http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 6 (14): 1208-1213, 2003
ISSN 1028-8880

Utilization Possibilities of Surplus Colostrum by Acidification with Formic Acid in Rearing Calves I. Changes in Some Characteristics of Acidified Colostrum Stored at Summer Ambient Temperatures or in a Refrigerator

[1]İ. Kaya, [1]C. Uzmay, [2]H. Uysal and [1]A. Kaya
[1]Department of Animal Science, Agricultural Faculty of Ege University, Bornova, 35100 İzmir-Turkey
[2]Department of Milk Technology, Agricultural Faculty of Ege University, Bornova, 35100 İzmir-Turkey

Abstract: Use of surplus colostrum, which was collected from the first eight milkings postpartum, in calf rearing programs was investigated in two trials. In trial 1, colostrum that was acidified with formic acid and stored at summer ambient temperatures (ACAT), or milk replacer that was acidified with formic acid were fed to calves. In trial 2, calves were fed colostrum stored in refrigerator (2 to 4 °C) after formic acid addition (ACRE). Liquid diets were acidified with formic acid at 0.23% vol/wt. Each batch of acidified colostrum (8 batches in ACAT and 10 batches in ACRE) was labelled 0 days old when colostrum from first eight milkings was mixed. Colostrum samples were collected at days 0, 5, 10, 15, 20 and 25 of storage. Mean pH for acidified colostrum stored at summer ambient temperatures was 4.35 at day 0, it decreased to 3.56 at day 10 ($P<0.05$) and then began increasing and rose to 4.59 on the 25th day of storage ($P<0.05$). Mean pH for acidified colostrum stored in refrigerator was almost constant during 20 days of storage. Then it began increasing, but the increase was slow. During the storage period, there was no significant change in titratable acidity, specific gravity, or DM content of acidified colostrum stored in refrigerator. DM content of colostrum stored in refrigerator was 14.13% at day 0 and 13.90% at day 25. Titratable acidity of acidified colostrum stored at summer ambient temperatures increased rapidly during the first 10 days of storage ($P<0.05$) and then began decreasing. There was a marked decline with time in the specific gravity of colostrum stored at summer ambient temperatures ($P<0.05$). DM content of acidified colostrum stored at summer ambient temperatures decreased significantly with storage time. It was 14.00% at day 0 and declined to 12.21% at day 15 and to 9.95% at day 25 ($P<0.05$). Storing acidified colostrum in refrigerator ensured an effective preservation.

Key words: Acidified colostrum, storage, summer ambient temperatures, refrigeration, pH, acidity, dry matter, specific gravity

Introduction

Colostrum produced by dairy cows during the first 3-4 days postpartum is much more than can be utilized by the calf. A large amount of this surplus colostrum generally is discarded because it is unmarketable. Surplus colostrum that was stored conveniently is a highly nutritive and cost-free liquid feed source for calves as a substitute for whole milk or milk replacer (MR) (Foley and Otterby, 1978).

Colostrum can be stored by freezing without nutrient loss during storage. However, storage by freezing of colostrum has required freezer facilities and some extra handling of colostrum is required to package it for freezing and thaw it for feeding (Foley and Otterby, 1978).

Colostrum can also be stored by fermentation. Firstly, Swannack (1971) reported that colostrum could be stored successfully by natural fermentation and that the fermented product was accepted by calves readily. Several studies (Muller *et al.*, 1975; Yu *et al.*, 1976; Otterby *et al.*, 1976; Jenny *et al.*, 1977a) showed that fermented colostrum could be used in calf feeding programs as an alternative to whole milk or MR. However, several problems occurred during storage of colostrum at warm ambient temperatures. Undesirable fermentation, excessive acidity, putrid odour, reduced acceptability by calves, increased nonprotein nitrogen (NPN), or increased nutrient losses were reported by several researchers when colostrum was stored at warm ambient temperatures (Muller and Syhre, 1975; Muller *et al.*, 1976; Rindsig, 1976; Jenny *et al.*, 1977b; Polzin *et al.*, 1977; Rindsig and Bodoh, 1977; Rindsig *et al.*, 1977).

