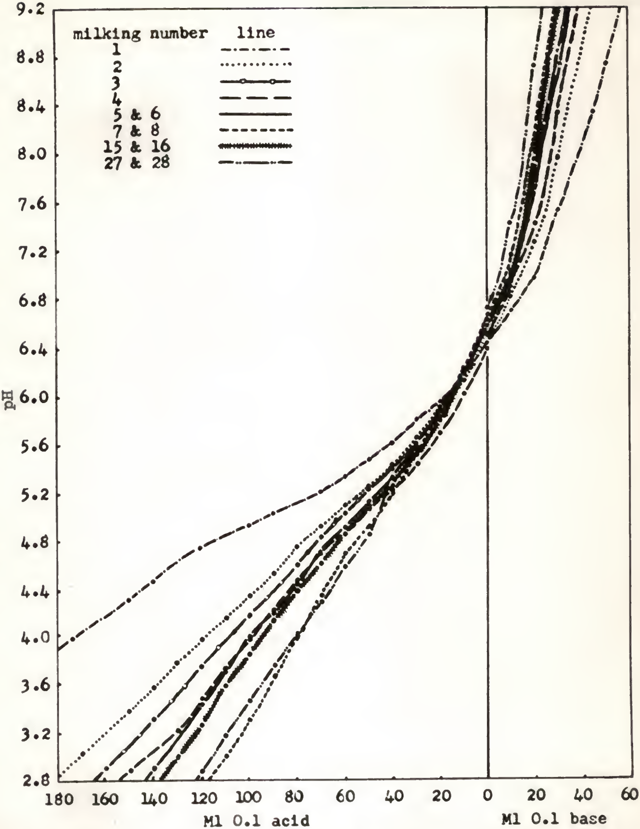

Fig. 11. Titration curves of 100 ml samples of colostrum and early milk from cow 392A.

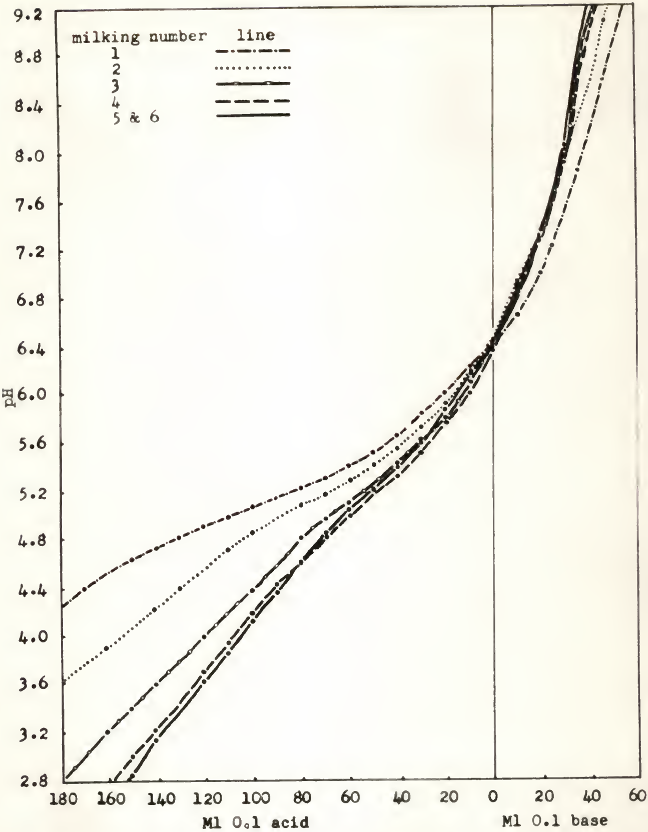

Fig. 12. Titration curves of 100 ml samples of colostrum and early milk from cow 303B.

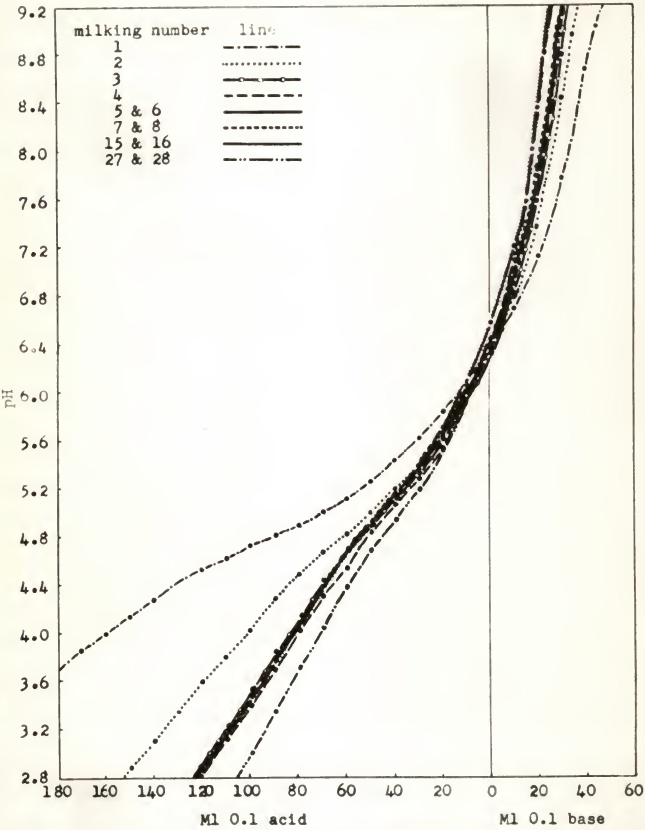

Fig. 13. Titration curves of 100 ml samples of colostrum and early milk from cow 324B.

