CORN-SOYBEAN FLOUR RATIONS

IN THE NUTRITION OF THE YOUNG CALF

I. The Use of Milk Replacers with Limited Whole Milk for Feeding Young Calves.

II. Digestibility and Balance Studies with Milk and Milk Replacers

by

CARL H. NOLLER

A Thesis

Submitted to the School of Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy

1955

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Doctor C. F. Huffman, Research Professor in Dairying, and to Doctor G. M. Ward, Assistant Professor in Dairying, for their counsel, guidance and critical reading of the manuscript; and to Doctor E. P. Reineke, Professor in Physiology, for his critical reading of the manuscript.

The author wishes to express his gratitude to Mr. C. W. Duncan, Associate in Agriculture Chemistry, for the chemical analyses; to Doctor Frank Thorp, Jr., Professor in Animal Pathology, and Doctor J. A. Williams, Instructor in Animal Pathology, for the post mortem examinations; and to Mr. Ralph Reid, herdsman, for his help in caring for the calves.

The author is also indebted to Distillers Feed Research Council, Cincinnati, Ohio, and Commercial Solvents Corporation, Terre Haute, Indiana, for the funds which helped make this investigation possible; to Lederle Laboratories, Pearl River, New York, for the Aureofac; to Commercial Solvents Corporation, Terre Haute, Indiana for the Baciferm-5; and to Distillers Feed Research Council, Cincinnati, Ohio, for the distillers dried solubles.

The author wishes to express his gratitude to his wife for her encouragement, sacrifices and for the typing of this thesis.

CORN-SOYBEAN FLOUR RATIONS IN THE NUTRITION OF THE YOUNG CALF

I. The Use of Milk Replacers with Limited Whole Milk for Feeding Young Calves.

II. Digestibility and Balance Studies with Milk and Milk Replacers.

By

Carl H. Noller

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy

1955

Approved C. F. Huffman

Carl H. Noller

ABSTRACT

Twenty-one Holstein calves were placed on three predominantly vegetable milk replacers---basal, basal with 5 percent dried whey and basal with 3.5 percent lactose. The three groups of calves consumed an average of 54.9, 51.9, and 50.7 lb. of whole milk, respectively, during the experimental period.

The average daily gains of the calves on the basal, whey and lactose rations were $0.87 \pm .08$, $0.92 \pm .05$ and $0.87 \pm .07$ lb., respectively. The differences were not statistically significant. Growth patterns indicated the existence of a critical period in the life of the young calf from birth to approximately 25 days of age. The end of the critical period was characterized by increased growth, increased feed consumption and improved appearance of the calf.

Calves receiving the whey ration had the more costive fees, smoother haircoat and were more alert. Lactose appeared to have no benefit under the conditions of this experiment.

Two groups of four 10-day-old male calves each were assigned to 4 X 4 Latin square metabolism studies. Fecal collections were made utilizing a simplified bag technique. The apparent digestibilities of five milk replacers, evaporated milk and raw whole milk were determined. Nitrogen, calcium and phosphorus balances were determined. The effect of age of the calves on the apparent digestibilities of the various feeds was studied. One experiment was conducted with two calves to compare the digestibility of evaporated and raw whole milk in a continuous trial.

The variability of the milk replacer data in the first experiment indicated the inadequacy of 2-day fecal and urine collection periods. The use of 4-day collection periods appeared to be sufficient.

The mean coefficient of apparent dry matter digestion of raw whole milk was 94.8; crude protein, 90.1; ether extract, 97.8; and nitrogen-free extract, 97.1. The dry matter of evaporated milk was 76.8 percent digested by a 10-to 14-day-old

Abstracts (cont'd)

calf and an average of 90.0 percent by 19-to 38-day-old calves. The average apparent dry matter digestibility of the milk replacers increased from 25.0 percent to 10-to 14-day-old calves to an average of 75.4 percent for 26-to 38-day-old calves. Similar increases in digestibility with increased age of the calves were noted for the crude protein and nitrogen-free extract fractions. The most digestible fraction was the nitrogen-free extract and the least digestible the crude protein.

The crude protein of the raw whole milk was slightly less digestible by the 10-to 14-day-old calf than in subsequent periods. For the evaporated milk it was low for the 10-to 14-day-old calf and at its maximum value by 19 to 22 days of age. During the first collection period the crude protein of the milk replacers was considerably less digestible than that of the milks. It attained its maximum value by 26 days of age.

Crude fiber was essentially indigestible throughout the experiments.