Chemical additives have been used to control fermentation, especially at warm ambient temperatures. In laboratory and feeding trials, organic acids, such as propionic, formic, lactic and acetic acids and formaldehyde were added to colostrum for preservation (Muller and Syhre, 1975; Polzin *et al.*, 1977; Rindsig and Bodoh, 1977; Rindsig *et al.*, 1977; Foley and Otterby, 1979 and Mbuthia *et al.*, 1997). Dry chemicals, such as benzoic acid, sodium benzoate (Muller and Smallcomb, 1977; Jenny *et al.*, 1980) and adipic acid (Foley and Otterby, 1979), also were used to avoid handling problems and corrosiveness of liquid chemicals.

Additions of propionic acid, formic acid, formaldehyde, benzoic acid, or sodium benzoate to colostrum stored at high temperatures maintained a relatively constant pH, odour and physical consistency, reduced nutrient losses and retarded bacterial growth (Muller and Syhre, 1975; Carlson and Muller, 1977; Muller and Smallcomb, 1977; Polzin *et al.*, 1977; Rindsig *et al.*, 1977).

The objective of this study was to examine changes in some characteristics of acidified colostrum that was stored at summer ambient temperatures or in a refrigerator.

Materials and Methods

Two trials were conducted to examine utilization possibilities of surplus colostrum preserved by addition of formic acid in rearing Holstein calves. In trial 1, acidified colostrum that was stored at summer ambient temperatures (ACAT), or acidified MR (AMR) were fed to calves. The trial continued throughout summer and excess sourness and putrid odour occurred in colostrum stored at summer ambient temperatures until it was depleted. Therefore, refusals of colostrum by calves occurred. Because of these undesirable developments, a second trial was conducted, in which calves were fed acidified colostrum stored in refrigerator (ACRE).

Calves on ACAT and AMR were brought from the Agricultural Faculty Farm of Ege University, except one calf on each one. Calves on ACRE were born at the dairy farm of Animal Science Department of Ege University. The trial 1 continued from June to October and the trial 2 from mid-September through March. Temperatures averaged 26.2, 29.7, 28.6, 23.3, 17.5, 14.0, 10.1, 9.9, 9.4 and 15.4°C for the months of June, July, August, September, October, November, December, January, February and March. Calves on ACAT and ACRE were fed colostrum collected from their dam. When calves depleted their dam's colostrum, whole milk that was acidified with formic acid was fed until the end of the 5th week of the trial. Calves on AMR were fed all-milk sources MR. The MR powder was diluted 1:7 (1 kg powder to 7 kg of water).

Colostrum collected for the first eight milkings postpartum from dams of calves assigned to the experiments was acidified with formic acid and stored separately in covered plastic containers of 60 or 120 l. Acidification of colostrum from each dam was performed in two stages. Firstly, colostrum from the first to the fourth milkings postpartum was mixed and acidified after the fourth milking (first composite). Then, colostrum from the 5th-8th milkings postpartum was mixed and acidified after 8th milking (second composite). Thereafter, first and second composites were mixed (total composite).

In ACAT, first and second composites were stored in a cool place (10 to 15°C) before acidification. Each composite was transported to location of the experiment immediately after it was completed and then acidified. First and total composites were stored at summer ambient temperatures after acidification. In ACRE, all colostrum composites were stored in a refrigerator (2 to 4°C) at the experimental location before and after acidification.

Pure formic acid of 98-100% (Riedel-de Haën) was used for acidification of liquid diets. Firstly, formic acid was diluted 1:10 (0.1 l formic acid to 1 l of water). 25 ml of diluted formic acid was added kg^{-1} of liquid diets. Thus, approximately 2.27 ml of pure formic acid was added kg^{-1} of liquid diet (approximately 0.23% vol wt^{-1}) and pH was reduced to 4.4 to 4.6.

The pH was determined before and after acidification in all liquid diets. After acidification, samples were collected from first and second colostrum composites from dams of calves assigned to the experiments. Samples were also collected from total composites. The colostrum was labelled 0 days old after total composite was obtained. Thereafter, the pH was determined and samples were collected at 5 days intervals until colostrum was depleted. Samples of acidified whole milk and AMR were collected at different periods of the trials. Samples of liquid diets were stored in refrigerator for 1 to 3 days prior to laboratory analysis.

