MILK REPLACER STUDIES WITH DAIRY CALVES

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INTRODUCTION

Many dairy calves are being raised successfully on various milk replacement formulas containing animal and vegetable products; however some of these substitutes have only limited usefulness due to their diarrheic effect.

In recent work at this station, the role of minerals and fat as factors influencing the incidence and severity of diarrhea was investigated. Still other factors relating to the composition of milk substitutes and the way in which they are fed to the calf need to be evaluated.

If sufficient basic information were available on this problem, milk replacer rations could possibly be formulated in a manner more nearly compatible with the physiological needs of the calf. The research reported here represents a further attempt to obtain information concerning the dietary suitability of feeding milk replacer rations to dairy calves. The specific objective of the present experiment was to ascertain the independent and interacting effects of curd formation (normal vs. prevention with sodium citrate), and temperature of feeding a milk replacer on the health and growth of young dairy calves.

REVIEW OF LITERATURE

This review is limited as far as possible to studies involving the coagulation, dilution, and temperature of feeding milk or milk replacer as these factors affect the growth and health of dairy calves during the first six weeks of life. This age span was chosen for the problem under study because the specific character of the diet during this period is more important than at any other time in the life of the calf. However, where information is restricted on young calves similar information on older calves may be noted.

Curd Formation in Calf's Stomach

Since the rapid passage of material through the abomasum of the calf would result in a high concentration of partially digested feed in the small intestine, it is important to know what relationship, if any, exists with respect to curd formation and gastric digestion. There is evidence (2, 11) suggesting that the formation of a curd is necessary to avoid digestive disturbances and scours; however, Owen et al. (17) found that feeding calves milk of different curd tensions did not have a significant effect on the consistency of the feces of young calves, and many milk replacers which do not form a curd in the stomach have been successfully employed in calf-feeding (19).

Effect of Composition of Diet and Incidence of Scours

Blaxter and Wood (2) found in a series of experiments that reduction of the casein content of liquid diets, which leads to inhibition of clot formation, resulted in decreased digestibility of dietary fat and protein and induced severe, uncontrollable scours. Replacement of casein, which forms a clot with rennet, by gelatin leads to profuse diarrhea.

A further aspect concerns the nature of the clot and the dependence of the rennet clotting of casein on calcium ions, acidity, and the inhibitory effect of salts of the alkali metals. In one series of experiments by Blaxter and Wood (2), lowering the calcium content of an artificial diet from 110 to 80 mg. per 100 ml., thus increasing clotting time, resulted in scouring. Similarly, Kastelic et al. (11) reported that severe diarrhea occurred in colostrum-deprived calves up to 14 days of age when fed a semi-synthetic diet in which rennet coagulation was prevented by adjusting the calcium to sodium ratio to 0.8-1.0. However, calves performed satisfactorily when fed the same diet with a calcium to sodium ratio of 2.5 to 1.0 which allowed coagulation. It is of interest that many reconstituted milk powders do not clot with rennet, probably as a result of changes in the solubility and ionization of the calcium, and that ability to clot is restored by the addition of a calcium salt. Williams and Jensen (25) found that the feces of calves fed added calcium (5 and 8% hydrated lime; 5% calcium caseinate) were firmer than those of calves fed a replacement ration containing 1.5 percent di-calcium phosphate.

On the other hand, Owen et al. (17) reported that prevention of curd formation with sodium citrate in either whole or skim milk did not increase the incidence of diarrhea, and the diet was as satisfactory for calves 11 days of age and older as milk in which coagulation occurred normally. More recently, Owen and Brown (16) found that a curd formation is not needed for satisfactory performance of calves from 14 to 42 days of age.

It has been suggested by Sheehy (21) that formation of very hard curds in the abomasum of young calves can lead to abomasal and duodenal irritation and hence to the rapid passage of subsequent meals, resulting in undigested feed materials in the lower part of the intestine. Dicky and Cannon (3) found that one-liter portions of skim milk having curd tensions of 142 and 40 g. required approximately 9 1/2 and 3/4 hours, respectively, to be liquified and leave the calf's abomasum. However, no significant difference was observed in the final rate of passing through the digestive tract as determined by the appearance of a carmine marker in the feces. Mortenson et al. (13) observed that two liters of raw skim milk usually left the abomasum in about 12 to 18 hours, while the equivalent amounts of boiled and autoclaved milk required about 8 to 12 hours for evacuation. It has been shown by Espe and Dye (6) and Hill (9) that prolonged heat treatments or boiling, softens the curd of the milk or lowers its curd tension. Further, Shoptaw et al. (22) reported that soybean gruel does not form a hard curd and leaves the stomach more rapidly than the curd from milk; while Owen (18) reported that citrated milk left the calf's stomach in 1 hour in comparison to about 15 hours for untreated milk. More recently, Schuh (20) has concluded that the average time required for experimental diets (fat and/or minerals added to a basal diet of reconstituted dried skim milk containing 10% total solids) to be liquified and leave the abomasum decreases as the calves grow older. This may well be the result of increased development of the gastric secretion and enzyme functions. Although the experimental diets had low curd tension values, ranging from 0 to 5 g. as determined by the rennet coagulation test, they were observed radiographically to remain in the abomasum for a considerable time. The average time required for emptying of the stomach was 14.2 ± 9.8 hours (standard deviation) in the calves at 4 days of age as compared to 8.2 ± 4.4 hours at 11 days of age.

In addition to being a valuable source of food, fat would appear to affect the type of curd and aid digestion when incorporated in the milk in limited amounts. Espe and Cannon (5) reported that curd from milk containing up to six percent fat tends to leave the stomach more rapidly than skim milk due to the difference in texture of the curd formed. Hill (9, 10) also has shown by an *in vitro* milk curd test that the presence of fat or butterfat in milk has a softening effect on the curd; its removal by separation increases the hardness of the curd of milk. Owen *et al.* (17) found that the presence of milk fat (3%) reduced calf diarrhea. Hargrave (8) had shown that skim milk forms a firm, tough curd in the stomach of the calf, but when fat was added to skim milk, the physical character of the curd was changed. The curds from three and six percent milks were soft and friable and more digestible than those of skim milk. Schuh (20) found that a high level of minerals seems to be a definite factor in the cause of the diarrhea which occurred in his study. It was noted, however, that the most diarrheic diet contained both minerals and fat. From the radiographic data obtained on the passage of the experimental diets from the abomasum, there did not appear to be any definite relationship between the composition of the experimental diets and the rate of their disappearance from the abomasum. Furthermore, the consistency of the feces, on the day the radiographs were taken, did not appear to be associated with the length of time that the experimental diets remained in the abomasum. Thus the diarrheic effect of the high-mineral diets used in this study could not be attributed to an alteration in abomasal-emptying time.