Nitrogen, calcium and phosphorus retentions were greater for calves fed raw whole milk than those fed the evaporated milk or milk replacer rations. Nitrogen and phosphorus balances were low or negative in 10-to 22-day-old calves fed the milk replacer rations. The older calves had positive balances.

The milk replacers used in this investigation were not satisfactorily utilized by the calf until the calf was approximately 25 days of age.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

PART II

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

INTRODUCTION

The use of milk replacers in calf raising is increasing in importance. The impetus for the increased attention is provided by the desire to market more milk and the fact that changes in marketing practices make less skimmilk available on the farm. The use of a nutritionally adequate and economical milk replacement in lieu of milk would enable the farmer to raise calves which otherwise would have to be sold.

Down through the years experiment stations and commercial firms have proposed many different milk replacers and feeding programs for the young calf. However, they either were unsatisfactory from the standpoint of replacing milk nutritionally or they were uneconomical due to the high percentage of dried milk solids and other animal by-products. It is the use of the expensive animal by-products which makes most milk replacers economically prohibitive for the rearing of calves. In the last few years inexpensive vegetable by-products such as soybean oil meal have been used with some degree of success. However, more information is needed with regard to which vegetable products to use and how to use them to the best advantage.

It was the purpose of this investigation to study the value of simple milk replacers containing only small amounts of animal by-products for feeding the young calf.

PART I

THE USE OF MILK REPLACERS
WITH LIMITED WHOLE MILK FOR FEEDING YOUNG CALVES

REVIEW OF LITERATURE

The nutrient requirements of the young calf are dependent on the extent of rumen function. At birth the calf's rumen is non-functional and the nutrient requirements closely resemble those of monogastric animals. Milk satisfies these requirements for practical purposes. Many investigations have been conducted on feeds and combinations of feeds as replacements for whole milk. In general, results with milk replacements have not been equal to those with whole milk. As the rumen becomes functional the nutrient requirements of the calf become less specific. At this time calves can be weaned from milk or milk substitutes with substitution of a less refined ration.

This review includes discussions on the development of rumen function, weaning age and the use of dried whey and lactose, soybean oil meal, distillers dried solubles and antibiotics in feeding the young calf.

Rumen Development in the Young Calf

The relative size of the four stomachs of calves before birth and at full term was studied by Becker and coworkers (1951). In early fetal life the rumen is the largest of the four stomachs. After about 4 months the abomasum begins to increase rapidly; at 6 months it is equal to the rumen in weight and at full term it weighs twice as much as the other three stomachs combined. According to Parrish and Fountaine (1952) activity occurs in the intestinal tract before birth of the calf.

This was indicated by the presence of hair in the lower colon and by the relative concentrations of minerals in different parts of the tract.

The development of the stomachs after birth has been studied by the slaughter technique. Marshall et al. (1950) observed that between the ages of 7 and 30 days the weight of fresh contents from the abomasum exceeded that of the rumen. According to Schmaltz (1938) in 4-week-old calves the true stomach contains 62 to 66% of the total stomach contents, the rumen and reticulum 33 to 38% and the omasum nothing. At 8 weeks of age the true stomach is nearly equal in size to the rumen-reticulum. The rumen-reticulum contains 70% of the total at 10 to 12 weeks and 84% at 4 months of age. In a 4- to 12-week-old calf the omasum contains practically nothing, at 4 months about 2 l. and at 7 months 2.5 to 3 l. Kesler et al. (1951) studied rumen development in calves fed a normal diet of grain, hay and milk. In calves 32 days of age or younger the weight of rumen tissue increased slowly but steadily with age. Between 32 and 42 days a pronounced increase in weight occurred. At approximately 42 days of age or older, all animals had rumen contents characteristic of an adult ruminant. Their data indicate that, with the feeding regime used, rumen function begins at approximately 32 to 42 days of age.

An indirect method of determining rumen development by blood sugar levels has been proposed. An inverse relationship between the glycemic level and rumen development was first observed by McCandless and Dye (1950). Craine and Hansen (1952) reported similar results in their work with goats. Further studies by Dye and Orsini (1952) on two male calves indicated that diet influenced this relationship. They observed a post absorptive glycemia of 90 to 125 mg. per 100 ml. in newborn calves and a rapid decrease during the first month of life. After the first month of life the blood sugar levels decreased more slowly until adult levels of 40 to 60 mg. per 100 ml. were reached. The blood sugar level declined at a slower rate when milk was fed. When a calf was changed from a starter and hay diet to milk, the blood sugar level increased. Later Warner et al. (1953) demonstrated that blood glucose values declined uniformly for all groups until the sixth or seventh week, when the milk and grain groups leveled off at approximately 75 mg. per 100 ml. The hay group declined further and stabilized at 8 weeks at about 55 mg. per 100 ml. Similar results were reported by Conrad et al. (1954).