Colostrum, whole milk and MR samples were analysed for dry matter (DM) and ash by the Gravimetric method, fat by the Gerber method, specific gravity by the lactometer, acidity by the titratable acidity (°SH) and for protein (total N %x6.38=protein %) by the micro-Kjehldal method (Anonymous, 1981). Lactose was the difference between DM and the sum of protein, fat and ash. The pH and temperatures of liquid diets were determined by WTW Model 330 hand-held pH meter with SenTix 41 pH electrode with integrated temperature probe.

Data were analysed using SPSS (SPSS Inc., Chicago, USA). Duncan's multiple range test was used to compare pH, acidity, specific gravity and DM means for different days of storage within treatment.

Results

In this part of the study, analytical values of the liquid diets and changes in some characteristics of acidified colostrum that was stored at summer ambient temperatures or in refrigerator were given.

The mean composition, pH, titratable acidity and specific gravity of acidified colostrum, acidified whole milk and

Table 1: Composition and characteristics of acidified colostrum, AMR (reconstituted) and acidified whole milk (mean±s.d.)

	Colostrum				
	1st to 4th milkings	5th to 8th milkings	Total composite	MR[2]	Whole milk[2]
PH	4.63±0.29	4.41±0.17	4.53±0.20	4.64±0.08	4.39±0.08
Acidity, °SH	38.92±7.19	35.41±6.80	34.28±2.94	28.79±2.52	29.34±2.82
Specific gravity	1.041±0.005	1.037±0.005	1.036±0.004	1.040±0.003	1.033±0.002
DM, %	15.92±1.98	13.59±0.93	14.02±0.78	12.29±0.47	12.38±0.30
Protein, %	6.44±1.40	5.05±1.04	5.19±0.93	3.96±0.65	3.73±0.06
Fat, %	4.27±0.82	4.31±0.73	4.25±0.57	1.83±0.17	3.55±0.37
Lactose, %	3.75±1.02	3.55±0.92	3.83±0.82	5.66±0.81	4.19±0.21
Ash, %	0.85±0.13	0.75±0.13	0.75±0.13	0.81±0.12	0.64±0.11

[1] Mean values for colostrum samples from dams of 18 calves assigned to the experiments, [2] Mean values for samples collected at different times

Table 2: pH values of colostrum in ACRE and ACAT before and after acidification (mean ± s.d.)

	Colostrum in ACRE (n=10)			Colostrum in ACAT (n=8)		
	1st to 4th milkings	5th to 8th milkings	Total composite	1st to 4th milkings	5th to 8th milkings	Total composite
Before acidification	6.42±0.12	6.45±0.10	-	6.09±0.32	5.90±0.54	-
	(9.8±3.8)[1]	(10.4±2.6)		(18.6±6.2)	(17.0±4.7)	
After acidification	4.81±0.10	4.50±0.11	4.67±0.07	4.41±0.30	4.29±0.15	4.35±0.14
	(9.9±3.2)	(10.6±2.6)	(8.5±2.3)	(23.8±3.3)	(20.3±4.2)	(23.1±3.9)

[1] Temperature (°C) of colostrum during the pH measurement (mean±s.d.)

Table 3: pH values of whole milk and MR before and after acidification (mean ± s.d.)

	Whole milk (n=25)	MR (n=28)
Before acidification	6.73±0.11 (10.1±6.5)[1]	6.38±0.08 (25.4±2.3)
After acidification	4.39±0.08 (11.3±6.8)	4.64±0.08 (25.4±2.4)

[1] Temperature (°C) of whole milk or MR during the pH measurement (mean±s.d.)

Table 4: Changes in the pH of acidified colostrum according to the storage methods and storage time (mean±s.d.)