Growth and Feed Efficiency

Kastelic et al. (11) have shown that artificial milks which do not clot with rennet, as mentioned before, either because of a low concentration of calcium or a high concentration of sodium, lead to considerable weight loss and very high mortality in colostrum-deprived calves up to 14 days of age. It was suggested that calves 14 days of age or older performed satisfactorily on the diet with the Ca:Na ratio of 0.8 to 1.0 because of greater production of pepsin and HCl in the stomach at this later age bringing about coagulation. Also Blaxter and Wood (2) concluded as mentioned above that diarrhea was inevitable in dairy calves when curd formation was inhibited. In contrast to the above reports, Owen et al. (17) found that either whole or skim milk in which coagulation was prevented by the addition of sodium citrate was satisfactory for normal growth and feed efficiency for calves 11 days of age and older. More recently, Owen and Brown (16) presented further information showing that curd formation as independent factor has no significant effect on weight gains or efficiency of milk utilization during the 14- to 42-day age period. But, when diluted milk was fed citrated, gains were 13 lbs. greater than when fed without the curd inhibited. Also Williams and Jensen (25) reported, in the study mentioned above, that the hydrated lime when added at the five percent level promoted growth equal to that of whole milk.

Digestibility

Dickey and Cannon (3) assumed that more rapid, and possibly easier, passage of the curd from the stomach indicated a superior and more highly digestible milk. Also, Kastelic et al. (11) concluded that coagulation of milk in the stomachs of calves is of vital importance to the proper digestion and assimilation of nutrients in synthetic milk. The marked improvement in response of calves to rennet incoagulable milk of low Ca:Na ratio (0.8:1.0) as they grew older, coincident with an increased development of gastric secretion, is evidence that coagulation of ingested milk is an essential step in the assimilation of this food during early life. This offers evidence for the delayed development of the pepsin-HCl digestive function in the calf.

Hill (9, 10) reported that the evaporated or heated milk formed softer and more digestible curds in infants than untreated milk. Similarly, Espe and Dye (6) found that doubling the curd tension of milk increases the length of its digestive period by pepsin from 30 to 65%. Wallen and Koch (24) found that the tryptic digestions of raw and heat treated milks showed a marked difference in digestibility even though the size and consistency of the casein curd were not a complicating variable. They thought possibly other differences exist besides the physical character of the curd, which in part may explain the better ease with which milk when boiled or evaporated is handled in digestion. As far as the relation of fat content of milk to the milk curd digestion in the stomach of the calf is concerned, Espe and Cannon (5) showed that the curd from milk containing three to six percent of fat produced a much softer curd in the stomach of the calf about 2-3 weeks of age than fat-free milk while this amount of fat is sufficiently low to not inhibit the normal digestive functioning of the stomach. It would appear, therefore, that the action of the fat was not antagonistic to the commonly accepted methods of making the milk more digestible, such as diluting with lime water or boiling.

Temperature of Feeding Replacer

It is generally recommended that milk should possess nearly the body temperature when fed to calves and that it should be fed regularly and with little variation in temperature (14).

Relation to Incidence of Diarrhea

Information concerning temperature of feeding liquid diets to dairy calves, and its relationship to incidence of scours, has been reported by very few workers. Walker (23) reported slight scours during the first few days following the commencement of cold milk (0°C.) feeding to calves two days of age. Similarly, cold skim milk has been successfully fed to four-day-old calves by Dracy and Bartle (4). More recently, Owen and Brown (16) found that calves fed cold (50°F.) milk averaged slightly less moisture in the feces during the first four days on experiment than did calves on warm (100°F.) milk; however, there was no significant difference for the two temperatures (50 vs. 100°F.). Diarrhea was no problem and health and condition of calves were generally good.

Growth and Feed Efficiency

Although slight scours were observed by Walker (23) in three two-day-old calves fed milk at 0°C., satisfactory weight gains were made by them from birth to 3 weeks of age. Owen and Brown (16) reported that milk temperature, as an independent factor, did not have a significant effect on weight gains or efficiency of milk utilization during the 14- to 42-day age period. But, when the diluted milk was fed cold (at 50°F.), calves averaged 12 lb. more gain than when the diluted milk was warm (at 100°F.), but when milk was fed undiluted the difference in gains between the cold and warm treatments was only 6 lbs. However, the difference in gains between calves fed milk at the two temperatures was significantly greater

($P < 0.01$) when the milk was fed diluted than when fed undiluted. The TDN required to produce a pound of gain was significantly affected ($P < 0.05$) in the same manner as were gains.

Dilution of Milk Replacer

Dilution of the milk with water was found by Sheehy (21) to be effective in alleviating and preventing digestive disorders in young milk-fed calves. However, the incidence and severity of diarrhea among calves in the control group were extremely high. Although Gaunya _et al._ (7) reported that calves fed undiluted colostrum for the second day through the fifth week of age made 25% more gain in weight than calves fed diluted colostrum, this difference was found not to be significant. There was little difference in the incidence of diarrhea among calves fed diluted and undiluted colostrum. This result closely approximates what was found by Owen and Brown (16) in their recent study. They reported that milk dilution as independent factor did not have a significant effect on weight gains or efficiency of milk utilization during the 14 to 42 day age period. Calves fed diluted milk averaged slightly higher feces moisture than calves fed undiluted milk during the first four days on experiment. However, as mentioned above, the difference in gains between calves fed milk at the two temperatures (50 vs. 100°F.) was significantly greater ($P < 0.01$) when the milk was fed diluted than when fed undiluted. Dilution also interacted with curd formation in its effect on gains in weight of calves and their feed utilization. The difference in gains between calves fed citrated and noncitrated diets was significantly greater ($P < 0.01$) when the milk was diluted than when undiluted.