In his work with lambs Reid (1953) found that the major portion of the decrease in blood glucose during the first 4 to 5 weeks was in corpuscle glucose and that plasma glucose later fell to the adult level. He concluded from these results that the changes in blood glucose are independent of rumen development and therefore not a measure of it.

Another suggested method for measuring rumen development is the level of blood volatile fatty acids. Conrad et al. (1954) reported that in calves on a high roughage ration the volatile fatty acid content of rumen juice increased from an average of 60 meq. per l. at 4 weeks of age to a maximum of 92 meq. per l. at approximately 9 weeks of age.

A possible relationship between the rate of riboflavin and thiamine synthesis in the rumen and initiation of rumen function was investigated by Conrad and Hibbs (1954). They found a rapid rate of synthesis when the calves were about 3 weeks old. In contrast, Kesler and Knodt (1951) in their investigation of rumen synthesis could find no relationship between the age of a calf and the level of certain B-vitamins in the rumen. However, the difference in type of ration fed may have had an influence on the results.

In studies reported by McMeekan (1954) calves on pasture began ruminating as early as 7 days and rarely later than 3 weeks. Pasture consumption began at this time. He also reported that grass-fed calves showed better and faster rumen development than milk-fed calves. At 3 months of age a grass-fed calf had a rumen which was proportionately as large as that of an adult cow and relatively larger at 5 months. Digestibility studies showed that 8- to 10-week-old calves fed good quality, leafy, young pasture were able to digest 74.6% of the dry matter. Conrad et al. (1950) reported that 9-week-old calves were able to digest 72% of the dry matter and 82% of the cellulose in grass. Armstrong and coworkers (1954), using 10- to 12-week-old calves reared from birth on pasture and 34 gal. of milk, found digestibility values of 75% for dry matter and 84% for cellulose. The high digestibility of dry matter and cellulose by young calves suggests an advanced stage in rumen development.

Pounden and Hibbs (1947) suggested using cud-inoculation for speeding rumen development. In a later experiment Conrad and Hibbs (1953) found that 64.7 to 67.8% of the protein was digested by rumen-inoculated calves compared to 54.4 to 61.8% for uninoculated calves. When an uninoculated calf was later inoculated, the protein digestibility increased from 55.7 to 65.9%. The type of ration fed along with cud-inoculation influenced the establishment of organisms in the rumen and rumen development (Hibbs and Pounden, 1948; Pounden and Hibbs, 1948).

The agreement among workers concerning the value of cud-inoculation is not unanimous. Pelissier *et al.* (1954) used 48 calves divided into 2 groups, one of which was inoculated, the other serving as the control. They observed no significant differences in weight gains, heart girth, height at withers, severity or incidence of scours, thriftiness, general appearance or bacterial population in the rumen. McGilliard *et al.* (1952) also reported no favorable effects due to cud-inoculation.

Mann *et al.* (1954) reported that feeding aureomycin at the rate of 40 to 60 mg. per day to calves results in higher rumen pH and increased size of the rumen. Bacteria and protozoa increased in numbers at an earlier age but body growth was not significantly affected.

Use of Dried Whey and Lactose

An abundance of dried whey and concurrent low price have caused increased interest in its use as a substitute for milk in calf rations. Otis (1905) and Morrison *et al.* (1922) stated that whey could be used as a satisfactory substitute for milk in calf rations. Calves fed pasteurized skimmed whey and a simple concentrate mixture gained nearly as much as calves fed 10 lb. of skimmilk a day (Morrison *et al.*, 1924). Later Rupel (1929) conducted an experiment using liquid whey in a ration designed to test the comparative value of white and yellow corn for calf feeding. He found that whey-fed calves made an average daily gain of 1.48 lb. per day compared to 1.72 lb. for skimmilk-fed calves. Hathaway *et al.* (1943) and Trimberger *et al.* (1944) also reported satisfactory results with dried whey as a source of protein in calf rations.

In the above mentioned experiments the calves were two to three weeks old at the beginning of the experiment. In tests conducted by Van Poucke et al. (1947) 3- to 4-day-old Holstein calves were used. They concluded that a whey product in combination with vegetable calf meal produced gains as efficiently as in combination with an animal protein meal.

Seekles and Wegelin (1952), using 6 monozygotic twin calves, studied the effect of removing much of the lactose and salt from whey. They reported no difference in growth between two groups of calves receiving diets in which 6 and 27% of the protein originated from whey, respectively. A similar result was obtained with piglets receiving up to 30% of their protein from whey.