	Colostrum in refrigerator (ACRE)			Colostrum at summer ambient temperatures (ACAT)[1]		
Time (days)	n	Temperature[2]	pH	n	Temperature[2]	pH
0	10	8.54±2.26	4.67±0.07c	8	23.09±3.87	4.35±0.14a
5	10	2.08±0.35	4.76±0.06b	8	27.96±0.94	3.70±0.30b
10	9	2.74±1.60	4.73±0.05b,c	8	26.93±0.68	3.56±0.23b
15	8	2.43±1.21	4.79±0.06b	8	27.15±1.19	3.59±0.26b
20	8	2.73±0.93	4.78±0.06b	7	27.47±3.36	3.81±0.30b
25	8	2.74±0.63	4.89±0.08a	7	27.73±2.23	4.59±1.00a
Probability level			***			***

[1] From June to mid-September, [2] Temperature (°C) of colostrum during the pH measurement (mean±s.d.)
a, b, c Means in columns with unlike superscripts differ significantly (P<0.05), *** P < 0.001

Table 5: Changes in the titratable acidity (°SH) of acidified colostrum according to the storage methods and storage time (mean±s.d.)

	Colostrum in refrigerator (ACRE)			Colostrum at summer ambient temperatures (ACAT)[1]		
Time (days)	n	Mean	s.d.	n	Mean	s.d.
0	10	33.56	2.44	8	35.39c	3.21
5	10	35.51	4.13	8	67.89b	25.50
10	10	35.54	4.23	7	111.66a	21.21
15	8	35.53	4.40	7	93.65a, b	35.04
20	8	34.78	4.26	7	92.48a, b	30.96
25	7	31.03	2.06	5	85.66a, b	24.23
Probability level		NS			***	

[1] From June to mid-September, a, b, c Means in the ACAT column with unlike superscripts differ significantly (P<0.05)
NS = Non significant; *** P < 0.001

AMR are given in Table 1. DM, protein and fat contents of colostrum were higher than those of whole milk and MR, while lactose content of colostrum was lower.

Mean pH values, before and after acidification, of colostrum in ACRE and ACAT are in Table 2. Before acidification, the pH values of the first and second composite colostrums in ACRE were 6.42 and 6.45, respectively. The pH values of the first and second composite colostrums in ACAT were 6.09 and 5.90, respectively. After acidification, the pH of the first and second composite colostrums in ACRE dropped to 4.81 and 4.50, respectively. Mean pH of total composite was

Table 6: Changes in the specific gravity of acidified colostrum according to the storage methods and storage time (mean ± s.d.)

	Colostrum in refrigerator (ACRE)			Colostrum at summer ambient temperatures (ACAT)[1]		
Time (days)	n	Mean	s.d.	n	Mean	s.d.
0	10	1.036	0.002	8	1.036a	0.005
5	10	1.037	0.002	8	1.033a, b	0.004
10	10	1.037	0.002	7	1.031a, b, c	0.005
15	8	1.037	0.002	7	1.031a, b, c	0.006
20	8	1.036	0.001	7	1.029b, c	0.005
25	7	1.037	0.002	5	1.026 c	0.007
Probability level		NS			*	

[1] From June to mid-September, a, b, c Means in the ACAT column with unlike superscripts differ significantly (P<0.05)
NS = Nonsignificant (P > 0.10); * P < 0.05

Table 7: Changes in the DM content (%) of acidified colostrum according to the storage methods and storage time (mean ± s.d.)

	Colostrum in refrigerator (ACRE)			Colostrum at summer ambient temperatures (ACAT)[1]		
Time (days)	n	Mean	s.d.	n	Mean	s.d.
0	10	14.13	1.09	8	14.00a	0.76
5	10	14.21	1.41	8	12.88a, b	1.13
10	10	13.97	0.92	7	12.48a, b	0.96
15	8	14.09	1.01	7	12.21b	2.26
20	8	13.95	1.05	7	11.19b, c	1.92
25	7	13.90	0.59	5	9.95c	1.47
Probability level		NS			***	

[1] From June to mid-September, a, b, c Means in the ACAT column with unlike superscripts differ significantly (P<0.05)
NS= Nonsignificant (P > 0.10); *** P < 0.001

4.67. After acidification, the pH of the first and second composite colostrums in ACAT dropped to 4.41 and 4.29, respectively.

