A COMPARISON OF PELLETED VERSUS LIQUID MILK REPLACERS FOR DAIRY CALVES

By

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REPLACERS FOR DAIRY CALVES

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INTRODUCTION

Methods for raising dairy calves successfully with limited amounts of whole milk have been studied for many years. The high cost of raising calves on whole milk has led to the use of inexpensive milk replacers in the diets of dairy calves as early as three days of age. Also, the realization that calves can develop into ruminants at a very early age without the use of large quantities of liquid feed has led to the widespread use of early-weaning systems of calf raising.

However, there are certain inadequacies in the calf which must be taken into consideration during the first few months after birth. The nutrient requirements for newborn calves are similar to those of simple-stomached animals in that a dietary source of high quality protein and B-complex vitamins must be provided, since they cannot be synthesized by newborn calves. Complex carbohydrates also cannot be utilized efficiently by newborn calves.

For the feeding program to be successful, the ration must be formulated in such a way that it meets the dietary requirements of the calf at an early age. Also, for maximum economy to be realized, emphasis must be directed toward dietary changes which will result in early development of rumen function. If sufficient information were available in this area, milk replacer rations could possibly be formulated in a manner more nearly compatible with the physiological needs of the calf.

The information reported here represents an attempt to obtain information concerning the feasibility of feeding a pelleted milk replacer to young dairy calves. The specific objectives of the present experiment were: (a) to obtain information regarding the growth and feed consumption of young dairy calves fed a pelleted milk replacer as compared to calves fed a liquid milk replacer, (b) to determine the relationship of the type of replacer to general thriftiness of the calves and the incidence of certain infectious diseases, such as diarrhea and pneumonia.

LITERATURE REVIEW

This review is limited to studies which involve the more important aspects of nutrient utilization and rumen development as these apply to dairy calves during the first four 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. The ability of the calf to utilize certain dietary constituents increases after the first few weeks of age. However, where information is limited on very young calves or milk replacers, similar information on older calves or starter rations will be noted.

Status of the Calf at Birth

According to Warner et al. (54) the fore-stomach of the newborn ruminant is rudimentary and essentially nonfunctional. Tamate et al. (51) reported that the combined capacity of the omasum and abomasum of the newborn calf is nearly twice that of the rumen and reticulum. Papillae of the mucous membrane of the rumen are relatively undeveloped and absorption from this compartment probably is quite inefficient (27). Tamate et al. (51) observed that there is some regression of rumen papillae during postnatal life. Papillary development was observed to be greater in newborn calves than in milk-fed calves at four weeks of age.

In a study on the composition of the ruminal flora and fauna of young calves, Bryant et al. (3) found that ciliate protozoa were not established in the rumen of 1-13 week old calves raised under normal conditions. The counts of cellulolytic bacteria in the rumen of three-week-old calves were similar to those found in mature animals. Lactate-fermenting bacteria were present in high numbers (210 million to 1 billion/ml) up to three weeks of age, but declined toward adult values (5.5 million/ml) after nine weeks of age. Similarly, bacteria capable of growth under aerobic conditions were highest (82 million to 1.4 billion/ml) in numbers in calves under three weeks of age. The similarities observed between very young calves and mature animals were indicative that the rumen is physiologically well adapted for the development of the ruminal flora at an early age.

Colostrum and Immunity

Some years ago, Smith and Little (45) investigated the factors affecting the survival of newborn calves and found that intestinal infections were among the major causes of death. However, the feeding of colostrum was found to decrease the mortality rate considerably.

Colostrum has been found to contain much more protein, ash, carotene, and vitamin A than normal milk. According to Morrison (36), cows' colostrum may contain as much as 17 per cent protein. Moore and Berry (35) and Hansen et al. (17) have reported that the vitamin A levels of the blood plasma are low at birth. However, with adequate colostrum consumption, about a five-fold increase in these values was observed within 24 hours. Garret and Overman (15) reported that the calcium, magnesium, sodium, phosphorous, and chlorine content of colostrum is above normal at parturition and during the early hours of lactation. Potassium content was found to be below normal at parturition but gradually increased toward the more normal levels.

Smith et al. (46) reported that gamma globulins are concentrated in the udder of the cow prior to parturition and are highly concentrated in the colostrum. The newborn calf derives passive immunity by absorbing these gamma globulins from the colostrum; however, this ability to absorb whole proteins is limited to the first 24 to 30 hours of the calf's life. Thereafter, even if gamma globulin is fed, no measurable increase can be detected in the calf's serum gamma globulin. When the calf reaches about eight weeks of age it acquires the ability to produce its own immune antibodies.

Esophageal Groove Reflex

Several workers (19, 43, 44) have shown that the esophageal groove is functional during the early life of the calf, allowing liquids to effectively by-pass the rumen and enter the abomasum. Hegland et al. (19) observed that when gelatin capsules of various sizes were administered to the young calf with a liquid they passed directly into the abomasum. When the capsules were given alone they were deposited in the rumen. These workers found that nipple pail feeding affected closure of the esophageal groove to about 13 weeks of age.

Smith (44) suggested that there is no loss in efficiency of the esophageal groove function of milk-fed calves up to about 32 weeks of age and that any loss in efficiency of normally fed calves as they get older is a result of a change in the diet rather than a result of increased age. He estimated the amount of milk which entered the rumen of milk-fed calves to be less than five per cent in the majority of cases. Similarly, there did not appear to be any increase in the amount of milk which entered the rumen of young milk-fed calves as they aged.

The milk which had entered the rumen was observed by Smith (44) and Schalk and Amadon (43) to flow very slowly from the rumen into the omasum.

Digestive Enzymes

Digestive enzyme activity in young calves has been studied by several workers (10, 21). Huber et al. (21) reported that the intestinal lactase activities of the calf were highest at one day of age and decreased thereafter. Intestinal maltase levels were low, as compared to lactase, and did not change with age. Intestinal sucrase was not detected. Gastric protease was highest at eight days of age and decreased thereafter. Pancreatic amylase, lipase, and protease activities were lowest at one day of age, increased the first week, and changed little thereafter with increasing age. Similarly, Dollar and Porter (10) reported that lactase activity was high in very young calves but decreased with age. Amylase and maltase were found to be low in young calves, but increased with age.

Nutrient Utilization

Carbohydrate utilization in the young calf has been studied by several workers (4, 10, 13, 14, 22, 23, 41, 52). The results of these studies are in general agreement that glucose and lactose are the carbohydrates utilized to the greatest extent by the young calf. In contrast, sucrose and starch have been found to be only slightly utilized by the young calf prior to development of the rumen.

Studies conducted with milk replacers (2, 9, 24, 29) have shown that the level at which protein should be furnished in the diet of the young calf is approximately 20 per cent of the dry matter. Brisson et al. (2) obtained similar rates of growth in calves fed rations containing protein at a rate of 22.1, 29.5, and 36.9 per cent of dry matter intake. Lassiter et al. (29) have reported that calves can make normal growth when fed milk replacer rations containing approximately 24 per cent protein. They also stated that the protein level of replacers fed to young calves could be decreased to approximately 19 per cent without seriously affecting the growth rate. Cunningham et al. (9) reported that a protein level of 19.4 per cent of the dry matter intake was optimum where a combination of growth and protein efficiency was measured.

Structural Development of the Rumen

Several investigators (18, 27, 33, 34, 51, 55) have shown that milk consumption alone is not sufficient to stimulate rumen function and development. Harrison et al. (18) fed calves milk only for 27 weeks and upon examination of the rumen mucosa found that it contained only papillary buds. When 16-week-old calves on a high hay or grain ration were changed to a milk diet, a retrogression of the rumen papillae was noted. Also, the rumen of these calves collapsed around less fill, but maintained the same potential (water-filled) volume after 18 weeks of milk feeding as did the rumen of 16-week-old calves on dry feed. These workers suggested that mucosal and muscular development are independent as evidenced by: (a) a more rapid retrogression of the reticulo-rumen mucosa than of the reticulo-rumen muscle, (b) an extensive muscular development in the absence of mucosal development when calves were fed shavings, and (c) a lower nitrogen percentage in well developed mucosa than in muscle, when expressed on a fat-free dry matter basis (13.3 and 15.1%, respectively).

Warner et al. (55) reported that the total amount of rumen tissue per unit of body weight of eight-month-old milk-fed calves is essentially the same as for calves only a few weeks old. An increase in muscle tissue of the rumen of calves which were fed shavings suggested that the work necessary to support and move the ingesta mass resulted in muscular development. They further stated that mucosal development was poor in calves which received a milk and shavings diet, but was extensive in treatments where fermentation was active.

Tamate et al. (51) reported that feeding hay and starter in addition to milk resulted in forestomach development which included papillary and muscular growth of the reticulo-rumen and pigment deposition in the rumen mucosa. Papillary growth in the rumen was observed in calves fed 61 and 63 moles of butyric and propionic acid, respectively, over an eight-week period. However, Gilliland et al. (16) observed a moderate degree of papillary development in calves fed 35 and 43 moles of propionic and butyric acids, respectively, over a seven-week period.

Sutton et al. (48) reported that the maximum absorption rate in the rumen of calves was low at one week of age. Calves fed milk alone showed no significant change in either maximum absorption rate or papillae development up to 13 weeks of age. The absorption rate in calves fed milk, hay, and grain increased markedly by the time the calves were 13 weeks of age. The authors stated that solid feed intake stimulated both absorptive ability and structural development of the rumen, as measured by the extent of papillary growth.

Flatt et al. (12) indicated that the most important stimulus for the development of rumen papillae was an active rumen fermentation. The end-products of this fermentation, rather than the coarse nature of the feed, appeared to be the specific stimulating entity.