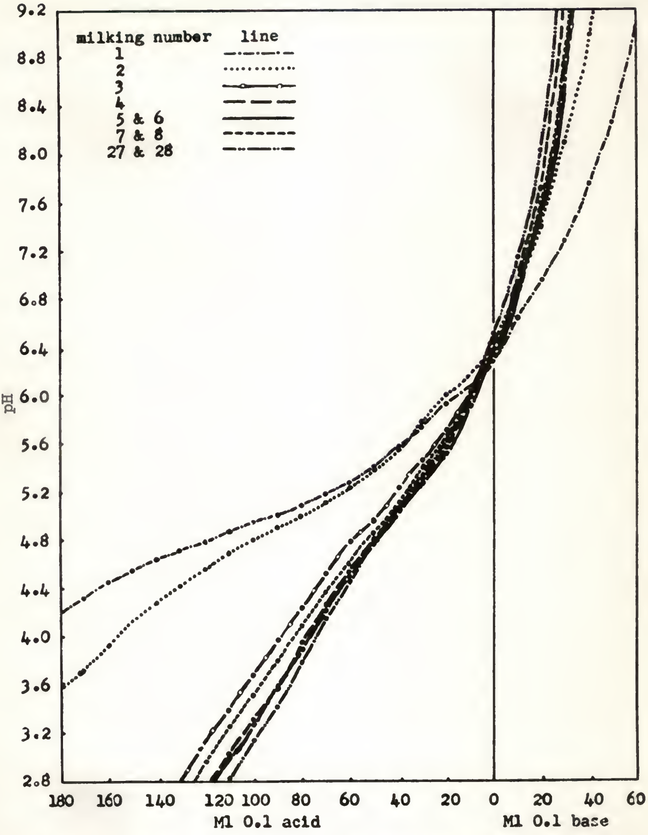

Fig. 14. Titration curves of 100 ml samples of colostrum and early milk from cow 325B.

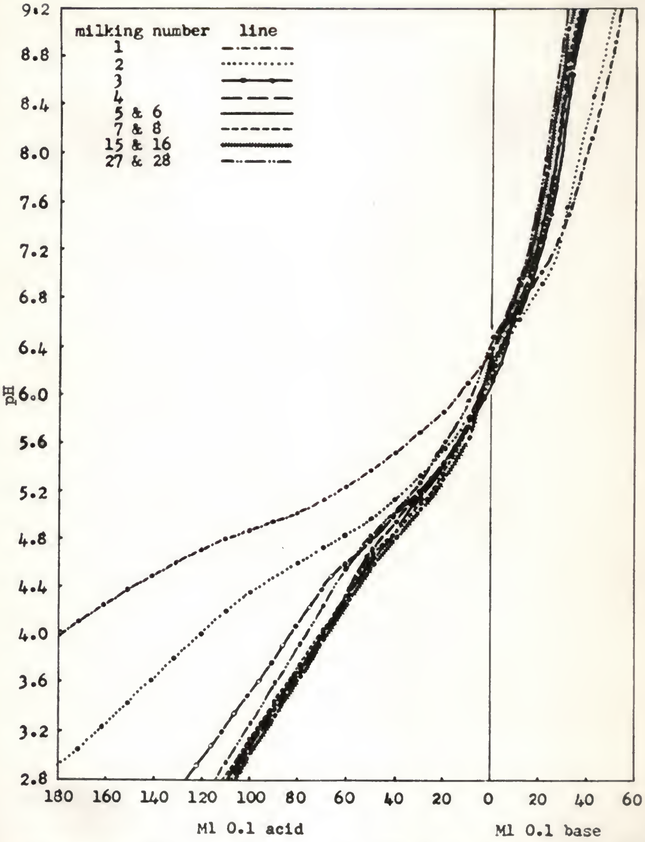

Fig. 15. Titration curves of 100 ml samples of colostrum and early milk from cow 328B.