EXPERIMENTAL PROCEDURE

Coagulation Studies

In vitro studies

The curd tension of the basal diet was determined by the A. D. S. A. method (12). This method was not satisfactory for determining the amount of citrate needed to prevent coagulation, however, because the reconstituted replacer formed a very soft curd. Therefore, the following method was used: Ten milliliters of milk replacer[1] were placed in each of 12 test tubes, and the following respective amounts of sodium citrate solution[2] were added in duplicate: 0, 0.2, 0.4, 0.6, 0.8, and 1.0 ml. Sufficient water was added to equalize the volume in all the tubes, and they were placed in a water bath at 95°F. for about 7-8 minutes. Each tube containing the milk replacer was then poured directly into a tube having one milliliter of pepsin-HCl solution[3] also at 95°F. The mixtures were placed again in water bath, and the extent of coagulation was determined after 10 minutes and at other intervals up to one hour.

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[1]The milk replacer was prepared by mixing 130 grams of dried replacer in one liter of water.

[2]The sodium citrate solution was prepared by dissolving 2.0 grams of U.S.P. granular sodium citrate in 100 ml. of distilled water.

[3]The pepsin-HCl solution was prepared by mixing 225 mg. pepsin in 50 ml. of 0.08 N HCl.

In vivo studies

Two Jersey calves, one of which was fed experimental diet 1 and the other experimental diet 4, were sacrificed at ten days of age for the purpose of determining the amount of curd formation in the abomasum. They were fed the respective experimental diets about one hour and 15 minutes before being sacrificed. The abdomen was opened immediately after killing and the contents of the abomasum examined for the presence of coagulated milk.

Growth Studies

Plan of experiment

Forty male Ayrshire calves were used to study the effects of coagulation and temperature of feeding a milk replacer. A randomized block design with a 2x2 factorial arrangement of treatments was employed. Four calves within each of ten blocks were assigned at random to the following treatment groups: 1, cold-milk replacer; 2, heated-milk replacer; 3, cold-citrated milk replacer; 4, heated-citrated milk replacer.

Feeding and management of calves

The calves were obtained at 1-3 days of age from the Oklahoma State University herd and some selected dairy farms nearby. They were placed in individual pens with wood shavings for bedding in the experimental dairy barn.

Each calf received colostrum until one and one-half days of age. On the evening of the second day all calves were fed homogenized milk. Beginning at four days of age, the experimental diets were administered via nipple pail twice daily at about 12-hour intervals. The calves were fed the experimental diets at the rate of 10% and 8% of initial body weight during the first and second three-week periods, respectively. The calves were weaned after 42 days on experiment. A calf starter containing 20 percent dehydrated alfalfa pellets (Appendix Table I) was fed free choice to the calves throughout the experiment. Each calf was encouraged to eat the starter during the first few weeks of the experiment by placing some of it in the calf's mouth following milk feeding. The amount of grain consumed by each calf was recorded weekly.

Milk was fed at temperatures of either 40 or 100°F., with or without sodium citrate solution, according to the assigned treatment. Each calf received chlortetracycline in the form of Aurofac D in the milk at the rate of 500 mg/day for the first week and 50 mg/day thereafter until weaned. Chlortetracycline was also included in the grain mixture. Body weights were obtained on two consecutive days at the beginning and end of the experiment and at weekly intervals throughout the experiment. Observations were made several times a day on the health of the calves and incidence of diarrhea. Fecal consistency was rated and recorded twice daily on an arbitrary scale of one through four denoting: 1, normal; 2, very soft; 3, semi-fluid; and 4, extremely fluid feces. The thriftiness of each calf was rated upon termination of the experiment at 8 weeks of age as follows: very thrifty, thrifty, and unthrifty.

Preparation of experimental rations

The basal diet was reconstituted Land O' Lakes[4] dried milk replacer (Appendix Table II) containing 13% total solids. The experimental diets

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[4]Land O' Lakes Creameries, Inc., Agricultural Service Division, Minneapolis, Minn.

were prepared at the time of feeding by reconstituting the replacer with water at either 40° or 100°F. to obtain diets to be fed cold and hot, respectively. Four milliliters of sodium citrate solution[5], containing 0.45 g. sodium citrate per milliliter, was added per pound of milk replacer in preparing diets 3 and 4.

Digestibility Studies

Twelve male Holstein calves from the Oklahoma State University herd were used for studying the digestibility of certain components (protein, dry matter, fat) of the milk replacer used in the growth studies described above. Three calves were assigned to each of the treatment groups as follows: (a) cold-milk replacer, (b) heated-milk replacer, (c) cold-citrated milk replacer, (d) heated-citrated milk replacer. During the first week the calves were fed whole milk, after which the experimental diets were fed in two equal portions each day at the rate of 10% of initial weight per day. A preliminary period of 13-19 days and a collection period of 9-10 days were used. Aliquot samples of the experimental diets were obtained at each time of feeding and frozen until time for analysis.

Fecal collections were begun when the calves were approximately 24 days of age, using 9" x 3" x 18" plastic bags as described by Noller et al. (15). Long strips of cellulose tape were placed along each side of the bag, as were shorter crosspieces at about midway between the two ends to prevent tearing when the long tapes were cut to form the flap. After the bag was taped and cut, the tail opening was made by cutting a reinforced

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[5]Sodium citrate solution was prepared by dissolving 450 g. of U.S.P. granular sodium citrate ($Na_3C_6H_5O_7 \cdot 2H_2O$) into each liter of solution.

square hole the approximate size of the tail. The entire area back of the hip bones and flank of the calf was clipped. The underside, posterior to the prepuce, also was clipped. Adhesive tape, 2 in. wide and approximately 9 in. long, was attached and sutured to the rump of the calf midway between the hip and pin bones. The tape on the underside of the calf was attached in the same way.

The prepared plastic bag (Figure 1) was attached by passing the tail through the tail opening and passing the end of the bag under the back tape, folding it over the tape and fastening with strips of cellulose tape. The lower flap was attached by passing the flap between the lower tape and the body, folding back and fastening with cellulose tape. Care was used to prevent undue strain on the bag.

The calves were observed three times daily and the bag was changed at these times if feces had been voided. The bag was removed by cutting with scissors. After removal, the bag and contents were weighed, the bag was opened and after mixing one tenth of the contents was taken for a composite sample. The samples were frozen in plastic bags until time for analysis. The dry matter, protein and fat of the milk replacer and feces were determined by A.O.A.C. methods (1).