Swanson and Harris (50) reported that calves began to ruminate at 5-7 days of age, but spent less than one hour per day ruminating. Most of the calves observed had begun ruminating by about two weeks of age. Similarly, Gilliland et al. (16) noted that of 16 calves studied all were ruminating by 11 days of age. Swanson and Harris (50) and Gilliland et al. (16) found that rumination time was positively correlated with dry feed consumption. However, less time per pound of feed was spent ruminating as the calves aged.

Microbial Development

Several workers (3, 33, 34) have found that the predominant bacteria found in 1-3 week old calves are basically different from those typical of mature animals. Lengemann and Allen (33) reported that gradual development of an adult-like rumen function starts early in the life of the calf. The one- and two-month-old calves showed a scarcity of hay type flora. However, in the 2-3 month old calves the digestion of cellulose, though low, had increased decidedly and protozoa had become established. In a later report (34), these workers reported that for calves fed solid feeds, the general pattern of rumen function development was a sharp fall in the aerobic bacteria within the first three weeks, an increase in the total numbers of bacteria, and the establishment of protozoa.

Bryant et al. (3) made a detailed study of microorganism types in calves fed whole milk until 60 days of age and fed grain and hay from ten days of age. The predominant bacteria found in 1-3 week old calves were mainly different from those of mature cattle. When the calves were six weeks of age many groups of bacteria typical of mature animals were found, but several groups not found in mature animals remained. At nine and 13 weeks of age, bacteria isolated were mainly those of mature animals.

Metabolic Development

Sutton et al. (49) have suggested that metabolic activity of the rumen mucosa is low shortly after birth and increases primarily in association with structural development of the mucosa. In this study three calves were fed milk and three were fed milk, hay and grain for 16 weeks. The calves were slaughtered and two-gram samples of rumen mucosa were collected. Two hundred micromoles of acetate, propionate, butyrate, and equimolar mixture of these three, or glucose, was added to the samples. Mean uptake of these substrates were 5.9, 29.6, 44.1, 31.5, and 3.8 micromoles/100 mg dry tissue/3 hrs, for the calves fed milk, hay, and grain. For the milk-fed calves the values were 2.9, 5.8, 4.7, 5.8, and 4.2, respectively. The percentage conversion of acetate and butyrate to ketones was 72 and 88, respectively, for the calves fed milk, hay, and grain. For the milk-fed calves the values were 17 and 29, respectively.

Early Weaning Systems

Several early weaning systems have been used in calf nutrition experiments (1, 7, 8, 16, 38, 39, 41, 56). Castle and Watson (7) reported on a comparison between a conventional system and an early weaning system of raising dairy calves. The conventional system consisted of feeding each calf 19 gal. of milk, 86 gal. of milk substitute and 195 lb. of calf meal (17.0% crude protein). The early weaning system consisted of feeding 5 gal. of milk, 19 gal. of milk substitute and 259 lb. of early weaning cubes (22.7% crude protein). The early weaned calves were weaned at 35 days of age. All calves had unlimited access to dried grass throughout the experimental period. The live weight gains were 1.26 lb. per day for the conventional system and 1.20 lb. per day for the early weaning system. They stated that at their location and at the prices at that time, the early weaning system was cheaper both per day and per pound of live weight gain.

Noller et al. (39) have reported that calves can be successfully weaned at 21 days of age. They found that weaning calves at 28 days of age did not appreciably increase weight gains. However, Yang et al. (56) found that 28 days of age was the earliest time at which calves could be weaned with consistent results. Pardue et al. (41) reported successful weanings with calves at 24 days of age when adequate amounts of a palatable calf starter and hay were fed.

Composition of Replacers

Various ingredients have been studied for use in milk replacer rations (1, 5, 20, 29, 31, 37, 40, 47, 53). Wallace et al. (53) reported approximately normal growth rates with young calves receiving milk replacers containing large amounts of dried milk solids.

As noted above, the level of high quality protein which a milk replacer should contain is approximately 20 per cent. However, Stein et al. (47) found that high levels of soybean flour fed at the expense of nonfat dry milk solids was not satisfactory. They also reported that a 5 per cent level of whey solubles increased appetite and produced more uniform gains than did dried whey.

Lassiter et al. (31) reported that calves fed a replacer ration which contained 10 per cent added fat (derived from cottonseed) gained 9 per cent faster than calves fed a replacer ration that contained no fat or replacers that contained either 20 or 30 per cent fat. Hopkins et al. (20) improved the digestibility of coconut fat, grease, and tallow in milk replacers by the addition of crude soybean lecithin.

Bush (5) stated that a good milk replacer should contain a supplemental source of vitamins A and D and certain of the trace minerals, particularly copper and iron. The B-complex vitamins should also be included.

Lassiter (28) presented a very complete review on the subject of antibiotics for dairy cattle. He stated that the principal interest in antibiotic feeding for young dairy calves has been their effect on growth, calf scours, feed consumption and feed efficiency, and metabolism. The feeding of antibiotics to young calves has been shown to be beneficial (30).

Pellet Acceptability

Jacobson et al. (25) stated that starter consumption by calves was influenced by composition, texture, amount of other feeds, and the individuality of the calf. Calves prefer a coarse-textured meal and one which is not dusty.

Lassiter et al. (32) observed that no nutritional advantages were found for pelleting of calf starters. When calves were given a choice among three types of starters over a period from seven to ten weeks of age they consumed 45.0 pounds of an all-pellet starter, 33.3 pounds of a part pellet-part meal starter, and 14.3 pounds of an all-meal starter. However, the voluntary consumption of all starters appeared to be equal when the calves were limited to one type.

EXPERIMENTAL PROCEDURE

This study was divided into two trials. In Trial I, 12 male Ayrshire calves and 16 male Holstein calves were used in pilot studies to determine whether calves could utilize a pelleted milk replacer, and, if so, the feeding rates at which the best results could be obtained. In Trial II, eight male Ayrshire calves and 12 male Holstein calves were used to compare a pelleted vs. a liquid milk replacer under a uniform set of experimental conditions. In addition, observations were made on one fistulated male Holstein calf to determine where the milk replacer pellets were deposited in the stomach.

Feeding and Management

The calves used in this experiment were obtained from the Oklahoma State University dairy herd and two selected dairy farms nearby. Each calf received colostrum from its dam for the first three days after birth. The calves were then placed in individual pens in the experimental dairy barn where wood shavings were used for bedding.

The 48 calves used in this study were started on the experiment at 3-4 days of age. The calves used were male calves of either the Ayrshire or Holstein breed and weighed at least 70 pounds at birth. The calves were paired on the basis of breed as they became available for experimental use. The form of milk replacer to be fed during the experiment was randomly assigned to the first member of each pair. The other member of the pair was then assigned the other form of the replacer. The experimental period for each trial was eight weeks in length.

Each calf was weighed when started on experiment, and this weight was used as the initial body weight from which calculations were made to determine milk and replacer feeding rates. Water was available at all times and milk feeding was done via nipple pail. During periods of starter feeding a calf starter ration (Table I) was fed *ad libitum*. The calves were encouraged to eat the pellets by placing a small amount in their mouths at each milk feeding. A daily record was maintained of the amount of feed consumed and observations of physical disorders, such as diarrhea, were made. Sick calves were treated as necessary to effect rapid recovery.

TABLE I

CALF STARTER RATION

Ingredients	Pounds
Cubed corn	530
Crimped oats	400
Wheat bran	160
Corn distillers solubles	160
Dried molasses	120
Soybean meal (50%)	240
Alfalfa crumbles	300
Aureomycin (Aurofac 10)	5
Vitamelk	50
Salt	20
Dicalcium phosphate	20
Total	2005

The milk replacer used in this study was manufactured either in a powdered or pelleted form. When the powdered form was fed it was mixed with water and fed via nipple pail. The rate of mixing was one pound of powder to nine pounds of water. (Hereafter, the terms powdered milk replacer and liquid milk replacer will be used interchangeably.) The pelleted form of the milk replacer was fed in open pails in the same manner as for grain feeding.

Specific Procedures for Trial I

This trial involved four groups of calves fed at different rates. The size of the milk replacer pellets used in this trial was one-fourth inch in diameter and approximately one-half inch in length.

In Group I, three pairs of calves were used. During the first week of the experiment these calves were fed milk at a rate of 10 per cent of initial body weight daily (Figure 1). During the second through the fourth week they were fed either the liquid or the pelleted milk replacer (Table II) at a daily rate of one pound of dry replacer per one hundred pounds of initial body weight (per cwt). These calves were also fed a calf starter, *ad libitum*, from the third through the eight experimental week.

TABLE II

COMPOSITION OF MILK REPLACER USED IN TRIAL I[a]

Component	Percentage
Crude protein, not less than	25.0
Crude fat, not less than	2.5
Crude fiber, not more than	1.5
Ash, not more than	9.0
Moisture, not more than	12.0

[a]Ingredients: Dried skimmed milk, wheat red dog, dextrose, soybean meal, dried whole whey, hydrogenated fish oil preserved with BHA, vitamin B_{12} supplement, chlortetracycline hydrochloride, vitamin A supplement, D activated plant sterol, riboflavin supplement, choline chloride, niacin, calcium pantothenate, 1.5% low fluorine rock phosphate, 0.5% iodized salt, and traces of iron oxide, cobalt carbonate, zinc oxide.