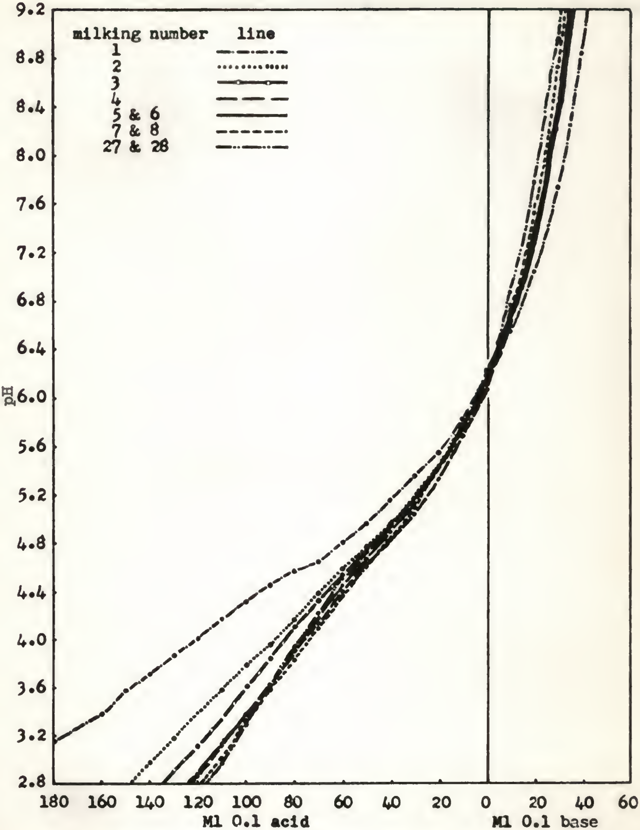

Fig. 16. Titration curves of 100 ml samples of colostrum and early milk from cow 453A.

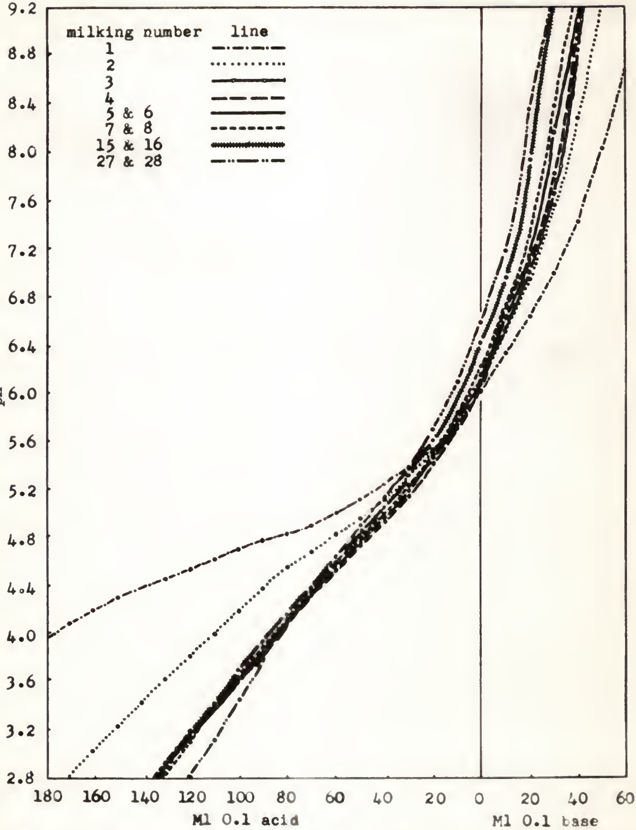

Fig. 17. Titration curves of 100 ml samples of colostrum and early milk from cow 470A.

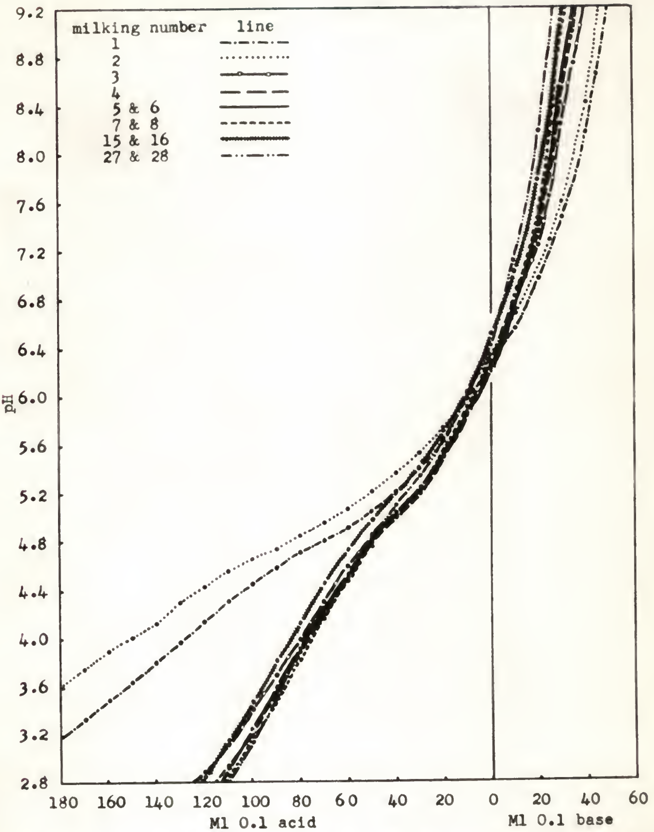

Fig. 18. Titration curves of 100 ml samples of colostrum and early milk from cow 489A.