Mean pH of total composite was 4.35. Mean pH values of whole milk before and after acifidification were 6.73 and 4.39, respectively. Corresponding values for MR were 6.38 and 4.64, respectively (Table 3).

Changes in the pH of colostrum according to the storage methods and storage time are shown in Table 4. Temperatures of colostrums during the pH measurement also are shown in the Table 4. Mean temperature of colostrum in refrigerator at day 0 was higher than temperatures measured at days 5, 10, 15, 20, or 25 of storage because measurement at day 0 was performed immediately after addition of warm colostrum from eighth milking to colostrum in refrigerator. The pH of colostrum stored in the refrigerator slightly increased (P<0.05) from 4.67 at day 0 to 4.76 at day 5. This increase was due probably to lower temperature of colostrum during pH measurement. Then, pH was almost constant during the first 20 days of storage. After 20 days of storage, the pH began increasing (P<0.05). The pH of colostrum stored at summer ambient temperatures markedly decreased (P<0.05) from 4.35 at day 0 to 3.70 at day 5 and to 3.56 at day 10. Thereafter, the pH began increasing and rose to 4.59 on the 25th day of storage (P<0.05).

Changes in the titratable acidity (°SH) of colostrum according to the storage methods and storage time are shown in Table 5. During the storage period, there was no significant change in acidity of colostrum stored in refrigerator. Whereas, the acidity of colostrum stored at summer ambient temperatures increased rapidly during the first 10 days of storage (P<0.05) and then began decreasing. The acidity was 35.39 at day 0, increased to 67.89 at day 5 and to 111.66 at day 10. It decreased to 85.66 on the 25th day of storage.

During the storage period, changes in the specific gravity of acidified colostrum stored in refrigerator or stored at summer ambient temperatures are in Table 6. There was no change in the specific gravity of colostrum stored in the refrigerator during 25 days of storage. In contrast, there was a marked decline with time in the specific gravity of colostrum stored at summer ambient temperatures. Specific gravity was 1.036 at day 0 and decreased to 1.026 on the 25th day of storage (P<0.05).

Changes in the DM content (%) of colostrum according to the storage methods and storage time are shown in Table 7. There was no significant change in DM content of colostrum stored in refrigerator. DM content was 14.13% at day 0 and was 13.90% at day 25. DM content of colostrum stored at summer ambient temperatures decreased markedly with storage time. DM content was 14.00% at day 0 and declined to 12.21% at day 15 and to 9.95% at day 25 (P<0.05).

Discussion

Analytical values (Table 1) of liquid diet samples collected immediately after acidification indicated that colostrum from 5th-8th milkings (second composite) included less DM, protein and ash and similar level of fat and its specific gravity was lower compared with colostrum from first to fourth milkings (first composite). Foley and

Otterby (1978) and Schmidt *et al.* (1988) also reported that DM, protein and ash contents and specific gravity of colostrums decreased gradually during the transition period. Composition of colostrum from the first eight milkings (total composite) was found to be near to that of colostrum from 5th-8th milkings. The reason for this is that two-thirds of the total composite was colostrum from 5th-8th milkings.

The pH values of colostrum composites before acidification were lower for colostrum stored at summer ambient temperatures than for colostrum stored in refrigerator (Table 2). The reason for this is the fact that colostrum stored at summer ambient temperatures was brought from the Agricultural Faculty Farm where colostrum was milked in unsuitable conditions (in maternity stall) and it could not be cooled sufficiently during the time before acidification. These unsuitable conditions have caused a fermentation to begin before addition of formic acid to colostrum. To avoid this, the acidification of colostrum immediately after each milking is necessary. Muller *et al.* (1976) also reported that waiting until after the third milking to add acid to colostrum may have allowed an undesirable fermentation to begin during warm ambient temperatures. Colostrum stored in refrigerator was harvested at the Animal Science Department's dairy farm (location of the experiment) where colostrum was milked in a milking parlor and stored in a refrigerator (2 to 4°C) during the time before acidification. Depending on lower pH values before acidification, the pH values of colostrum stored at summer ambient temperatures were also lower after acidification than the pH values of colostrum stored in refrigerator.