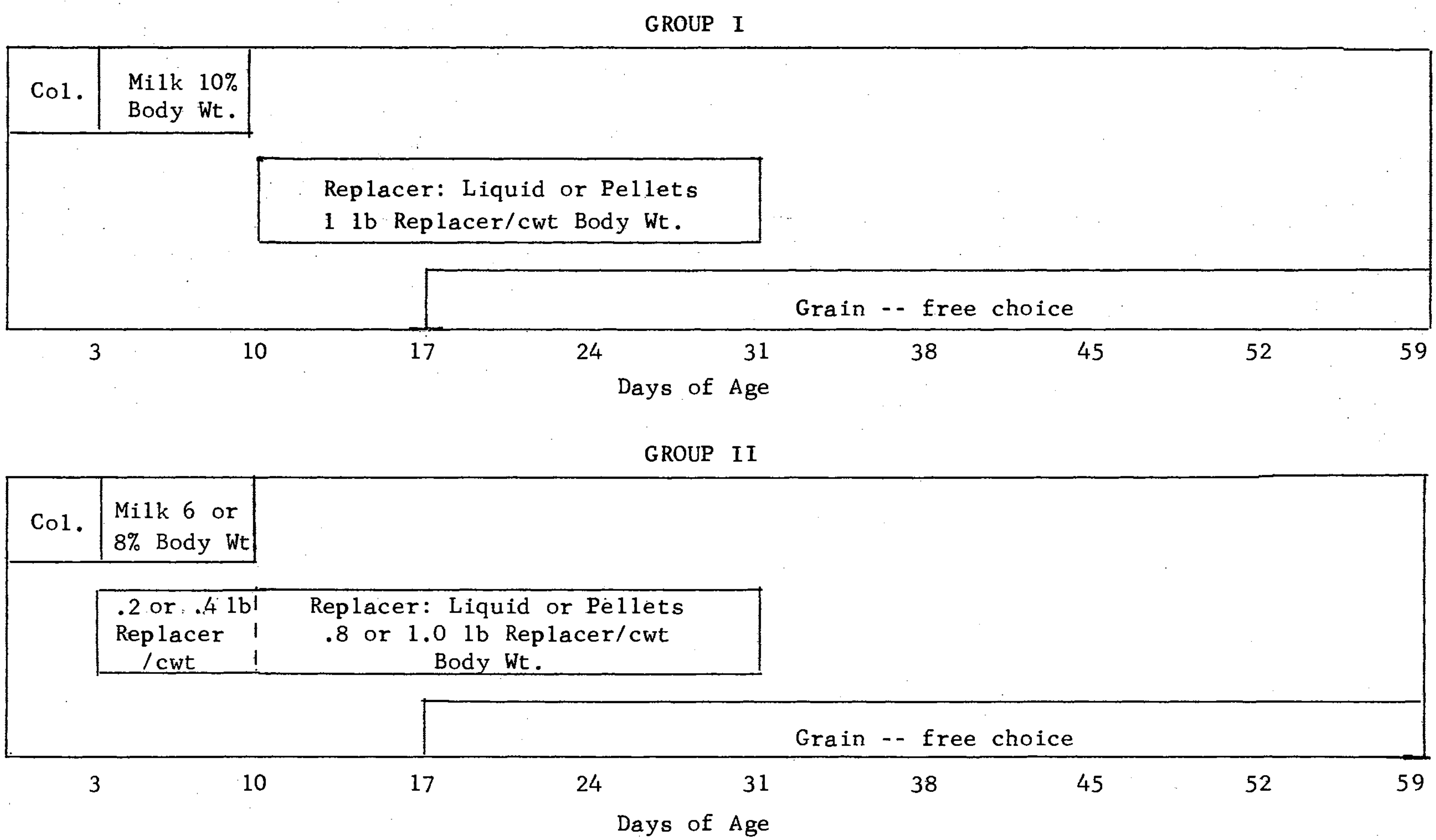

Figure 1. Feeding Schemes Used in Trial I

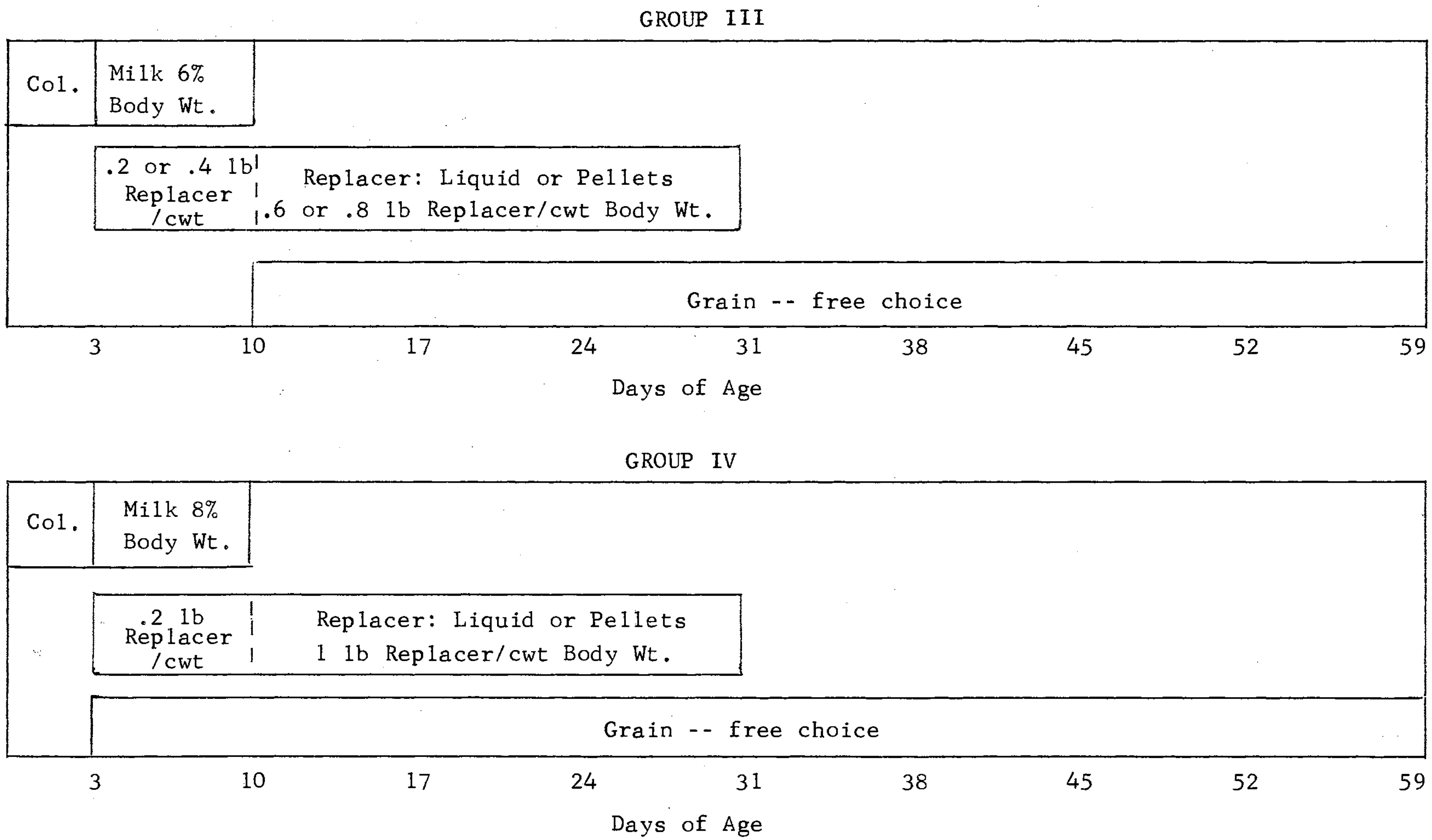

Figure 1. (Continued)

Three pairs of calves were used in Group II. With this group some of the replacer was fed along with the milk during the first week in an attempt to enhance pellet consumption (Figure 1). The daily feeding rate was maintained at a milk equivalent of 8 or 10 per cent of initial body weight. This was done using eight per cent milk and 0.2 pound of replacer/cwt, six per cent milk and 0.2 pound of replacer/cwt, and six per cent milk and 0.4 pound of replacer/cwt for the three pairs of calves, respectively. During the first week, the powdered form of milk replacer was fed in the milk and the pellets were placed before the calf in an open pail. During the second through the fourth week the replacer was fed at a rate of either 0.8 or 1.0 pound of replacer/cwt for the different pairs of calves.

In Group III, four pairs of calves were used. With this group, the starter was fed starting at 10 days of age, which was a week earlier than for Groups I and II (Figure 1). This change was made to promote earlier rumen function in the calves. Also, the amount of replacer fed during the second through the fourth week was decreased to either 0.6 or 0.8 pound of replacer/cwt for different pairs of calves.

Four pairs of calves were used in Group IV. With this group the milk equivalent was increased to the 10 per cent level and the starter ration was fed throughout the eight-week experimental period (Figure 2). The amount of replacer fed during the second through the fourth week was 1.0 pound of replacer/cwt.

The calves were weighed, heart girth measurements were made, and rumen fluid samples were taken at weekly intervals starting at the end of the first experimental week. The rumen sampling was done with a stomach tube equipped with a strainer as described by Raun and Burroughs

(43). The pH of the rumen fluid was determined using a Beckman Model N portable pH meter with a single electrode. Saturated mercuric chloride solution was added to the sample at a rate of 1 ml/100 ml rumen fluid to stop microbial activity. The samples were centrifuged to remove the small feed particles. Approximately 25 ml of the supernatant was put in a labeled test tube, frozen, and stored until analysis could be made.

Specific Procedures of Trial II

In this trial, a milk replacer of different composition and pellet size than that used in Trial I was used. This replacer contained 22 per cent protein and eight per cent fat. It was composed of approximately 24 per cent skim milk-fat product, 35.5 per cent skim milk, 35.5 per cent sweet dried whey, and five per cent of vitamin-mineral premix. The size of the milk replacer pellets used in this trial was 5/32 inch in diameter and approximately ½ inch in length. The 20 calves used in this trial were fed according to the plan used for Group IV of Trial I.