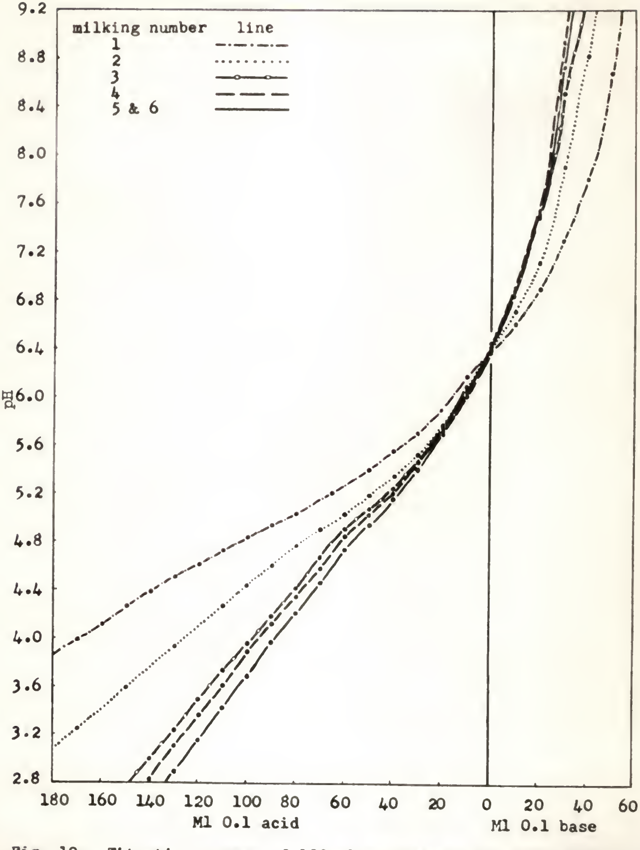

Fig. 19. Titration curves of 100 ml samples of colostrum and early milk from cow 494A.

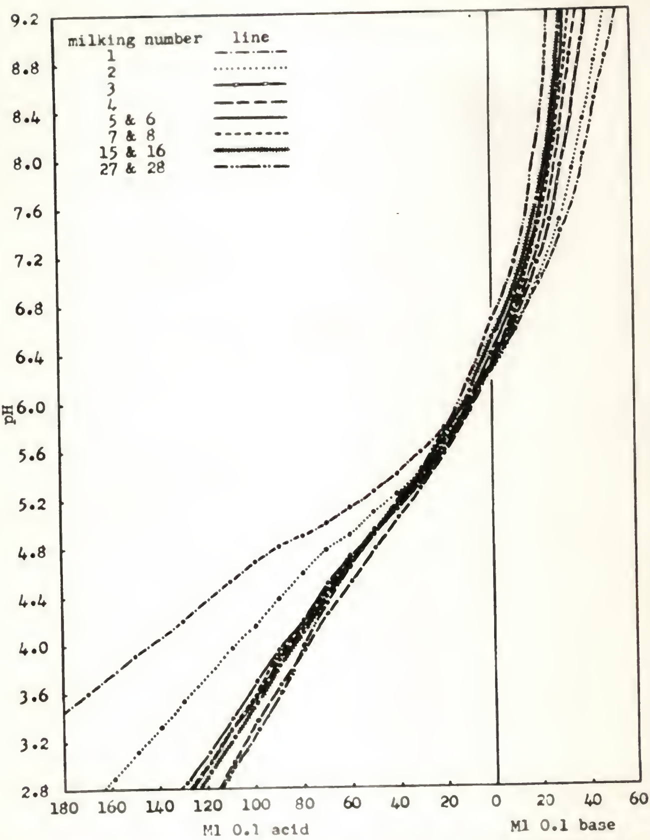

Fig. 20. Titration curves of 100 ml samples of colostrum and early milk from cow 495A.

Table 2. Number of ml of 0.1 N acid added to 100 ml of mammary secretion to lower the pH to 5.00.