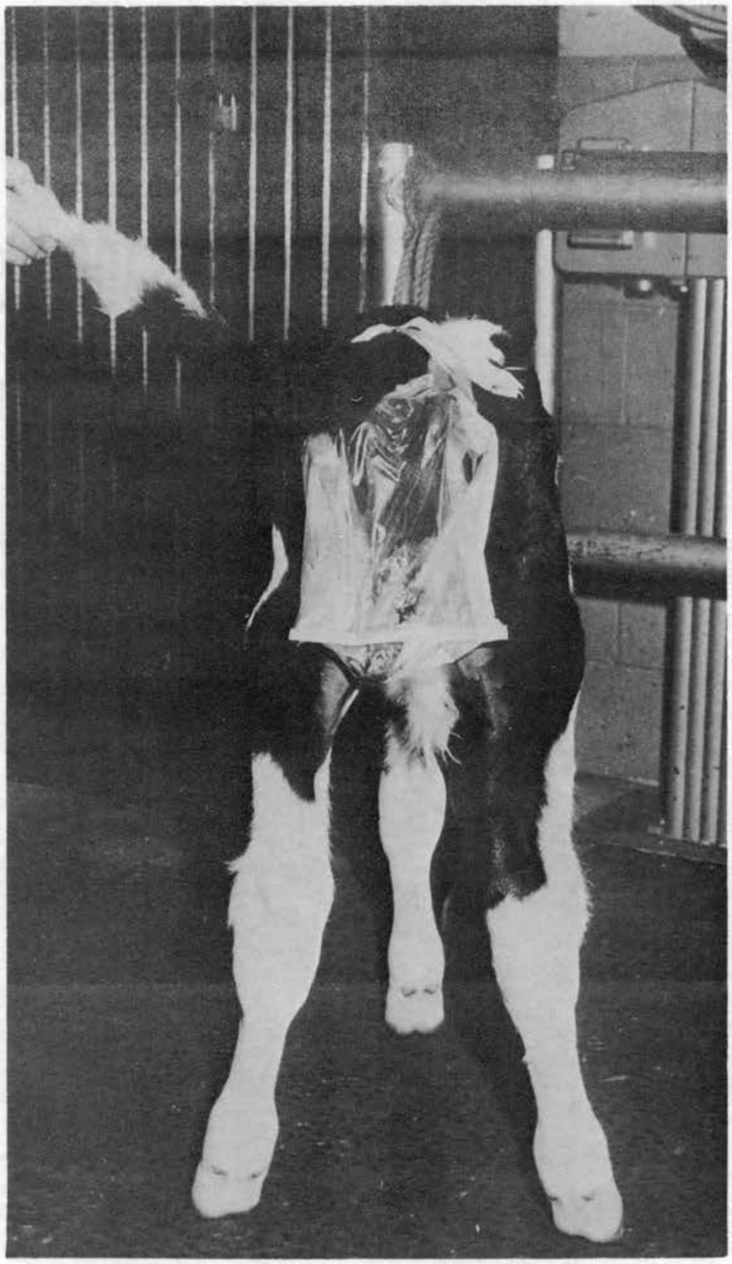

Figure 1. Example of Calf with Plastic Bag Attached for Feces Collection.

RESULTS AND DISCUSSION

Coagulation studies

<u>In vitro</u>: In both series of observations, firmness of the milk replacer curd decreased as the concentration of sodium citrate increased (Table 1). On the basis of these observations, it was concluded that approximately 1.8 g. of sodium citrate would be needed per pound of milk replacer to prevent coagulation. Therefore, four milliliters of sodium citrate solution containing 450 g./liter was added to each pound of replacer fed to calves receiving the citrated milk diets.

<u>In vivo</u>: The results obtained from sacrificing the two Jersey calves clarify the effects of sodium citrate in the milk replacer and temperature of feeding on extent and characteristics of curd formation in the abomasum of young dairy calves.

When cold non-citrated milk replacer (diet 1) was fed to one calf considerable fluid was found in the abomasum. This could have been partly water since the calf was allowed to drink water free-choice. There was also a large amount of curd present. The curd was soft and had a creamy color; it was in pieces about one inch or less in diameter. It was estimated that the total amount of curd present in the abomasum was about one pint, following a regular feeding of approximately 3.0 lb. of replacer containing 13% total solids. The contents of the anterior portion of the small intestine were dark yellow and there was no evidence of any curd present. The intestinal contents were quite fluid, although viscous. There was a large amount of shavings in the rumen of calf.

TABLE 1

Observations on *in vitro* Curd Formation Test

ml. of citrate solution added[a]	Extent of curd formation after different intervals of time		
	10 minutes	20 minutes	one hour
0.0	soft curd	soft curd	reasonably firm curd
0.2	soft curd	soft curd, definite form	reasonably firm curd
0.4	soft curd	soft curd, loose	definite curd, but broken up some
0.6	soft curd	soft curd, loose	definite curd, but loose
0.8	soft curd, loose	soft curd, loose	curd, but loose
1.0	very loose curd	very loose, broken up	definite curd, but loose
0.0[b]	soft curd	definite curd, soft and loose	
2.0[b]	fine granular curd (extremely loose)	very fine curd, extremely loose	
0.0[bc]	definite curd (soft, loose)	definite curd, soft and loose	

[a]Citrate solution contained 20 g. sodium citrate per liter.

[b]Second series of observations.

[c]Tap water was used.

On the other hand, when heated, citrated milk replacer (diet 4) was fed to the other calf, quite a lot of fluid was found in the abomasum, and no curd could be detected by palpation of the abomasum. Upon opening, about 1/2 to 3/4 gal. of material was noted in the abomasum. The milk replacer was not coagulated well at all, with the curd that was present being loose and in small pieces, about 1/4 inch or less in size. Most of it was of very small pieces of curd that did not hold together at all (pieces with irregular shape and no more than 1/8 inch for the largest dimension).

There was one mass of hard curd present, about 1 1/2 inch in diameter. This particular mass could have been whole milk curd since it looked so much different than the other curd present. Whole milk was last fed on the evening of September 23rd, and the animal was sacrificed on the morning of September 27th.