Observations on Deposition of Pellets in the Stomach

A male Holstein calf from the O.S.U. dairy herd was fistulated at six days of age. A soft plastic rumen fistula plug, 2.5 inches in diameter, was inserted into the fistula opening. During the first two weeks of the experimental period this calf was fed milk at a rate of eight per cent of initial body weight daily, milk replacer pellets at a daily rate of 0.2 pound of pellets per one hundred pounds of initial body weight, and grain *ad libitum*. During the third and last weeks this calf was fed milk at a rate of five per cent of initial body weight daily, milk replacer pellets at a daily rate of 0.5 pound of pellets per one hundred pounds of initial body weight, and grain *ad libitum*.

Observations were made on this calf at the end of the second and the third experimental weeks. In the morning before the observations were to be made the calf was fed only milk. That afternoon the fistula plug was removed from the calf and the rumen emptied. The rumen was then rinsed several times with a physiological saline solution. The calf was fed milk replacer pellets and their deposition in the stomach was observed. The calf was then fed its evening milk and esophageal groove function was observed. At this time the fistula plug was reinserted and the calf returned to the feeding scheme as previously described.

Determination of Total VFA

The total VFA in the rumen fluid was determined by a modification of the method of Fenner and Elliot (11). Ten mililiters of centrifuged rumen fluid were adjusted to pH 2.0 with H_2SO_4, antifoam agent was added, and the sample was steam distilled for 20 minutes. The distillate was titrated to a phenolphthalein endpoint with standardized NaOH (0.0565 N) from which the milliequivalents of acid were determined. A water blank, adjusted to pH 2.0 with H_2SO_4, was distilled and titrated. The titre thus obtained was used to correct the titration values for the samples. A VFA standard described by Bull (6) was used to standardize the procedure. The percentage recovery obtained on the standards was 97.4 ± 5.3 (standard diviation).

RESULTS AND DISCUSSION

TRIAL I

Trial I consisted of a series of pilot studies for determining the feeding conditions under which calves would respond most satisfactorily to milk replacer pellets. For the most part, the growth rate and general physical condition of the calves used in Trial I were considered to be below normal. Nevertheless, it was considered that some of the information derived from this trial was of value in defining the conditions under which milk replacer pellets could be used.

Feed Consumption

There was less difference between treatment groups in calf starter consumption in Groups I and IV than in the other groups (Tables III and XV). The values for Group IV were 128.7 pounds and 122.1 pounds for the calves fed the liquid and the pelleted milk replacer, respectively. The values for starter consumption in Group I were somewhat lower than those for Group IV, probably because the calves in Group I were fed the starter for only six weeks as compared to eight weeks for the calves in Group IV. Higher consumption was noted in Groups II and III with the calves fed the pelleted milk replacer, but the between-treatment difference was comparatively large. The low values, particularly for the liquid-fed calves in Group III, may have been due to the general unthriftiness of the calves. On the other hand, the value of 131.9 pounds for the pellet-fed calves in Group II was probably a reflection of a more thrifty condition on the part of these calves throughout the experiment.

TABLE III

TOTAL CALF STARTER CONSUMPTION PER CALF IN TRIAL I

Form of replacer fed	Group I	II	III	IV
	lb			
Liquid	81.7	91.3	86.3	128.7
Pelleted	84.3	131.9	114.9	122.1

There was considerable within-treatment variation in the starter consumption of calves in all the groups. For example, the starter consumption of the calves fed the pelleted replacer in Group IV ranged from 75.6 to 165.0 pounds for the eight-week trial. Similarly, the starter consumption for the calves fed the liquid replacer in Group II ranged from 73.6 to 110.1 pounds for the eight-week period. There was also considerable variation among calves in the amount of pellets voluntarily consumed (Table IV). Performance of the calves was not closely related to replacer consumption, however, since the growth rate of the calves fed specified amounts of the reconstituted powdered replacer via nipple pail was sub-optimum. Also, the amount of calf starter (grain) consumed was not closely related to milk pellet consumption, as was evident by comparison of the two calves in Group II which consumed the largest and the smallest amounts of pellets in the trial, respectively. These calves both gained 36 pounds and had starter consumptions of 129.1 pounds and 124.3 pounds, respectively.

Following the pattern of dry starter consumption noted above, there was less difference between the treatments in average weight gains of the calves in Groups I and IV than in the other groups (Tables V and XV). The average eight-week gains of the calves in Group I were 33.7 pounds

TABLE IV

TOTAL DRY REPLACER CONSUMPTION BY INDIVIDUAL CALVES IN TRIAL I

Group	Form of Replacer	
	Liquid	Pelleted
	lb	
I	--- [a]	22.40[b]
	15.12	9.95
	15.96	13.95
II	17.28	24.14
	21.42	14.48
	19.60	20.34
III	22.70[c]	15.71
	17.58	12.25
	13.65[d]	--- [a]
	17.92	14.67
IV	--- [a]	20.59
	--- [a]	12.17
	17.60	13.31[e]
	15.26	17.44

[a]Calf died before end of replacer feeding period.

[b]Calf fed pellets for five weeks by mistake.

[c]Calf fed pellets into fifth week but died during fifth week.

[d]Calf taken off after six weeks due to malnutrition and injury.

[e]Calf died during fifth week.

for those fed the liquid milk replacer and 37.0 pounds for those fed the pelleted milk replacer. The average eight-week gains of the calves in Group IV were 49.5 and 47.7 pounds for those fed the liquid and the pelleted milk replacers, respectively. Although the average weight gains of the pellet fed calves in Groups II and III were comparable to that of the calves in Group IV, the corresponding gains for the calves fed the liquid replacer were definitely unsatisfactory. This was no doubt due partly to lower calf starter consumption by these calves, but was also considered to be a reflection of the general unthriftiness of the calves.

TABLE V

AVERAGE WEIGHT GAINS OF THE CALVES USED IN TRIAL I

Form of replacer fed	Group I	Group II	Group III	Group IV
	lb			
Liquid	33.7	32.3	22.0	49.5
Pelleted	37.0	41.3	50.0	47.7

The average growth rates of the within-treatment groups of calves completing the eight-week trial ranged from 0.39 to 0.89 pounds per day. The average daily gain for the calves in Group IV which completed the trial were 0.88 for the liquid-fed calves and 0.85 for the calves fed the pelleted milk replacer. These growth rates were less than optimum for Ayrshire and Holstein calves.

Seven calves were lost during the experimental period. In Group I, one calf being fed the liquid replacer was lost due to scours. In Group III, two calves were lost due to malnutrition; one calf being fed the pelleted replacer died during the fourth week and one calf being fed the liquid replacer died during the fifth week. Another calf in this group being fed the liquid replacer was removed from the experiment at six weeks of age due to an injury and malnutrition. In Group IV, two calves were lost due to malnutrition; one calf being fed the liquid replacer died during the third week and one calf being fed the pelleted replacer died during the fifth week. A third calf being fed the liquid replacer died of a heart attack during the third week while drinking from the nipple pail.

pH and Concentration of Total VFA

On the basis of the data on rumen pH and total VFA concentration it appeared that a certain amount of the replacer pellets were deposited in the rumen of the calves, rather than in the abomasum. During the first few weeks, the pH of the rumen contents declined more rapidly and the total VFA concentration increased more rapidly in the calves fed the pelleted milk replacer than in those fed the liquid milk replacer (Tables VI and VII). It is generally understood that as fermentation is initiated in the rumen there is a buildup of acids and a resultant decrease in the pH of the rumen contents (56). As rumen function becomes increasingly more efficient this buildup of acids is removed with a resultant increase in pH and a decline in the concentration of VFA. As fermentation increases more acids are produced, but increased rumen absorption removes them before a considerable buildup can occur. Thus, the pH and VFA concentration tend to stabilize within a certain range, as was demonstrated in this trial.

Milk Replacer Composition

The quality of a milk replacer in terms of ingredient composition is very important, since a major portion of the required nutrients must

TABLE VI

AVERAGE pH OF RUMEN FLUID FROM CALVES IN TRIAL I

Group	Form of replacer fed	Number of calves	Weeks on Experiment 1	2	3	4	5	6	7	8
I	L[a]	3[c]	5.80	6.15	6.15	5.68	5.48	5.87	6.30	5.95
	P[b]	3	6.62	5.65	5.33	5.20	5.52	5.97	6.38	6.26
II	L	3	6.45	6.65	5.60	5.58	5.90	5.40	5.65	5.70
	P	3	6.26	5.40	5.18	5.03	5.93	6.33	6.17	6.33
III	L	4[d]	6.53	6.00	6.13	6.15	5.33	5.42	5.85	5.65
	P	4[e]	5.83	5.30	5.22	4.92	5.23	5.72	5.22	5.30
IV	L	4[f]	6.21	6.24	5.87	5.40	5.37	5.43	5.75	5.60
	P	4[g]	5.66	5.32	5.13	5.17	5.45	5.42	5.67	5.65

[a]Liquid Milk Replacer

[b]Pelleted Milk Replacer

[c]One calf died during third week.

[d]One calf died during fifth week and one taken off the sixth week.

[e]One calf died during fourth week.

[f]One calf died during third week and one died during fourth week.

[g]One calf died during the fourth week.