Cow	No. of milking							
No.	1	2	3	4	5&6	7&8	15&16	27&28
133A	67	50	44	40	39	42		
143A	47	42	40	38	40	40	36	38
156A	90	71.5	60	53.5	52.5	48	46.5	47
157A	82	65	68	50	47	50	53	43
158A	41	39	35	32	31	33	34	39.5
167A	78	60	49	46.5	43	41.5	45	36.5
168A	45	36	36	33	33	35.5	43.5	35.5
169A	56.5	45	43	38.5	38.5	40	43	
258A	62	55	38	34	40	40	37.5	43
275A	100	62	54	49	35	47	47	
392A	92	65	61	63	55.5	46.5	52	46.5
303B	108	87	68	59	61.5			
324B	70.5	50	45	43	48	48.5	46.5	37
325B	93	81	49	43	41.5	45		43
328B	81	48	40	38	35	34	33	41.5
453A	74	59	56.5	50.5	52.5	50		54
470A	59	45.5	37	35	37	39	40.5	44.5
489A	53	65	41	39	41	39	49	44
494A	83	62	55	52	47			
495A	70	54.5	44.5	41	47	47	48	46
Av.	72.6	57.1	48.2	43.9	43.2	42.6	43.6	42.6

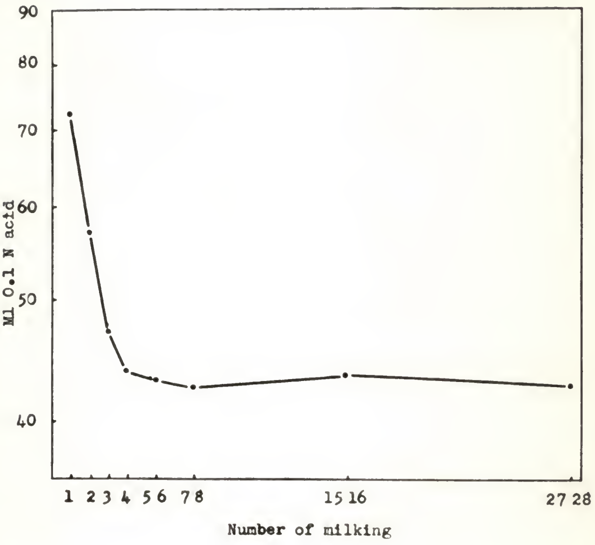

Fig. 21. Changes in the number of ml of 0.1 N acid required to lower the pH to 5.00 in early postpartum milkings.

decline of buffering capacity in the three milkings following the initial milking and a slight, but unimportant, rise in the 15th and 16th composite sample collected on the eighth day.

Colostrum samples from Holsteins had the lowest buffering power, while samples from the Jerseys exhibited the greatest buffering action. Colostrum from the Guernseys and Ayrshires had about the same buffering action and did not exhibit as much buffering action as that from the Jerseys but more than that from Holsteins. Although the data are limited, pasturing and season had no perceptible influence on the buffering capacity of colostrum and early milk.

Reducing Capacity. The total reducing capacity (expressed as absorbance) of samples of colostrum and transition milk from individual cows (Table 3) varied in an erratic manner. The average results, when represented graphically (Fig. 22), indicated that the total reducing substances were more abundant in early colostrum than in the milk obtained later in the transition period. There was, however, no consistent trend in the early colostrum samples. In samples collected after the 5th milking, the reducing capacity declined rapidly. Comparing average values, the first colostrum has a reducing capacity equivalent to 1.4×10^{-6} moles of ferricyanide per ml of mammary secretion while the corresponding value 2 weeks later was 9.2×10^{-7} moles per ml.

Osmotic Pressure. The osmotic pressure (Table 4) declined rapidly in early samples after the initial milking but tended to show relatively small changes after the 3rd milking. A graph

Table 3. Reducing capacity (expressed as absorbance) of colostrum and early milk.

Cow No.	No. of milking 1	2	3	4	5&6	7&8	15&16	27&28
133A	0.1922	0.1412	0.1264	0.1308	0.1235	0.0862	0.0580	
143A	0.0992	0.0992			0.0862	0.0888	0.0543	0.0875
156A	0.1412	0.1412	0.2656	0.2218	0.2384	0.2129	0.1051	0.0580
157A	0.1549	0.1580	0.1472	0.1177	0.1093	0.1192	0.1612	0.0915
158A	0.0901	0.0593	0.0848	0.1503	0.1010	0.0955	0.1352	0.0942
167A	0.1675	0.2076	0.1612	0.1821	0.2403	0.1821	0.1065	0.0892
168A	0.1457	0.1051	0.1010	0.1249	0.2249	0.1079	0.1121	0.0458
169A	0.0770	0.1235	0.1264	0.0928	0.1412	0.1107	0.0915	
258A	0.1249	0.1093	0.1065	0.1072		0.0783	0.0386	0.0942
275A	0.1149	0.0942	0.0848	0.0848	0.1206	0.0901	0.0888	
392A	0.1135	0.1135	0.1010	0.1010	0.0969	0.0783	0.0888	0.0718
303B	0.1278	0.1518	0.1821	0.1565	0.1397			
324B	0.0982	0.0955	0.0875	0.0915	0.1308	0.1308	0.0955	0.0875
325B	0.1163	0.1675	0.1206	0.1382	0.1079	0.0982		0.1121
328B	0.1427	0.1707	0.1489	0.1079	0.1065	0.1024		
453A	0.1427	0.1956	0.2111	0.1565	0.2798	0.2147		0.0680
489A	0.1308	0.1580	0.1221	0.1024	0.1121	0.0928	0.1135	0.0458
494A	0.1472	0.0770	0.1010	0.0835	0.1308			
495A	0.1352	0.1472	0.0996	0.1352	0.1093	0.0942	0.0928	0.0543
Av.	0.1236	0.1323	0.1320	0.1269	0.1388	0.1177	0.0958	0.0769