The intestine was opened just below abomasum and there was yellow, viscous material present. Farther down there was yellow, watery material. The feces of this calf was loose, although not enough so to be classed as having diarrhea. The rumen contained shavings and some fluid with a foul odor. There was no grain or hay in the rumen.

On the basis of these observations, it was concluded that the level of sodium citrated used was satisfactory for the prevention of coagulation of milk replacer under in vivo conditions.

Growth and feed consumption

The general performance of the calves may be considered satisfactory in view of the nature of the experimental diets used in this study (Figures 2 and 3). However, one calf in Group 2 (receiving diet 2) was taken

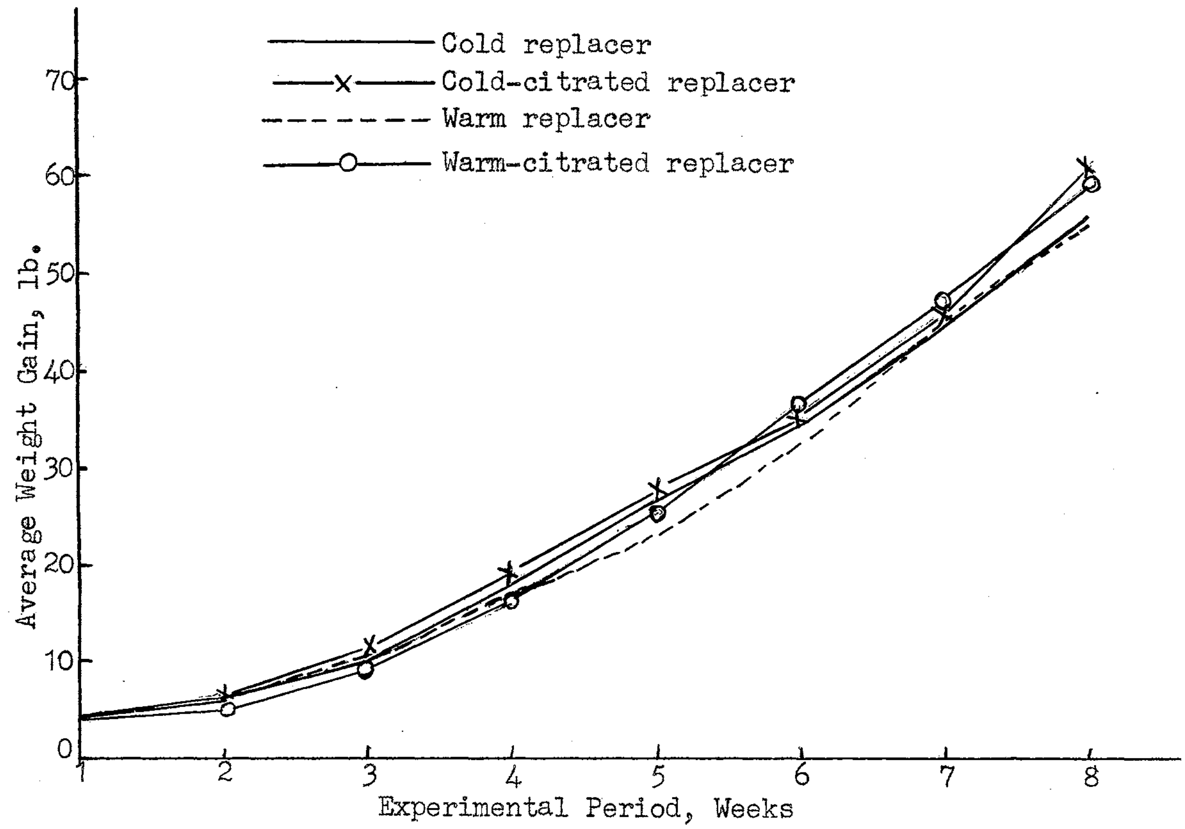

Figure 2: Cumulative Average Weight Gains of Calves Receiving Different Replacer Diets

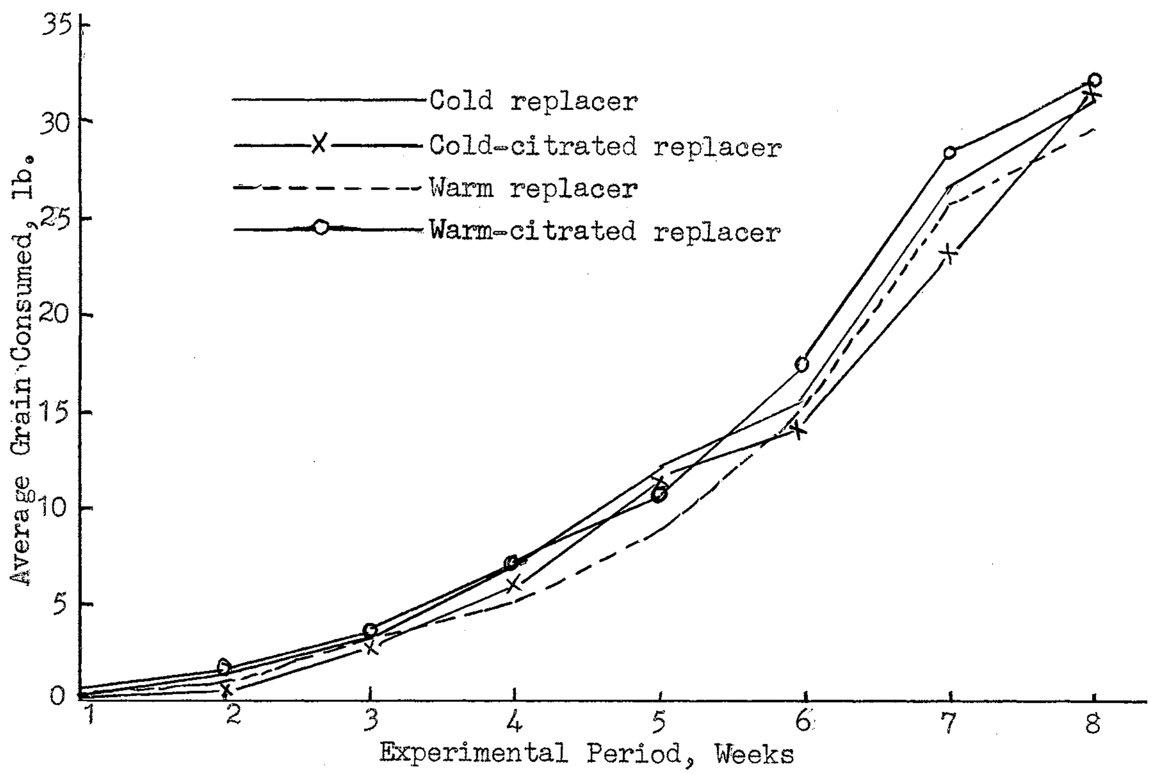

Figure 3: Cumulative Average Grain Consumed by Calves Receiving Different Replacer diets.