One of the principle problems in feeding whey is its effect on the incidence of scours. When Wallace et al. (1951) fed rations containing 30, 45 and 60% dried whey to calves the lower level of dried whey produced the most rapid gains. They also observed that diarrhea increased with the level of dried whey. Young (1953) likewise observed increased diarrhea when 80% of the whole milk was replaced by whey on an isocaloric basis.

To combat the incidence of scours and promote growth Daniel and Harvey (1947) suggested the removal of a considerable portion of the soluble salts from whey by means of dialysis. Brown et al. (1953) proposed the addition of slacked lime ($\frac{1}{4}$ teaspoon) to each feeding of reconstituted whey to decrease the incidence of scouring. In contrast, Wise (1941) used dried whey as a remedy for certain types of scours, loss of appetite and general weakness. The treated calves began to improve within five days after initiation of treatment.

Since dried whey contains approximately 70% lactose the lactose may be the causative factor in diarrhea. Riggs and Beaty (1947) observed that feeding diets containing 20, 25 and 30% lactose caused diarrhea. They concluded that the lactose linkage was responsible for the diarrhea from feeding rations containing equal parts of glucose and galactose at levels equivalent to 15, 30 and 50% lactose. A year later Rojas et al. (1948) reported that doubling the lactose content of milk caused an increase in urinary galactose. The galactosuria was accompanied by diarrhea and unthriftiness of the animals. In a review of the effect of lactose on gastro-intestinal motility Fischer and Sutton (1949) suggested that the effect of lactose in causing diarrhea is by interference with absorption of water and organic nutrients.

A number of workers have shown that lactose lowers the pH of the intestinal tract (Ascroft, 1933; Cannon and McNease, 1923; Kline et al., 1932; Robinson et al., 1929; Robinson and Duncan, 1931). This lowering of the pH of the intestinal tract by lactose is believed to influence calcium utilization (Fournier, 1954). He observed that incorporating 12% lactose in a wheat-casein diet prevented bone erosion and negative calcium balance in the lactating rat. Mill et al. (1940) in his work with children found 33.5% more calcium retention when lactose was fed than in its absence.

Schantz et al. (1938) have suggested that galactose affects fat utilization. Richter (1948) also credited lactose or, specifically, the galactose portion, with increasing the utilization of fat.

Although dried whey and lactose can both be used in calf rations the optimum level appears to be low due to the incidence of diarrhea associated with feeding at higher levels. Flipse et al. (1950) suggested 5 to 10% lactose as being optimum in a semi-synthetic calf ration.

Leighton (1955) reported that the addition of 10% of a fat substance (Marcol B-75) to a ration containing 35% dried whey prevented scours. Also, the addition of this substance to a diet will stop nutritional scours. In a recent review on the physiological effects of lactose Duncan (1955) concluded that fat and large amounts of B-vitamins can counteract the effects of excessive lactose intake.

Use of Calf Gruels

Historical. Liebig formulated the first known calf gruel by mixing 3.5 qt. of milk, 3.5 qt. of water, 10 oz. of wheat flour, 10 oz. of ground malt and 0.25 oz. of potassium bicarbonate (Kellner, 1926). Various modifications of calf gruels using potato starch, malt and wheat or rye feeding meals were proposed by Kellner (1926).

Many ingredients have been used by various workers in their attempt to formulate a gruel to replace all or part of the milk ration. Among the first gruels was that proposed by Morse (1898) who used skimmilk with flaxseed jelly added to replace the milk fat. Hayward (1902) reported little difficulty in raising calves without milk after they were two weeks old. He used a ration composed of 30% wheat flour, 25% coccoanut meal, 20% dried skimmilk, 10% linseed oil meal and 2% dried blood. The whole milk fed varied from 74 to 264 lb. per calf. Two years later Lindsey (1904) agreed that calves could be raised successfully on Hayward's calf meal providing reasonable precautions were taken.

Michels (1908) claimed that rolled oats made an excellent substitute in calf feeding if milk was scarce. However, Savage and Tailby

(1909) claimed that skimmilk was the best substitute for whole milk, although healthy calves could be raised without any milk after the third or fourth week of age. Two years later Savage and Tailby (1911) were able to demonstrate no difference between calves which had been fed skimmilk and those fed substitutes. Krauss <u>et al</u>. (1935) also observed that 2- or 3-year-old heifers raised on dry feed rations were indistinguishable from heifers raised on liquid skimmilk.