TABLE VII

AVERAGE OF TOTAL VFA CONCENTRATION FOR CALVES IN TRIAL I

Group	Form of replacer fed	Number of calves	Weeks on Experiment 1	2	3	4	5	6	7	8
			(mM/100 ml)							
I	L[a]	3[c]	3.35	2.72	7.44	9.71	7.41	8.80	6.46	9.13
	P[b]	3	1.33	7.53	7.46	10.05	6.63	8.69	5.88	7.98
II	L	3	0.99	0.91	7.85	7.60	5.67	8.10	9.63	9.95
	P	3	2.35	4.59	6.20	9.15	6.59	5.59	7.58	6.47
III	L	4[d]	2.21	4.74	5.29	8.47	10.12	9.19	7.31	11.40
	P	4[e]	3.43	7.13	10.71	11.88	10.29	6.94	8.38	6.26
IV	L	4[f]	3.53	5.81	7.04	10.98	10.82	11.95	11.30	11.51
	P	4[g]	5.70	7.32	10.76	13.62	10.48	11.13	12.85	10.52

[a]Liquid Milk Replacer

[b]Pelleted Milk Replacer

[c]One calf died during third week.

[d]One calf died during fifth week and one taken off the sixth week.

[e]One calf died during fourth week.

[f]One calf died during third week and one died during fourth week.

[g]One calf died during the fourth week.

be derived from the milk replacer by the young calf prior to development of rumen function. The major ingredients shown to make up the milk replacer used in this trial were dried skimmed milk, wheat red dog, dextrose, soybean meal, dried whole whey, and hydrogenated fish oil preserved with BHA (Table II). Several workers have reported (10, 21, 22, 23, 52) that the young calf does not have the digestive enzymes necessary to efficiently utilize complex carbohydrates such as wheat red dog. Also, plant proteins such as soybean meal have been reported (5, 25, 47) to be poorly utilized by the young calf. It has been stated (5, 31) that for maximum growth, milk replacers should contain at least 10 per cent fat, and the addition of lecithin has been found (20) to increase the digestibility of the fat and increase the growth obtained with milk replacers. The milk replacer used in this trial had a guaranteed analysis of only 2.5 per cent crude fat and contained no lecithin. It was concluded that the milk replacer used in this trial was not satisfactory in terms of ingredient composition and that this was the primary factor responsible for the unsatisfactory growth of the calves.

Since the overall performance of the calves in Group IV was more satisfactory than that of the calves in the other groups, the feeding regimen used for this group was selected for use in further work. Even though the milk replacer used in this trial was not entirely satisfactory, the data obtained from its use was interpreted as evidence that under certain feeding conditions a pelleted milk replacer of adequate composition could be used with satisfactory results.

TRIAL II

In Trial II, milk and liquid milk replacer consumption was very satisfactory. Only two calves refused any of their milk or liquid milk replacer, and this was during a period of scours in both cases. However, there was considerably variation among calves in total consumption of the pelleted milk replacer, as is evident in Table VIII. The dry milk equivalent consumed was figured by adding the actual weight of the dry replacer consumed and the amount of milk fed times a milk dry matter conversion factor of 0.13. A large decrease in milk equivalent consumption occurred immediately after weaning in the group fed the pelleted replacer (Figure 2). The pellet fed group was weaned at the end of the first week and the next day the dry milk equivalent consumed dropped to a low of 0.4 pounds. It took these calves about eight days to increase the daily dry milk equivalent consumption to the general level maintained throughout the remainder of the replacer feeding period. Thus, this period of low milk equivalent consumption proved to be the most critical period of the feeding regimen (Table IX).

TABLE IX

AVERAGE WEEKLY CONSUMPTION OF DRY MILK EQUIVALENT FOR TRIAL II

	Week on Experiment			
	1	2	3	4
	lb			
Liquid replacer	1.17	5.84	5.84	5.84
Milk	4.61	----	----	----
Total dry milk equivalent	5.78	5.84	5.84	5.84
Pelleted replacer	0.53	3.18	4.87	4.83
Milk	6.27	0.34[a]	----	----
Total dry milk equivalent	6.80	3.52	4.87	4.83

[a]One calf was accidentally fed some milk during the second week.

TABLE VIII

TOTAL MILK AND MILK REPLACER CONSUMPTION FOR TRIAL II

Pair	Breed	Calf No.	Initial weight	Form of replacer	Milk consumed	Dry replacer consumed
					lb	lb
1	Hol.	30	112	P[a]	63.0	20.07
		16	90	L[b]	50.4	20.16
2	Ayr.	26	77	P	39.4	13.45[d]
		82	65	L	34.3	15.05
3	Ayr.	91	80	P	70.4[c]	7.15
		73	79	L	48.0	18.00
4	Hol.	93	97	P	53.2	20.71
		205	87	L	41.8	19.54
5	Ayr.	202	82	P	46.2	15.14
		213	70	L	39.2	15.68
6	Hol.	211	84	P	47.6	17.13
		22	92	L	51.8	20.58
7	Hol.	81	85	P	45.0	16.62[e]
		9	94	L	53.2	21.00
8	Hol.	63	78	P	43.4	2.94
		61	70	L	39.2	15.68
9	Ayr.	88	82	P	46.2	14.02
		64	82	L	46.2	18.34
10	Hol.	48	89	P	53.2	12.72
		43	102	L	57.4	22.82
		Average		P	50.76	13.99
				L	46.15	18.68

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]Milk was fed for four days during the second week by mistake.

[d]One calf was accidentally fed 0.02 pound less milk replacer per feeding for the first three weeks.

[e]Milk replacer was fed for two days during the fifth week by mistake.

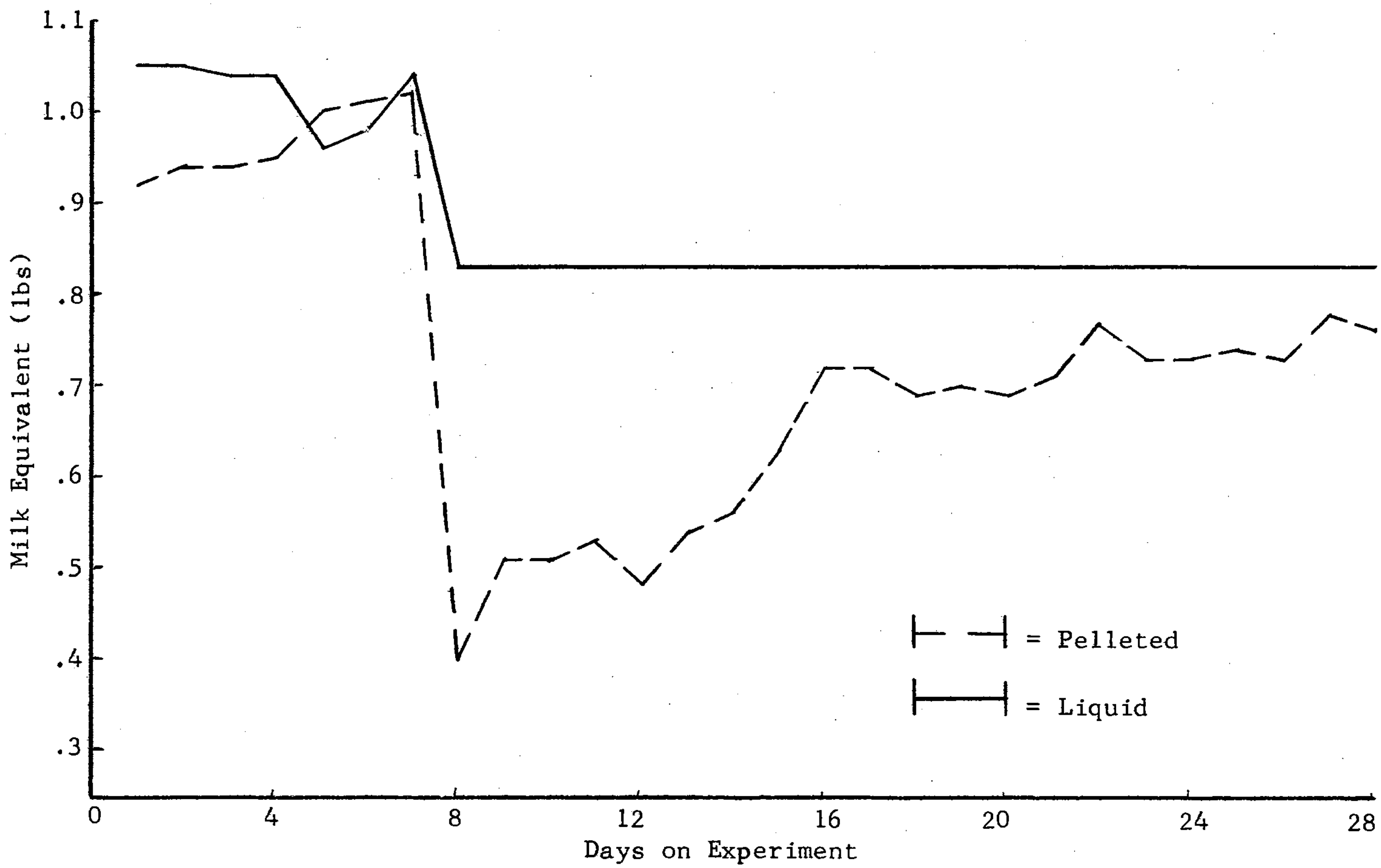

Figure 2. Consumption of Milk Dry Matter Equivalent in Trial II.

The group fed the liquid milk replacer consumed more of the starter until just after weaning at four weeks of age than did the group fed the pelleted milk replacer. During the second four weeks of the experimental period, starter consumption by the group fed the pelleted milk replacer surpassed that of the group fed the liquid milk replacer. However, there was very little difference in total consumption by the two groups. Average total consumption of the starter ration was 126.9 pounds for the calves fed the liquid milk replacer as compared to 125.3 pounds for the calves fed the pelleted milk replacer (Table X). The calves in the pellet fed group consumed less calf starter during the period of pellet feeding, but compensated for this in the last part of the trial where they consumed more than did the liquid fed group (Figure 3). It should also be noted that starter consumption for both groups during the first experimental week was essentially the same.