off the experiment during the seventh week, and another calf in Group 3 died during the last week of the experiment because of severe diarrhea. Since this condition developed in these two calves after they had been weaned, it could not be associated directly with the respective milk replacer diets. In general, all calves continued to consume the prescribed amounts of the experimental diets even though relatively severe infectious diarrhea was evident in some cases.

The calves receiving the diets which had citrate added, for the prevention of curd formation, had slightly higher average weight gains than those receiving non-citrated diets during first six weeks of experiment (Table 2). The average weight gain for the calves fed the milk replacer at 40° F. was 34.7 lb. as compared to 34.5 lb. for the calves fed the replacer at body temperature, 100° F. There was sufficient variation in weight gains among calves within each of the groups that the differences among groups were not statistically significant ($P > 0.05$).

TABLE 2

Average Weight Gains During First Six Weeks of Experiment

Treatment	No citrate	Citrate	Average
	lb.	lb.	lb.
Cold diet	34.2	35.2	34.7
Hot diet	32.2	36.7	34.5
Average	33.2	35.9	34.6

The differences in weight gains within the four groups of calves in the present study were probably at least partly due to differences in grain consumption. However, there were no appreciable differences among the four treatment groups with respect to the average amount of grain consumed by the calves during the first six weeks of experiment (Table 3).

TABLE 3

Grain Consumed by Calves During First Six Weeks on Experiment

Treatment	No citrate	Citrate	Means
	lb.	lb.	lb.
Cold diet	39.1	34.9	37.0
Hot diet	33.9	40.5	37.2
Means	36.5	37.7	37.1

On the basis of the results of this experiment, it appears that curd formation in the abomasum following milk-replacer feeding is not needed for satisfactory performance of calves from 4 to 42 days of age. Also, since the growth of calves receiving the milk-replacer diets at 40 vs. 100° F. was quite similar, it may be concluded that the temperature at which a replacer is fed to calves is not a critical factor. Other workers (16, 17) have also found that milk diets in which coagulation was prevented by the addition of sodium citrate, and those fed at different temperatures (50 vs. 100° F.) were satisfactory for normal growth of calves up to 42 days of age.

During two weeks following weaning, the calves had higher rates of body weight gains than during the milk-replacer feeding period (Figure 2). This was partly due to higher total feed consumption by calves during the last two weeks of the experiment (Tables 3, 5). However, the differences among the four treatment groups with respect to body weight gains during the eight weeks of experiment were not statistically significant ($P > 0.05$).

TABLE 4

Average Weight Gains During the Eight-Week Experimental Period

Treatment	No citrate lb.	Citrate lb.	Average lb.
Cold diet	55.7	60.7	58.2
Hot diet	55.2	59.0	57.1
Average	55.5	59.9	57.6

TABLE 5

Grain Consumed by Calves During the Eight-Week Experimental Period

Diets	No citrate lb.	Citrate lb.	Average lb.
Cold	95.5	91.8	93.7
Hot	92.1	100.8	96.5
Average	93.8	96.3	95.2

Health of the calves and fecal consistency

All except two of the forty calves in this experiment ranged from thrifty to very thrifty in general appearance and health at the end of the 8-week trial (Table 6). In general, most of the calves were in good condition throughout the experimental period even though relatively severe infectious diarrhea was evident in some cases.

TABLE 6

Thriftiness Rating on Calves at End of Experiment

	Thriftiness Rating		
Treatment group	Unthrifty	Thrifty (No. of calves)	Very thrifty
Cold replacer	0	8	2
Cold-citrated replacer	1[a]	7	2
Hot replacer	1[b]	7	2
Hot-citrated replacer	0	8	2

[a]Died prior to termination of experiment.

[b]Killed prior to termination of experiment, because of severe diarrhea.

There were no appreciable differences among the four treatment groups with respect to average number of days on which the calves received various ratings on fecal consistency (Table 7). Therefore, neither curd-inhibition nor feeding of the replacer at a low temperature (40° F.) had any adverse effect on the health of the calves. On the majority of days during the eight-week period, calves in each group were observed to have normal fecal consistency. Similarly, other workers (4, 16, 23) have

TABLE 7

Feces Consistency Ratings on Calves

	Average number of days with following feces ratings[1]			
Diets	1	2	3	4
Cold	45.9	7.5	2.2	0.4
Hot	46.7	6.4	2.6	0.3
Cold-citrated	44.8	7.0	3.1	1.1
Hot-citrated	45.8	5.1	4.0	1.1

[1]Rating scale: 1, normal; 2, very soft; 3, semi-fluid; 4, extremely fluid.

observed only slight scours following the feeding of cold milk or skim milk to very young calves. The absence of adverse effects due to feeding curd-inhibited diets in the present experiment is in agreement with the findings of some other workers (16, 17), but appears contrary to the conclusions of others.

Blaxter and Wood (2) stated that when curd formation was inhibited, scours inevitably followed. However, the absolute effect of coagulation was not ascertained in their work, since the diets used either were abnormally low in casein or contained gelatin. Kastelic *et al.* (11), using synthetic diets, reported that scours and death resulted when colostrum-deprived calves were fed diets in which the Ca:Na ratio was altered to prevent curd formation.

Digestibility

There were no marked differences among the four treatment groups with respect to the apparent digestibility of dry matter, protein, and fat in the milk replacer (Table 8). The average apparent digestibility of dry matter, protein, and fat were 92.2, 88.4, and 99.6, respectively. Thus, it is evident that the constituents of the diet were highly digestible, and that none of the four various treatments had any effect on the digestibility of it by the calves in this experiment. Moreover, these results give additional evidence that curd formation of the milk replacer is not needed in the feeding of young dairy calves for satisfactory performance. The formulated milk diet can be fed either cold (40° F.) or warm (100° F.) to young calves without any adverse effect on the nutritional value of the diet as determined by its digestibility.