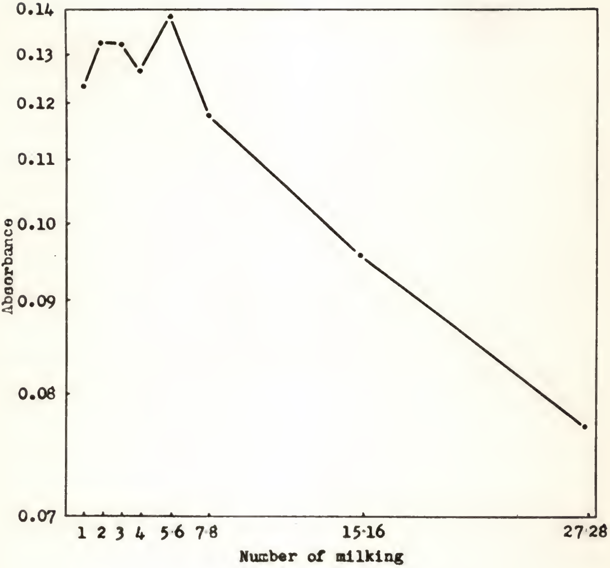

Fig. 22. Changes in the reducing capacity of the mammary secretion in early postpartum milkings.

Table 4. Osmotic pressure (expressed in mm) of colostrum and early milk.

Cow No.	No. of milking 1	2	3	4	5&6	7&8	15&16	27&28
133A	457	437	363	319	323	294	329	
143A	582	503	423	389	355	352	348	366
156A	516	480	401	490	342	382	360	372
157A	567	401	441	413	357	354	384	402
158A	342	304	342	379	361	348	399	350
167A	537	431	400	342	407	365	346	338
168A	503	314	339	328	325	374	388	312
169A	525	351	277	290	360	189	364	
258A	430	392	357	364	374	411	340	347
275A	521	448	367	397	395	457	368	
324B	643	439	396	366	401	385	484	367
325B	624	594	445	382	356	352		357
392A	563	453	421	368	431	436	583	366
453A	584	440	378	393	330	373		316
489A	438	558	379	370	393	375	400	330
495A	483	395	330	354	373	418	365	376
494A	640	725	427	392	439			
303B	583	453	392	493	385			
328B	587	668	535	388	395	404		354
470A	466	436	328	358	368	392	370	297
Av.	530	461	387	379	378	370	389	350

of the average osmotic pressure of the secretions from all cows (Fig. 23) indicated that the osmotic pressure rose slightly in the composite obtained from the 15th and 16th milkings. The graph of the osmotic pressure tended to follow the curve of average buffering (Fig. 21).

A scatter diagram (Fig. 24), prepared by plotting the osmotic pressure of the first four milkings postpartum against the specific gravity of the same samples (Fig. A2), showed a correlation between these properties.

DISCUSSION

The average pH of the first colostral secretion of 20 cows was found to be 6.32 with a range from 6.00 to 6.61. Variances could not be ascribed to known factors. Van der Burg (30) found the average pH of the first colostrum of 163 cows was 6.22 with the pH of individual samples varying from 5.95 to 6.88. Climatic or feeding conditions might have had some influence on the pH of colostrum therefore accounting for the small difference in the average pH found in these two investigations.

Whittier (34, 35, 36), in a series of investigations concerning the buffering constituents of normal milk, found that casein, phosphates and citrates exhibited buffering action. Since the citrate content of the normal mammary secretion is small (Whittier, 35), it was suggested the buffering was primarily due to the action of casein and phosphates. Parrish et al. (20) traced the decline in the total protein content during the

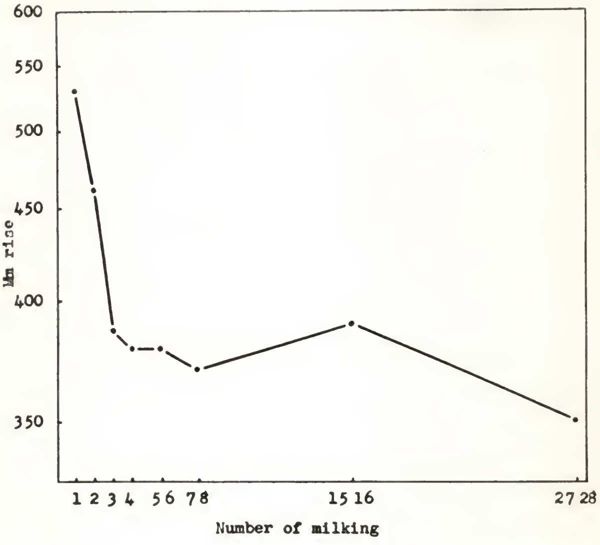

Fig. 23. Changes in osmotic pressure of the mammary secretion in early postpartum milkings.