The pH of acidified colostrum stored at summer ambient temperatures decreased rapidly during five days after the total composite was obtained and began increasing after 15 days of storage. Decreased pH in acidified colostrum indicates that fermentation have continued although addition of acid. Otterby *et al.* (1980) also reported that the pH of colostrum decreased after addition of propionic acid, especially during summer and about 50% of titratable acid was other than propionic acid. They suggested that considerable fermentation must have occurred after acidification. On the other hand, some researchers reported that addition of propionic acid (Carlson and Muller, 1977; Muller and Syhre, 1975) or formic acid (Muller and Syhre, 1975) maintained a constant pH for three weeks at high temperatures.

Both our results and results from other studies indicate that acid addition to colostrum before fermentation has begun will ensure a more effective preservation.

The reason of increased pH in acidified colostrum stored at summer ambient temperatures as from 15th day of storage could be attributed to protein breakdown to simpler compounds like ammonia and amines. These compounds cause an increase in pH of their environment (Çon and Gökalp, 1997).

Although it was not equally proportional, acidity of colostrum stored at summer ambient temperatures increased as pH decreased and began decreasing when pH began increasing. During fermentation, acidity increases because of acid production and consequently pH decreases (Bush *et al.*, 1980).

There were no marked changes in pH and acidity values of acidified colostrum stored in refrigerator during 25 days of storage. This can be explained by the fact that no considerable fermentation occurred because colostrum was milked under sanitary conditions and stored in a refrigerator before and after acidification.

Specific gravity and DM content of colostrum stored at summer ambient temperatures decreased markedly during 25 days of storage. DM content was 14% at day 0 and decreased to 9.95% on the 25th day of storage. The DM in colostrum stored at ambient temperatures, with or without chemical additives, decreased with storage (Otterby *et al.*, 1976, 1977; Daniels *et al.*, 1977; Rindsig *et al.*, 1977). The level of DM loss, however, could change according to season, chemicals used and the amount of chemicals added. Some researchers found that DM in colostrum acidified with propionic acid during summer months was higher than that of naturally fermented colostrum (Carlson and Muller, 1977; Polzin *et al.*, 1977). Conversely, Muller *et al.* (1976) and Rindsig and Bodoh (1977) found that DM content of colostrum with propionic acid was lower than those of naturally fermented colostrum or colostrum with formaldehyde. The decrease in DM with storage time is related to decreases in fat and protein and probably lactose because of microbial fermentation (Carlson and Muller, 1977). In our study, the marked loss of DM in acidified colostrum stored at summer ambient temperatures can be explained by the fact that fermentation began before acidification and continued intensively due also to the effect of high ambient temperatures although acid addition. Both specific gravity and DM content of acidified colostrum stored in refrigerator were almost constant during 25 days of storage. Colostrum could also be stored by freezing and no changes occurred in the composition of frozen colostrum (Carlson and Muller, 1977). No marked changes during storage time in pH, acidity, specific gravity and DM content of colostrum stored in refrigerator indicate that storing colostrum in refrigerator after acidification have ensured a preservation, for three to four weeks, similar to that obtained by freezing.

Acknowledgements
Financial assistance of the Commission for Ege University Scientific Research Projects is gratefully acknowledged.

References

Anonymous, 1981. Handbuch zur Stiekstoff Bestimmung nach Kjeldahl. Gerhardt GmbH, Bonn.

Bush, R.S., R.E. McQueen and J.W.G. Nicholson, 1980. Chemical changes in bovine colostrum preserved with formalin or by fermentation. J. Dairy Sci., 63: 464-470.

Carlson, S.M.A. and L.D. Muller, 1977. Compositional and metabolic evaluation of colostrum preserved by four methods during warm ambient temperatures. J. Dairy Sci., 60: 566-571.

Çon, A.H. and H.Y. Gökalp, 1997. Gıda Mikrobiyolojisi (Food Microbiology). Pamukkale Üniv. Müh. Fak. Ders Notları, Yayın No: 007. Müh. Fak. Basım Ünitesi, Denizli-Turkey.