TABLE 8

Average Apparent Digestibility of Dry Matter, Protein, and Fat in the Milk Replacer

Treatment groups	Constituent		
	Dry matter	Protein	Fat
	%	%	%
Cold-noncitrated	91.1	87.1	99.5
Hot-noncitrated	91.1	88.3	99.6
Cold-citrated	92.4	88.0	99.6
Hot-citrated	94.1	90.3	99.7
Average	92.2	88.4	99.6

SUMMARY AND CONCLUSIONS

Forty male Ayrshire calves were used to evaluate the effects of coagulation and temperature of feeding a milk replacer on the health and growth of young dairy calves. The calves were grouped on the basis of season of birth and assigned at random to the following treatment groups: 1, cold-noncitrated milk replacer; 2, warm-noncitrated milk replacer; 3, cold-citrated milk replacer; 4, warm-citrated milk replacer.

The differences among the four groups of calves were not significant ($P > 0.05$) in terms of live weight gain and grain consumption during the first six or eight weeks of the experiment. This implies that curd formation (normal vs. prevention with sodium citrate) in the abomasum following milk-replacer feeding is not necessary for satisfactory performance of calves from 4 to 42 days of age. Also, since the growth of calves receiving the milk-replacer diets at 40 vs. 100° F. was quite similar, it may be concluded that the temperature at which a replacer is fed to calves is not a critical factor. On the majority of days during the eight-week period, calves in each group were observed to have normal fecal consistency. There were no appreciable differences among the four treatment groups with respect to average number of days on which the calves received various ratings on fecal consistency.

Twelve male Holstein calves were used for studying the digestibility of certain components (protein, dry matter, fat) of the milk replacer used in the growth studies. Three calves were assigned to each of the four treatment groups mentioned above. A preliminary period of 13-19 days and a collection period of 9-10 days were used.

No appreciable differences were obtained among the four treatment groups with respect to the apparent digestibility of any of the constituents of the milk replacer. Thus additional evidence was obtained to support the observation that curd formation of the milk replacer is not needed in the feeding of young dairy calves for satisfactory performance.

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A P P E N D I X

TABLE I

Composition of Grain Ration

Ingredients	Pounds per ton
Cubed corn	480
Crimped oats	480
Wheat bran	160
Corn distiller's solubles	100
Dried molasses	80
Soybean meal	240
Dicalcium phosphate	20
Trace mineral salt	20
Dehydrated alfalfa meal pellets	400
Antibiotic-vitamin mixture*	20
Total	2000

*Amount per pound of ration: Aureomycin, 25 mg.; Vitamin A, 2500 I.U.; Vitamin D, 312.5 I.U.

TABLE II

Composition of Milk Replacer*

Constituents	Percentage
Crude protein, not less than	24.00
Crude fat, not less than	10.00
Crude fiber, not more than	00.25
Ash, not more than	09.00
Moisture, not more than	05.00

*Ingredients: Dried skim milk, dried buttermilk, dried whole whey, dried whey product, dried whey solubles, lecithin, animal fat (preserved with butylated hydroxyanisole, propyl gallate, citric acid and propylene glycol), Vitamin A palmitate, Vitamin D_2 supplement, Vitamin E supplement, antibiotic feed supplement (source of chlortetracycline hydrochloride), niacin, ferrous carbonate, potassium iodide, manganese oxide, copper carbonate, cobalt carbonate, zinc carbonate.

TABLE III

Weight Gain and Grain Consumed by Individual Calves During First Six Weeks of the Experiment

	Treatment groups							
	Cold diet		Cold-citrated diet		Hot diet		Hot-citrated diet	
Blocks	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.
1	36.5	37.9	27.0	24.8	25.5	25.2	41.5	37.8
2	41.5	54.8	47.0	34.0	31.5	40.5	31.5	28.8
3	49.5	51.5	40.0	30.5	15.0	8.6	41.5	59.5
4	26.5	30.0	21.5	30.2	39.5	39.1	43.0	36.5
5	40.5	53.0	30.0	41.1	21.5	30.3	27.0	33.6
6	16.5	21.2	43.0	40.0	38.5	42.2	26.5	30.4
7	31.0	28.5	47.0	60.2	32.5	38.1	39.0	39.8
8	34.5	41.0	35.0	45.9	29.5	37.9	31.0	43.5
9	15.5	5.2	46.5	31.7	42.5	52.5	48.5	65.7
10	50.0	67.8	14.5	11.1	46.0	24.5	37.8	29.0
Average	34.20	39.09	35.15	34.95	32.20	33.89	36.73	40.46

TABLE IV

Weight Gain and Grain Consumed by Individual Calves During the Eight-Week Experimental Period

	Treatment groups							
	Cold diet		Cold-citrated diet		Hot diet		Hot-citrated diet	
Blocks	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.	Weight gain lb.	Grain consumed lb.
1	48.5	89.4	49.5	72.7	41.0	67.4	59.5	99.7
2	73.0	115.9	73.0	88.4	54.0	89.0	47.5	79.6
3	76.5	117.7	69.0	90.6	--	--	68.0	134.8
4	44.0	74.0	--	--	48.0	76.1	55.5	86.3
5	69.5	115.2	57.0	103.3	47.0	80.6	38.5	73.0
6	36.5	72.4	67.5	103.6	63.0	101.8	48.0	84.7
7	54.0	80.5	71.0	129.1	55.1	93.3	66.0	101.7
8	58.5	100.7	66.0	115.9	66.0	121.4	64.0	105.1
9	16.5	38.2	67.0	80.7	70.5	132.7	76.0	145.7
10	80.0	150.7	26.0	42.2	52.5	66.9	67.3	97.0
Average	55.7	95.47	60.67	91.83	55.23	92.13	59.03	100.76

TABLE V

Analysis of Variance on Six-Week Weight Gains

Source of variance	Degrees of freedom	Sum of squares	Mean square	F
Total	39	3964.4		
Blocks	9	357.2	39.7	
Treatment	3	107.6		
Coagulation	1	75.5	75.5	0.580
Temperature	1	00.8	00.8	0.006
Coag. x Temp.	1	31.3	31.3	0.240
Error	27	3499.6	129.6	