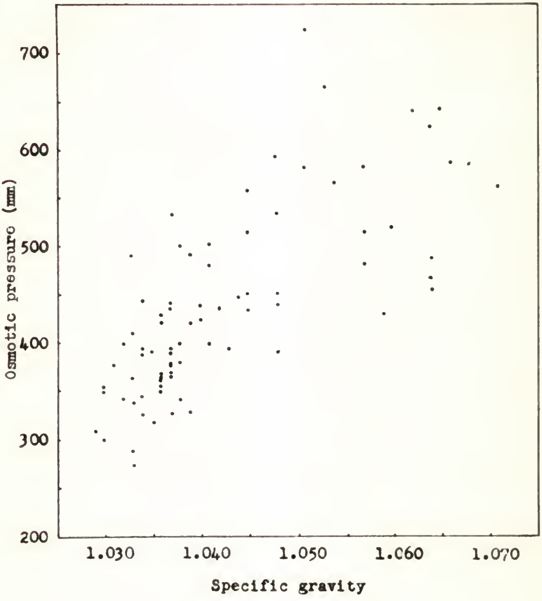

Fig. 24. Relation of the specific gravity and the osmotic pressure of the first four milkings postpartum.

transition period to decreasing amounts of both casein and globulins. The high buffering action of colostrum is presumed to be due to the enormous protein content consisting chiefly of globulins and casein and the relatively large concentrations of phosphates (Garrett and Overman, 8).

The results reported herein are in agreement with the report of Koestler (9) in which colostrum was shown to have a higher buffering action than normal milk. Watson (32) found Jersey herd milk had a greater buffering effect than Holstein herd milk. The buffering capacity of the colostrum and early milk, as reported in this study, was found similar to the results of the foregoing author in that the secretion from the Jerseys exhibited a greater buffering effect than the secretion from Holsteins. Results of the present study confirm those of Watson (32) who found that neither season nor pasture grazing effected the buffering of the mammary secretion.

Vodak and Tarassuk (31) found a decrease in buffering of normal bovine milk with increasing temperature but the reaction was reversible. As the samples which were titrated in this work were at room temperature (23° to 25° C.), differences due to temperature variances were negligible.

Because of the high buffering capacity of the early colostrum, it is questionable whether the new-born calf is capable of increasing the hydrogen ion concentration of the first food to a sufficient level so that the pepsin in the stomach is able to hydrolyze the protein in a normal manner.

Ascorbic acid, cysteine, glutathione and lactose-protein complexes are present in the normal mammary secretion and these constituents, according to Crowe et al. (4), accounted for the reduction of ferricyanide ions. As the lactose content of colostrum is low compared to milk (Parrish et al., 20), it is not known if sufficient quantities of lactose-protein complex is formed to materially effect the reducing capacity.

Smith and Greene (26) have reported the combined cystine and cysteine content is approximately 3.3 per cent of the globulin fraction of bovine colostrum. Since the globulin content of colostrum is high (Crowther and Raistrick, 5), the cysteine content of this protein may contribute significant numbers of sulfhydryl groups to the total reducing capacity of colostrum as determined in the present investigation.

The ascorbic acid content of colostrum of the ewe (Satterfield et al., 23) varies from two to ten mg per 100 ml of colostrum with normal levels of approximately 0.8 mg per 100 ml being reached on the 5th or 6th day postpartum. Since other constituents in ovine and bovine colostrum have been found to follow similar trends, it is suggested that bovine colostrum contains higher concentrations of ascorbic acid than later milk. Crowe et al. (4) found that one mole of ascorbic acid reduced 1.95 moles of ferricyanide, hence, if the ascorbic acid content of colostrum is high, the concentration of this compound would materially effect the total reducing capacity of the mammary secretion.

In regard to units for expression of the reducing power of the mammary products, Chapman and McFarlane (3) prepared their calibration curve using glutathione, but Crowe et al. (4) reported this compound was not reduced stoichiometrically. In view of the lack of knowledge of the specific groups involved in the reaction, it is preferable, according to Lea (12), to express the results in terms of moles of ferricyanide reduced.

The method employed for determining the reducing capacity was found to be sensitive to changes brought about when the untreated sample was allowed to stand at room temperature for a period of time. If the samples were not refrigerated immediately following collection, some of the variations noted in the reducing capacity might have been due to bacterial action; probably few, if any, of the samples collected for this study were allowed to stand until such action occurred.

Lillie (13), in studies of the effect of electrolytes and nonelectrolytes on the osmotic pressure of colloidal solutions (gelatin and egg albumin), found that the addition of salts depressed the osmotic pressure of these solutions. The addition of nonelectrolytes had no perceptible influence on this property. It appears probable that the high osmotic pressure of colostrum as compared to milk is the result of high concentrations of proteins since the data of Lillie (13) has shown that high concentrations of salt would not effect the osmotic pressure of colloidal solutions. The fat content would not effect this property.