Daniels, L.B., J.R. Hall, Q.R. Hornsby and J.A. Collins, 1977. Feeding naturally fermented, cultured and direct acidified colostrum to dairy calves. J. Dairy Sci., 60: 992-996.

Foley, J.A. and D.E. Otterby, 1978. Availability, storage, treatment, composition and feeding value of surplus colostrum: A review. J. Dairy Sci., 61: 1033-1060.

Foley, J.A. and D.E. Otterby, 1979. Performance of calves fed colostrum stored by freezing, fermentation, or treatment with lactic or adipic acid. J. Dairy Sci., 62: 459-467.

Jenny, B.F., B.A. Costello and Van H.J. Dijk, 1980. Performance of calves fed colostrum treated with sodium benzoate or benzoic acid. J. Dairy Sci., 63: 959-963.

Jenny, B.F., S.E. Mills and G.D. O'Dell, 1977a. Dilution rates of sour colostrum for dairy calves. J. Dairy Sci., 60: 942-946.

Jenny, B.F., G.D. O'Dell and M.G. Johnson, 1977b. Microbial and acidity changes in colostrum fermented by natural flora at low and high ambient temperatures. J. Dairy Sci., 60: 453-457.

Mbuthia, E.W., F. Klobasa, C.K. Gachuiri and A. Abate, 1997. Effect of treatment with formaldehyde and formic acid on immunoglobulin content of stored bovine colostrum. Anim. Feed Sci. Tech., 67: 291-298.

Muller, L.D., G.L. Beardsley and F.C. Ludens, 1975. Amounts of sour colostrum for growth and health of calves. J. Dairy Sci., 58: 1360-1364.

Muller, L.D., F.C. Ludens and J.A. Rook, 1976. Performance of calves fed fermented colostrum or colostrum with additives during warm ambient temperatures. J. Dairy Sci., 59: 930-935.

Muller, L.D. and J. Smallcomb, 1977. Laboratory evaluation of several chemicals for preservation of excess colostrum. J. Dairy Sci., 60: 627-631.

Muller, L.D. and D.R. Syhre, 1975. Influence of chemicals and bacterial cultures on preservation of colostrum. J. Dairy Sci., 58: 957-961.

Otterby, D.E., R.E. Dutton and J.A. Foley, 1977. Comparative fermentations of bovine colostral milk. J. Dairy Sci., 60: 73-78.

Otterby, D.E., D.G. Johnson, J.A. Foley, D.S. Tomsche, R.G. Lundquist and P.J. Hanson, 1980. Fermented or chemically-treated colostrum and nonsalable milk in feeding programs for calves. J. Dairy Sci., 63: 951-958.

Otterby, D.E., D.G. Johnson and H.W. Polzin, 1976. Fermented colostrum or milk replacer for growing calves. J. Dairy Sci., 59: 2001-2004.

Polzin, H.W., D.E. Otterby and D.G. Johnson, 1977. Responses of calves fed fermented or acidified colostrum. J. Dairy Sci., 60: 224-234.

Rindsig, R.B., 1976. Sour colostrum dilutions compared to whole milk for calves. J. Dairy Sci., 59: 1293-1300.

Rindsig, R.B. and G.W. Bodoh, 1977. Growth of calves fed colostrum naturally fermented, or preserved with propionic acid or formaldehyde. J. Dairy Sci., 60: 79-84.

Rindsig, R.B., J.G. Janecke and G.W. Bodoh, 1977. Influence of formaldehyde and propionic acid on composition and microflora of colostrum. J. Dairy Sci., 60: 63-72.

Schmidt, G.H., Van L.D. Vleck and M.F. Hutjens, 1988. Principles of Dairy Science. 2nd Ed. Prentice Hall, Englewood Cliffs, New Jersey.

Swannack, K.P., 1971. Dairy heifer calf rearing on cold milk substitute or colostrum. Anim. Prod., 13: 381.

Yu, Y., J.B. Stone and M.R. Wilson, 1976. Fermented bovine colostrum for Holstein replacement calf rearing. J. Dairy Sci., 59: 936-943.