TABLE X

AVERAGE WEEKLY CALF STARTER CONSUMPTION IN TRIAL II

Form of replacer	Week on Experiment 1	2	3	4	5	6	7	8	Total
Liquid	1.54	3.32	6.53	10.69	19.26	26.40	29.21	29.96	126.9
Pelleted	1.60	1.27	3.15	7.03	19.78	26.18	32.99	33.34	125.3

The total weight gains of calves in Trial II were quite variable both within treatments and between pairmates. The average weekly weight gains (Figure 4) follow the general trend of dry milk equivalent consumption and calf starter consumption. The large loss in weight during the second week (Table XI) on the part of the group fed the pelleted replacer corresponded to the decrease in milk equivalent consumed. The sharp decrease in weight gains observed at 5 weeks with the liquid fed group could be explained by a decrease in total nutrient intake. At this point, starter consumption presumably had not increased sufficiently to make up for the decrease caused by weaning of the calves at four weeks. There was very little difference in total heart girth increase between the two treatment groups and the difference between the total weight gains of the two treatments was found to be of no statistical significance ($P > 0.10$).

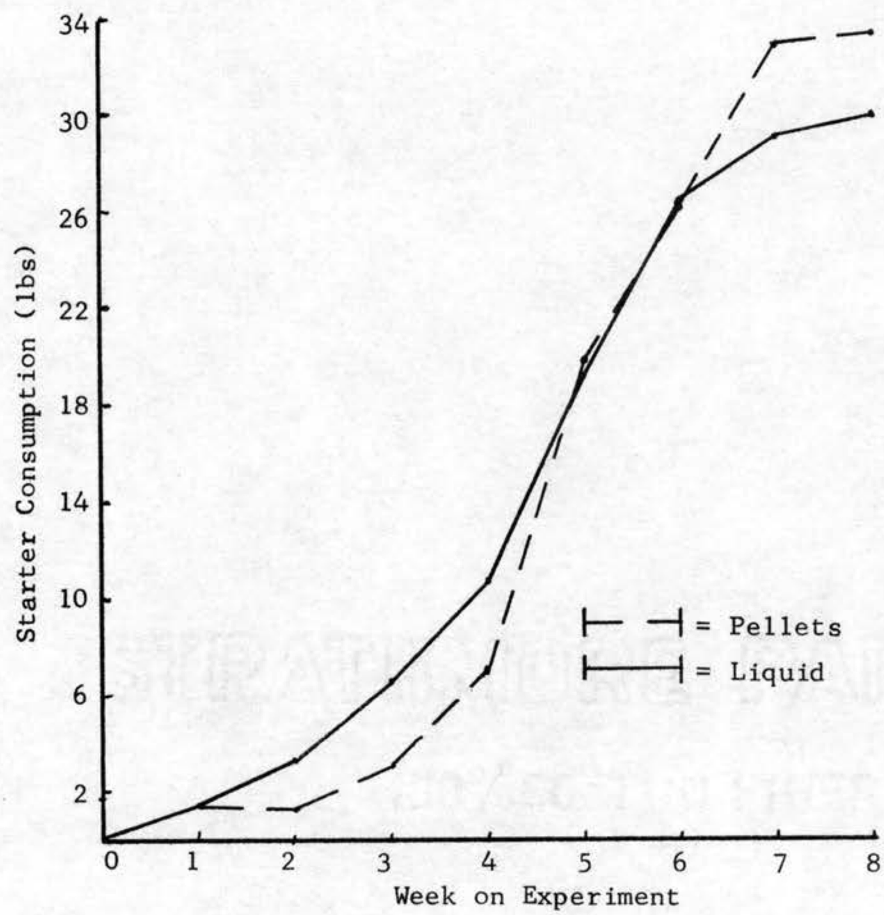

Figure 3. Average Weekly Calf Starter Consumption in Trial II.

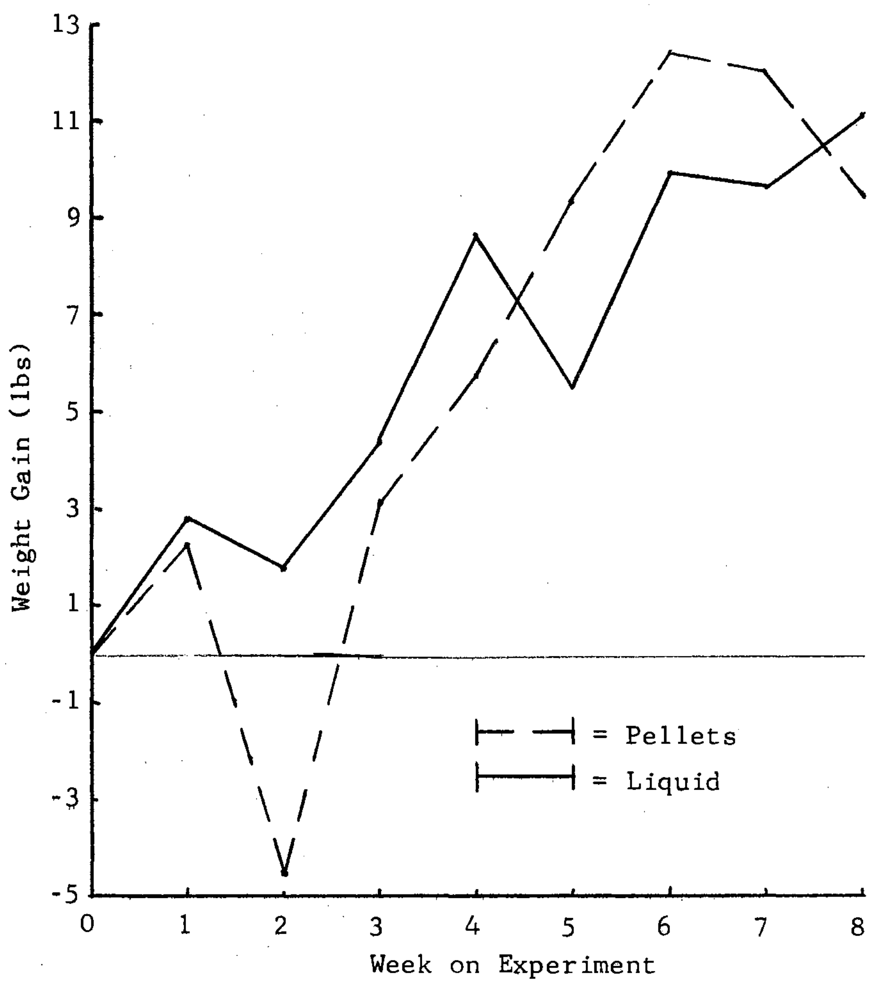

Figure 4. Average Weekly Weight Gains in Trial II.

TABLE XI

AVERAGE WEEKLY WEIGHT GAIN FOR CALVES IN TRIAL II

Form of replacer	Week on Experiment								Total
	1	2	3	4	5	6	7	8	
	lb								
Liquid[b]	2.4	2.1	5.4	9.4	6.8	10.3	11.0	11.1	58.7
Pelleted	2.3	-4.5	3.1	5.8	9.4	12.5	12.1	9.5	50.2

[a]Difference between treatment groups not statistically significant ($P > 0.10$).

[b]One calf died during eighth week.

The pH values for the group fed the pelleted milk replacer were consistently below the values for the liquid fed group (Table XII). The concentration of total VFA were generally higher for the pellet fed calves than for the calves fed the liquid milk replacer (Table XIII). The notable exception was the value of 7.64 mM/100 ml for the liquid fed group as compared to 5.85 mM/100 ml for the group fed the pelleted milk replacer. This was possibly due to the lower consumption during the second week by the pellet fed group of both the milk replacer and the calf starter. The general trend of the pH and VFA values supported the hypothesis that the pellets were deposited in the rumen, resulting in a larger amount of the total ration being subjected to rumen fermentation in these calves.

TABLE XII

AVERAGE pH VALUES OF TRIAL II

Form of replacer	Week on Experiment							
	1	2	3	4	5	6	7	8
Liquid	6.3	5.7	5.5	5.6	5.5	5.6	5.8	6.0
Pelleted	5.8	5.5	4.9	5.1	5.4	5.4	5.6	5.8

TABLE XIII

AVERAGE VALUES OF TOTAL VFA CONCENTRATION FOR TRIAL II

Form of replacer	Week on Experiment							
	1	2	3	4	5	6	7	8
	mM/100 ml							
Liquid	3.00	7.64	6.72	7.65	10.22	9.66	9.17	7.83
Pelleted	5.49	5.85	9.28	9.92	9.58	11.28	8.74	9.53

The calves were evaluated for thriftiness at four and eight weeks of age and assigned scores as follows: 1-weak, 2-fair, 3-good, and 4-very good. There was little difference between groups in the number of calves in each treatment group given the respective ratings (Table XIV) and, in general, the thriftiness of the calves reflected the amount of feed consumed. Moreover, there was little change in the ratings from four to eight weeks. The calves in the pellet fed group changed less on the average than did the liquid group. The average rating changed from 2.9 at four weeks to 2.8 at eight weeks for the pellet group and from 3.0 at four weeks to 2.7 at eight weeks for the liquid fed group.

Observations on Deposition of Pellets in the Stomach

At three weeks of age the rumen contents were removed from the fistulated calf and the volume was found to be approximately 250 milliliters. The calf consumed 0.02 pound of the pellets during the 15-minute feeding period. The pellets were observed to be deposited in the rumen. Hegland et al. (19) obtained similar results with gelatin capsules when fed without any liquid.