Lactose, under the conditions of these studies, would have no influence on the osmotic pressure, since, as Lillie (13) pointed out, nonelectrolytes, as the sugars, have no effect on the osmotic pressure of colloidal solutions.

The correlation between the buffering capacity and the osmotic pressure is believed to be due to the protein content since both these factors are dependent upon protein concentrations.

The standard method of expressing osmotic pressure is in terms of mm of mercury. Since the density of the fluid in the manometer was not constant, due primarily to variances in the fat content of the mammary secretion and the rate at which the fat separated from the liquid, the osmotic pressure could not be converted to mm of mercury. The results were, therefore, only approximate but were useful in studying the relative changes in osmotic pressure.

SUMMARY

The pH of bovine colostrum was slightly acid and a small increase in pH was noted during the transition period.

Colostrum was found to exhibit a large buffering action towards acid and a slight buffering action toward base. During the transition period the acid buffering decreased rapidly with a buffering action similar to normal being exhibited on the third day postpartum.

Colostrum from Jerseys showed the highest buffer action while that from the Holsteins showed the least buffering action. The buffering action of colostrum from Ayrshires and Guernseys was less than that from the Jerseys and greater than that from the Holsteins.

Buffering capacity appeared to be unaffected by season and pasture grazing.

The total reducing capacity of colostrum, as measured by a modified ferricyanide method, was higher than that of milk. The reducing capacity exhibited only slight changes during early transition; but, following the 5th milking postpartum, rapid declines were observed.

The osmotic pressure of the mammary secretion was high in the early secretion but declined rapidly during the period of transition. A correlation was noted between specific gravity and osmotic pressure.

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APPENDIX

Table A1. Essential data on feeding and management of dairy cows.

Cow number	Breed*	Lactation number	Date of parturition	Feeding and remarks
133A	Hol	4	2/17/50	
143A	Hol	4	5/1/50	Pasture after 4th day
156A	Hol	2	3/8/50	
157A	Hol	2	4/12/50	
158A	Hol	2	5/8/50	Pasture after 4th day
167A	Hol	1	4/8/50	
168A	Hol	1	4/21/50	Pasture after 4th day
169A	Hol	1	2/2/50	
258A	Ayr	3	4/30/50	Pasture after 4th day
275A	Ayr	1	2/2/50	
392A	Jer	3	2/24/50	
303B	Jer	2	3/3/50	
324B	Jer	1	4/26/50	Pasture after 4th day
325B	Jer	1	3/23/50	
328B	Jer	1	5/15/50	Pasture after 4th day
453A	Gur	4	2/9/50	Severe mastitis
470A	Gur	3	5/19/50	Pasture after 4th day
489A	Gur	2	4/22/50	Pasture after 4th day
494A	Gur	6	3/21/50	Mastitis
495A	Gur	4	2/12/50	

* Abbreviations are: Hol = Holstein, Ayr = Ayrshire, Jer = Jersey and Gur = Guernsey.

Table A2. Specific gravity of colostrum and early milk.

Cow number	No. of milking 1	2	3	4	5 & 6	7 & 8	15&16	27&28
133A	1.064	1.037	1.036	1.035	1.033	1.033	1.032	
143A	1.051	1.041	1.036	1.034	1.032	1.033	1.034	1.032
156A	1.057	1.041	1.038	1.033	1.034	1.032	1.033	1.032
157A	1.054	1.041	1.048	1.033	1.034	1.036	1.034	1.033
158A	1.037	1.030	1.032	1.031	1.033	1.033	1.034	1.029
167A	1.048	1.036	1.032	1.030	1.032	1.032	1.032	1.032
168A	1.038	1.029	1.033	1.034	1.034	1.035	1.034	1.032
169A	1.045	1.036	1.033	1.033	1.033	1.035	1.030	
258A	1.059	1.048	1.030	1.033	1.032	1.033	1.033	1.030
275A	1.060	1.044	1.037	1.034	1.036	1.034	1.032	
392A	1.071	1.045	1.039	1.037	1.035	1.033	1.031	1.036
303B	1.068	1.053	1.042	1.039	1.036			
324B	1.065	1.042	1.037	1.036	1.036	1.036	1.033	1.033
325B	1.064	1.048	1.034	1.034	1.034	1.035		1.033
328B	1.066	1.053	1.037	1.033	1.034	1.034	1.034	1.032
453A	1.057	1.040	1.037	1.035	1.034	1.035		
470A	1.064	1.045	1.037	1.036	1.034	1.033	1.031	1.032
489A	1.061	1.065	1.039	1.037	1.036	1.035	1.033	1.033
494A	1.062	1.051	1.040	1.037	1.035			
495A	1.057	1.043	1.039	1.030	1.036	1.03	1.033	1.032
Average	1.057	1.043	1.037	1.034	1.034	1.034	1.033	1.032