TABLE VI

Analysis of Variance on Eight-Week Weight Gains

Source of variance	Degrees of freedom	Sum of squares	Mean square	F
Total	39	21386.8		
Blocks	9	2146.7	238.5	
Treatment	3	446.5		
Coagulation	1	169.0	169.0	0.22
Temperature	1	6.1	6.1	0.01
Coag. x Temp.	1	271.4	271.4	0.36
Error	25	18793.6	751.7	

TABLE VII

Comparison of Apparent Digestibility of Dry Matter, Protein, and Fat Among the Treatment Groups

Treatment group	Calf no.	Dry matter	Protein	Fat
Cold	24	87.3	81.5	99.5
	32	92.3	89.7	99.6
	215	93.7	89.9	99.6
	Ave.	91.1	87.1	99.6
Hot	44	89.4	90.4	99.5
	77	92.3	86.7	99.6
	69	91.4	87.9	99.6
	Ave.	91.1	88.3	99.6
Cold-citrated	45	93.4	88.5	99.5
	63	93.7	88.7	99.7
	56	90.1	86.8	99.7
	Ave.	92.4	88.0	99.6
Hot-citrated	83	91.9	86.9	99.7
	202	94.5	90.5	99.7
	132	96.1	93.5	99.8
	Ave.	94.1	90.3	99.7

TABLE VIII

Apparent Digestibility of Dry Matter in the Milk Replacer

Calf no.	Preliminary period (days)	Collection period (days)	Total feed intake (g.)	Dry matter in feed (%)	Intake of dry matter (g.)	Total feces excreted (g.)	Dry matter in feces (%)	Fecal dry matter (g.)	Digested dry matter (g.)	Apparent digestibility of dry matter (%)
24	16	10	35451.0	11.4	4056.3	2195.3	23.5	516.2	3540.1	87.27
32	17	10	45454.5	11.3	5119.5	1790.2	21.9	392.0	4727.5	92.34
215	13	10	43636.3	12.6	5508.2	1586.0	22.0	349.5	5158.7	93.65
44	18	10	45454.5	11.4	5185.5	2421.0	22.6	547.9	4637.6	89.43
77	17	10	48181.8	12.0	5765.0	2109.5	21.0	443.6	5321.3	92.30
69	16	10	45454.5	12.0	5365.5	1983.5	23.2	460.1	4905.3	91.42
45	17	10	44545.4	15.0	6700.1	2353.0	18.9	444.2	6255.9	93.37
63	15	8	37090.9	12.4	4580.7	1424.8	20.2	287.5	4293.2	93.72
56	17	10	38181.8	9.6	3664.3	2097.1	17.3	363.4	3301.0	90.08
83	19	10	41363.6	11.3	4653.8	1817.2	20.9	379.1	4274.7	91.85
202	19	10	41818.1	11.3	4712.5	1323.1	19.6	259.7	4452.8	94.49
132	18	8	38545.4	11.0	4217.6	1084.2	15.3	166.1	4051.6	96.06

TABLE IX

Apparent Digestibility of Protein in the Milk Replacer

Calf no.	Preliminary period (days)	Collection period (days)	Total feed intake (g.)	Protein in feed (%)	Intake of protein (lbs.)	Total feces excreted (g.)	Protein in feces (%)	Fecal protein (lbs.)	Digested protein (lbs.)	Apparent digestibility of protein (%)
24	16	10	35451.0	3.4	2.1	2195.3	10.1	0.49	2.14	81.5
32	17	10	45454.5	3.2	3.2	1790.2	8.3	0.33	2.87	89.7
215	13	10	43636.3	3.8	3.6	1586.0	10.4	0.36	3.25	89.9
44	18	10	45454.5	3.4	3.4	2421.0	6.1	0.33	3.08	90.4
77	17	10	48181.8	3.4	3.6	2109.5	10.4	0.48	3.14	86.7
69	16	10	45454.5	3.3	3.3	1983.5	9.2	0.40	2.89	87.9
45	17	10	44545.4	4.3	4.2	2353.0	9.3	0.48	3.69	88.5
63	15	8	37090.9	3.3	2.7	1424.8	9.7	0.30	2.38	88.7
56	17	10	38181.8	3.3	2.8	2097.1	8.0	0.37	2.42	86.8
83	19	10	41363.6	3.3	3.0	1817.2	9.9	0.40	2.64	86.9
202	19	10	41818.1	3.8	3.5	1323.1	11.5	0.33	3.16	90.5
132	18	8	38545.4	3.2	2.7	1084.2	7.6	0.18	2.57	93.5

TABLE X

Apparent Digestibility of Fat in the Milk Replacer

Calf no.	Preliminary period (days)	Collection period (days)	Total feed intake (g.)	Fat in feed (%)	Intake of fat (g.)	Total feces excreted (g.)	Fat in feces (%)	Fecal fat (g.)	Digested fat (g.)	Apparent digestibility of fat (%)
24	16	10	35451.0	9.7	3454.3	2195.3	0.87	19.05	3435.3	99.5
32	17	10	45454.5	9.7	4429.1	1790.2	1.08	19.28	4409.8	99.6
215	13	10	43636.3	9.7	4251.9	1586.0	1.08	17.10	4234.8	99.6
44	18	10	45454.5	9.7	4429.1	2421.0	0.93	22.61	4406.5	99.5
77	17	10	48181.8	9.7	4694.8	2109.5	0.90	18.92	4675.9	99.6
69	16	10	45454.5	9.7	4429.1	1983.5	0.87	17.20	4411.9	99.6
45	17	10	44545.4	9.7	4340.5	2353.0	0.92	21.69	4318.8	99.5
63	15	8	37090.9	9.7	3614.1	1424.8	0.73	10.47	3603.7	99.7
56	17	10	38181.8	9.7	3720.4	2097.1	0.61	12.73	3707.7	99.7
83	19	10	41363.6	9.7	4030.5	1817.2	0.66	12.07	4018.4	99.7
202	19	10	41818.1	9.7	4074.8	1323.1	1.07	14.20	4060.6	99.7
132	18	8	38545.4	9.7	3755.9	1084.2	0.55	6.01	3749.9	99.8

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