Additional observations made at four weeks of age were somewhat more conclusive. The calf consumed 0.01 pound of pelleted milk replacer in the 15-minute feeding period. All of the pellets appeared to be deposited in the rumen.

The rumen was then rinsed out with saline and observations of esophageal groove function were noted. The calf was fed 2.4 pounds of the liquid milk replacer. Of this amount, no leakage into the rumen was observed. The esophageal groove, although displaced a little due to fistulation, functioned to shunt all the liquid replacer into compartments of the stomach other than the reticulo-rumen.

TABLE XIV

FOUR AND EIGHT WEEK EVALUATIONS[a] OF CALVES IN TRIAL II

Pair	Calf	Ration	Weeks Rated 4	Weeks Rated 8
1	30	P[b]	3	3
	16	L[c]	4	3
2	26	P	3	2
	82	L	2	--[d]
3	91	P	3	2
	73	L	3	2
4	93	P	4	3
	205	L	3	3
5	202	P	3	3
	213	L	3	2
6	211	P	3	3
	22	L	3	3
7	81	P	3	3
	9	L	3	3
8	63	P	2	2
	61	L	3	3
9	88	P	2	3
	64	L	3	2
10	48	P	3	4
	43	L	3	3

[a]Evaluation Scale

1 = weak
2 = fair
3 = good
4 = very good

[b]Pelleted Milk Replacer

[c]Liquid Milk Replacer

[d]Calf died after 54 days on experiment.

SUMMARY AND CONCLUSIONS

Forty-eight male Ayrshire and Holstein calves were used in two trials to compare pelleted vs. liquid milk replacers. Also, an effort was made to determine the feeding conditions under which calves could most efficiently utilize pelleted milk replacers as evaluated by weight gains, feed consumption, and pH and total VFA concentration of the rumen fluid. The calves were paired on the basis of breed, with the first member of each pair being randomly assigned either the liquid or pelleted milk replacer and the other member of the pair receiving the other form of replacer.

Trial I was conducted as a pilot study in which various feeding regimes were used to determine the conditions most satisfactory for feeding of a pelleted milk replacer. The regimen found to be most satisfactory consisted of feeding milk at a daily rate of eight per cent of initial body weight, dry replacer at a daily rate of 0.2 pounds per hundred pounds of initial body weight for the first week and then switching to feeding dry replacer at a daily rate of 1.0 pound of dry replacer per one hundred pounds of initial body weight during the second through the fourth week. Feeding of the calf starter ad libitum throughout the trial, starting at 3 days of age, also appeared desirable.

Trial II was conducted, using the feeding regimen described above to compare the performance of calves fed a pelleted vs. a liquid replacer under a uniform set of conditions. There was a slight advantage in favor of the liquid replacer in terms of average consumption and weight gains for the eight-week trial; however, the difference between the treatments in weight gains was not statistically significant ($P > 0.10$) and there was little difference in the thriftiness ratings. The general trend of the pH and VFA values supported the hypothesis that the pellets were deposited in the rumen, resulting in a larger amount of the total ration being subjected to rumen fermentation in these calves. On the basis of observations made on a fistulated calf while eating, it appeared that all of the pellets were deposited in the rumen, whereas the liquid replacer passed via the esophageal groove to the abomasum.

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APPENDIXES

TABLE XV

AVERAGE STARTER CONSUMPTION AND WEIGHT GAINS OF CALVES IN TRIAL I

Week	Group I				Group II			
	Starter Consumption		Weight Gains		Starter Consumption		Weight Gains	
	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer
	lb							
1	0	0	2.0	3.7	0	0	-3.3	8.0
2	0	0	-6.0	-3.3	0	0.87[b]	-4.7	-5.3[b]
3	2.43	0.80[a]	0	-3.5[a]	2.07	1.87	1.7	0
4	5.48	4.05	2.3	5.0	8.23	5.33	4.7	4.7
5	12.43	12.90	11.0	6.5	22.20	13.57	10.3	-1.0
6	18.17	19.10	9.0	6.0	29.77	17.50	11.7	8.0
7	21.73	20.90	6.0	7.5	33.80	25.10	10.3	9.0
8	24.73	23.60	9.3	13.0	35.80	27.10	10.7	9.0

[a]One calf died during third week.

[b]One calf fed grain during second week by mistake.

TABLE XV (Continued)

Week	Group III				Group IV			
	Starter Consumption		Weight Gains		Starter Consumption		Weight Gains	
	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer	Pelleted replacer	Liquid replacer
	lb							
1	0	0	-1.5	-2.2	1.36	1.44	1.25	4.50
2	2.87	2.10	-3.7	-4.5	1.76	2.32	-7.0	-3.00
3	4.05	3.37	-1.2	-0.5	3.92	3.70[f]	1.25	1.67[f]
4	7.57[c]	5.17	4.0[c]	-1.0	7.70	5.88[c]	5.0	5.00[c]
5	16.17	9.07[d]	10.0	2.0[d]	14.80[d]	15.26	11.0[d]	3.55
6	26.10	15.47[e]	11.7	4.0[e]	25.83	25.54	11.67	14.00
7	29.87	22.05	13.0	10.5	31.48	33.42	11.67	12.50
8	28.93	22.30	13.3	7.5	28.55	32.53	9.67	7.00

[c]One calf died during fourth week.

[d]One calf died during fifth week.

[e]One calf taken off experiment due to injury during sixth week.

[f]One calf died during third week.

TABLE XVI

MILK REPLACER CONSUMPTION FOR CALVES IN TRIAL II

Pair	Calf No.	Form of replacer	Days of Milk Replacer Feeding													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			lb													
1	30	P[a]	.02	.04	.07	.09	.07	.1	.18	.17	.28	.58	.59	.88	.64	.68
	16	L[b]	.18	.18	.18	.18	.18	.18	.18	.90	.90	.90	.90	.90	.90	.90
2	26	P	.01	.04	.05	.06	.06	.07	.08	.46	.24	.26	.29	.23	.32	.66
	82	L	.26	.26	.14	.14	.11	.14	.14	.66	.66	.66	.66	.66	.66	.66
3	91	P	.05	.14	.05	.02	.16	.16	.16	.16	.16	.16	.16	.21	.24	.52
	73	L	.16	.16	.16	.16	.16	.16	.16	.80	.80	.80	.80	.80	.80	.80
4	93	P	.16	.16	.17	.20	.20	.20	.20	.96	.96	.96	.64	.92	.96	.68
	205	L	.18	.18	.18	.18	.08	.08	.18	.88	.88	.88	.88	.88	.88	.88
5	202	P	.05	.05	.09	.16	.16	.16	.16	.39	.57	.61	.56	.29	.44	.53
	213	L	.14	.14	.14	.14	.14	.14	.14	.70	.70	.70	.70	.70	.70	.70
6	211	P	.01	.04	.0	.03	.07	.07	.09	.22	.84	.64	.84	.84	.84	.84
	22	L	.18	.18	.18	.18	.18	.18	.18	.92	.92	.92	.92	.92	.92	.92
7	81	P	.00	.02	.01	.00	.01	.01	.01	.16	.32	.26	.49	.51	.71	.69
	9	L	.18	.18	.18	.18	.18	.18	.18	.94	.94	.94	.94	.94	.94	.94
8	63	P	.02	.01	.03	.00	.00	.02	.02	.13	.17	.17	.05	.20	.07	.06
	61	L	.14	.14	.14	.14	.14	.14	.14	.70	.70	.70	.70	.70	.70	.70
9	88	P	.01	.02	.00	.03	.06	.03	.04	.23	.41	.39	.48	.30	.49	.28
	64	L	.16	.16	.16	.16	.16	.16	.16	.82	.82	.82	.82	.82	.82	.82
10	48	P	.02	.02	.07	.13	.20	.18	.20	.33	.34	.29	.37	.38	.71	.64
	43	L	.20	.20	.20	.20	.20	.20	.20	1.02	1.02	1.02	1.02	1.02	1.02	1.02

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

TABLE XVI (Continued)

Pair	Calf No.	Form of replacer	Days of Milk Replacer Feeding													
			15	16	17	18	19	20	21	22	23	24	25	26	27	28
			lb													
1	30	P[a]	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
	16	L[b]	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90	.90
2	26	P	.70	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74	.74
	82	L	.66	.66	.66	.66	.66	.66	.66	.66	.66	.66	.66	.66	.66	.66
3	91	P	.19	.34	.18	.29	.22	.28	.37	.49	.48	.44	.48	.35	.56	.47
	73	L	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80	.80
4	93	P	.86	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96
	205	L	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88	.88
5	202	P	.56	.66	.82	.68	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82
	213	L	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
6	211	P	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84
	22	L	.92	.92	.92	.92	.92	.92	.92	.92	.92	.92	.92	.92	.92	.92
7	81	P	.82	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84	.84
	9	L	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94	.94
8	63	P	.00	.08	.05	.09	.27	.19	.22	.16	.15	.10	.02	.10	.31	.25
	61	L	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70	.70
9	88	P	.59	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82
	64	L	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82
10	48	P	.61	.76	.88	.57	.40	.24	.40	.87	.50	.67	.74	.74	.75	.75
	43	L	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

TABLE XVII

WEEKLY STARTER CONSUMPTION OF THE CALVES IN TRIAL II

Pair	Calf	Ration	Week on Experiment 1	2	3	4	5	6	7	8	Total
			lb								
1	30	P[a]	2.08	0.99	1.00	2.30	20.25	33.09	38.00	38.43	136.14
	16	L[b]	2.29	2.86	7.28	16.18	24.25	33.52	43.96	41.72	172.06
2	26	P	2.10	2.00	4.73	10.98	24.41	26.68	27.44	30.55	128.89
	82	L	0.92	2.60	3.83	3.57	9.29	9.75	12.19	1.74[c]	----
3	91	P	1.80	1.80	0.99	0.46	5.99	12.80	19.76	15.89	59.49
	73	L	1.70	5.10	11.11	13.05	20.90	30.56	23.20	24.38	130.00
4	93	P	1.67	1.25	2.70	7.40	20.27	30.48	38.40	36.96	139.13
	205	L	1.23	2.21	5.54	12.74	27.90	34.73	38.80	38.38	161.53
5	202	P	1.12	0.93	0.68	2.11	17.65	26.69	20.84	26.06	96.08
	213	L	1.12	1.80	3.26	3.32	11.20	17.10	24.88	23.90	86.58
6	211	P	1.54	1.02	3.66	6.38	21.44	24.76	42.01	42.40	143.21
	22	L	3.20	5.51	7.73	15.86	26.10	33.36	35.00	42.99	169.75
7	81	P	0.60	0.80	4.16	6.30	19.88	32.15	33.40	35.70	132.99
	9	L	0.90	2.08	8.85	12.15	20.70	29.74	37.75	38.46	150.63
8	63	P	1.80	1.08	5.18	10.70	20.93	16.36	27.58	33.50	117.13
	61	L	0.59	4.15	7.97	12.20	17.56	28.88	33.09	37.94	142.38
9	88	P	1.08	0.89	1.99	10.97	20.50	24.58	32.18	32.20	124.39
	64	L	0.66	1.30	0.53	1.25	7.62	10.45	11.27	14.18	47.26
10	48	P	2.17	1.97	6.40	12.73	26.52	34.22	50.30	41.70	176.01
	43	L	2.79	5.64	9.18	16.62	27.04	35.92	32.00	35.87	165.06

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]Calf died at 54 days of age.

TABLE XVIII

WEEKLY WEIGHT GAINS OF THE CALVES IN TRIAL II

Pair	Calf	Ration	Week on Experiment 1	2	3	4	5	6	7	8	Total
			lb								
1	30	P[a]	-2	-6	2	1	11	20	16	13	55
	16	L[b]	4	-2	6	12	8	8	16	12	64
2	26	P	-1	-1	9	12	4	6	12	9	50
	82	L	6	-1	-4	2	-6	7	-2	--[c]	--
3	91	P	2	-2	0	-4	-1	5	13	2	15
	73	L	5	0	12	5	4	9	0	6	41
4	93	P	4	0	0	5	16	16	9	10	60
	205	L	-3	8	1	13	14	17	14	6	70
5	202	P	2	-4	2	2	12	16	7	5	42
	213	L	0	0	5	4	3	10	12	8	42
6	211	P	2	0	3	4	15	12	15	18	69
	22	L	7	5	4	12	12	12	13	17	82
7	81	P	-5	-6	6	9	11	18	12	8	53
	9	L	3	0	9	13	77	12	15	11	70
8	63	P	0	-6	-1	7	4	10	12	12	38
	61	L	-2	6	6	10	4	14	14	13	65
9	88	P	4	-10	4	11	13	8	9	12	51
	64	L	0	-2	3	1	4	-2	8	12	24
10	48	P	17	-10	6	11	9	14	16	6	69
	43	L	8	4	3	15	5	13	7	15	70

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]Calf died at 54 days of age.

TABLE XIX

HEART GIRTH MEASUREMENTS OF THE CALVES IN TRIAL II

Pair	Calf	Ration	Week on Experiment 1	2	3	4	5	6	7	8
			inches							
1	30	P[a]	32.5	33.5	32.5	33.5	33.0	33.5	36.0	39.5
	16	L[b]	30.0	30.0	30.5	32.2	32.5	33.0	34.0	35.5
2	26	P	30.0	30.0	31.0	32.0	32.0	33.0	33.5	34.0
	82	L	28.7	28.0	28.5	29.0	28.5	28.5	29.5	--[c]
3	91	P	30.0	31.0	31.0	30.0	30.0	31.0	31.0	31.2
	73	L	30.0	30.5	31.0	32.0	32.5	33.5	33.5	34.0
4	93	P	31.0	31.5	32.0	32.0	33.0	34.5	35.0	36.5
	205	L	29.5	32.0	30.5	32.0	34.0	33.5	35.5	36.0
5	202	P	29.5	31.5	29.5	29.5	32.5	32.5	32.5	33.5
	213	L	27.5	27.5	28.0	29.0	28.5	30.0	31.0	31.5
6	211	P	29.5	29.5	30.5	30.0	31.5	32.5	34.0	35.5
	22	L	31.0	31.5	33.0	33.5	34.5	36.5	37.0	37.5
7	81	P	29.5	32.0	31.0	30.5	31.0	33.0	33.5	35.0
	9	L	31.5	32.0	32.5	33.5	34.5	35.5	37.5	37.5
8	63	P	29.5	29.0	29.0	30.0	30.5	30.5	31.5	33.5
	61	L	28.0	29.0	29.0	30.5	31.0	32.0	34.0	34.0
9	88	P	30.5	31.0	31.0	31.5	32.5	32.0	33.5	35.0
	64	L	29.0	29.5	30.5	30.0	29.0	29.5	30.0	31.5
10	48	P	29.0	31.0	32.0	33.5	33.5	35.0	26.5	37.0
	43	L	33.0	33.5	33.5	34.0	35.5	35.5	37.0	38.0

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]Calf died at 54 days of age.

TABLE XX

pH VALUES OF THE RUMEN FLUID FROM CALVES IN TRIAL II

Pair	Calf	Ration	Week on Experiment							
			1	2	3	4	5	6	7	8
1	30	P[a]	5.6	5.4	4.8	4.5	5.0	5.0	5.4	5.6
	16	L[b]	6.6	6.1	5.8	6.2	6.0	5.8	5.6	6.0
2	26	P	6.2	5.8	--[c]	5.6	6.5	6.2	5.4	5.8
	82	L	7.1	5.5	5.3	5.7	5.3	5.2	5.5	--[d]
3	91	P	6.1	5.5	5.8	6.2	5.7	5.3	5.2	5.2
	73	L	6.4	5.2	5.5	5.2	5.1	5.8	6.8	6.3
4	93	P	5.8	5.6	4.8	5.0	5.0	5.5	5.9	6.1
	205	L	5.8	5.2	5.0	5.4	5.5	5.4	5.8	6.6
5	202	P	5.4	6.2	4.5	5.0	5.4	5.3	5.8	6.4
	213	L	6.6	6.6	5.2	6.5	6.4	5.7	6.2	6.7
6	211	P	6.1	4.8	4.7	4.7	5.2	5.4	6.2	6.4
	22	L	5.5	5.6	6.1	5.8	5.8	6.1	6.5	5.3
7	81	P	6.2	6.0	4.6	5.0	5.1	5.1	--[c]	5.6
	9	L	6.3	5.7	5.1	5.3	5.5	6.1	5.6	5.4
8	63	P	5.9	--[c]	4.7	5.3	5.2	5.2	5.3	6.1
	61	L	6.3	5.3	5.2	5.1	5.2	5.1	5.1	5.9
9	88	P	5.9	--[c]	4.9	5.1	5.2	6.2	6.1	5.7
	64	L	6.6	6.5	6.4	5.8	5.2	5.2	5.6	6.0
10	48	P	4.8	4.9	4.9	4.7	5.1	5.1	5.2	5.4
	43	L	6.2	5.2	5.0	5.2	5.4	5.4	5.5	5.8

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]No values recorded.

[d]Calf died at 54 days of age.

TABLE XXI

CONCENTRATION OF TOTAL VFA OF THE RUMEN FLUID FROM CALVES IN TRIAL II

Pair	Calf	Ration	Week on Experiment							
			1	2	3	4	5	6	7	8
			(mM/100 ml)							
1	30	P[a]	5.31	9.46	9.25	6.65	10.88	12.39	10.47	11.66
	16	L[b]	1.60	4.96	6.82	8.04	8.46	10.06	7.63	4.30
2	26	P	6.37	3.93	3.75	7.72	9.81	4.69	4.87	9.20
	82	L	1.38	8.42	8.76	7.14	11.02	13.69	6.72	--[c]
3	91	P	4.76	6.21	10.08	6.82	9.49	11.18	8.76	11.00
	73	L	3.69	10.28	7.29	8.91	11.92	8.10	7.81	7.17
4	93	P	3.82	6.59	12.88	16.31	7.56	10.87	6.69	8.57
	205	L	1.32	14.30	5.66	8.24	10.65	6.56	8.68	3.11
5	202	P	13.78	3.69	9.81	9.23	13.81	13.75	8.88	7.63
	213	L	2.56	3.31	6.24	4.73	7.24	14.24	8.32	7.86
6	211	P	1.78	5.98	12.36	8.59	9.63	10.93	3.85	6.05
	22	L	4.56	5.16	3.82	6.51	8.48	7.50	8.73	6.68
7	81	P	0.41	2.59	9.54	14.12	7.20	12.21	10.70	9.86
	9	L	0.44	8.53	11.46	8.10	10.48	8.47	12.50	14.33
8	63	P	4.91	--[d]	6.10	7.40	8.68	13.90	13.55	8.65
	61	L	3.82	5.70	6.09	8.28	11.47	6.00	11.43	7.30
9	88	P	2.98	--[d]	9.98	11.78	9.78	9.84	9.20	12.22
	64	L	8.24	4.09	1.22	5.95	13.19	12.15	10.20	8.72
10	48	P	10.80	8.36	9.07	10.54	8.93	13.02	10.41	10.45
	43	L	2.37	11.62	9.81	10.60	9.32	9.87	9.64	11.01

[a]Pelleted Milk Replacer

[b]Liquid Milk Replacer

[c]Calf died at 54 days of age.

[d]No sample taken

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