The use of calf gruels in rearing calves was reported favorably by Lindsey (1915). However, Bechdel (1917) did not recommend their use for veal production due to inferior carcass quality. For optimum veal production he recommended that an all-milk diet be used. McCandlish (1923) raised two calves to 150 days of age with milk as the sole ration. He concluded that milk alone was not an adequate diet for rearing calves because lack of bulk in the diet arrested the development of the alimentary tract and decreased the digestion of nutrients. This effect would seem to be undesirable in calves raised as replacements since a well developed rumen would enable the calf to make efficient use of roughages at an earlier age.

<u>Soybean type</u>. The soybean oil meal which was first available was of poor quality and had to be improved before its successful use in calf rations was possible. The first reported use of soybean protein was by Osborne and Mendel (1917) who found that it had a low biological value. This was confirmed by Hayward <u>et al</u>. (1936). Ham and Sandstedt (1944) succeeded in extracting a substance from unheated soybeans which retarded trypsin activity <u>in vitro</u>. The activity of the substance was destroyed by autoclaving. Bowman (1944) confirmed these results.

Later Melnick et al. (1946) reported that heat processing also improved the value of the soybean meal by increasing the availability of methionine. Claudinin et al. (1948) were able to produce a meal of high nutritive value by processing soybean oil meal in an autoclave at 15 lb. pressure for 4 minutes. However, overheating resulted in a soybean oil meal of low feeding value due to the destruction of lysine and methionine (Claudinin et al., 1946; Riesen et al., 1947; Claudinin et al., 1947).

The feeding value of unheated soybean oil meal was studied by Shoptaw (1936) on 25- to 70-day-old calves. The calves were unthrifty and had rough hair coats and considerable diarrhea. Wallace et al. (1951) also found that a mixture containing 20% of an unheated 20%-fat soya-flour caused severe diarrhea in calves at about 4 weeks of age. When Williams and Knodt (1950) fed ground raw soybeans at the 40% level, all calves in the groups died. Norton and Eaton (1946) reported good results with calf starters containing 16 to 18% soybean oil meal. The feeding method used was that reported by Savage and Crawford (1935) which allowed 350 lb. of whole milk per calf.

The use of soybean oil meal as the main source of protein in calf rations was unsuccessful until a special process soybean flour was developed (Noller and Huffman, 1953). In this experiment 25% soybean flour was used in a formula containing 10% dried whey as the only animal by-product. The whole milk fed varied from 59 to 89 lb. per calf. Later Stein et al. (1954) and Stein and Knodt (1954) reported the successful use of soybean flour in their milk replacement formulas.

Distillers dried solubles. The use of distillers dried solubles in calf rations has not been the subject of extensive research. Davis and Trimberger (1946) first reported satisfactory results with distillers dried solubles in the rations of 2-month-old calves. Schabinger and Knodt (1948) in an experiment with 3- to 14-day-old calves found that distillers dried solubles and distillers dried grains with solubles gave satisfactory results with no effect on palatability. In this experiment 300 lb. of whole milk was fed during the first 45 days of life. Experiments by Slack and Turk (1951) on 107 Holstein calves indicated that normal calves could be reared on starters containing 10 or 20% distillers dried solubles. About 350 lb. of whole milk was fed during the first 49 days of life. Lassiter et al. (1953) using 44 Jersey calves showed that corn or milo distillers dried solubles could replace an equal amount of dried skimmilk in a simple calf starter. These calves were fed hay and 170 to 227 lb. of whole milk per calf. Noller and Huffman (1953) obtained satisfactory weight gains in calves with a calf starter containing 10% distillers dried solubles. The whole milk intake varied form 59 to 89 lb. per calf.

Aureomycin. The effect of antibiotics on the growth of calves was reviewed by Knodt (1953). The author concluded that aureomycin, on the basis of reports available, increases growth and decreases the incidence of scours in dairy calves. The results with the other antibiotics were variable. A review on antibiotics in animal nutrition was published by Stokstad (1954) and one on the nutritional effects of antibiotics by Jukes and Williams (1953).

Weaning Age

The age when calves should be weaned from milk has been the subject of numerous investigations. Mead et al. (1924) were successful in weaning calves from whole milk to alfalfa hay and a grain mixture containing no milk at 30 to 40 days of age. The whole milk fed varied from 132 to 508 lb. per calf. Maynard et al. (1925) obtained similar results with skimmilk or gruel following the feeding of approximately 500 lb. whole milk until the sixth or seventh week of age. Bender and Bartlett (1929) raised calves satisfactorily on dry grain and hay after weaning them from milk at 30 days of age. Lindsey and Archibald (1931) did not recommend this dry feeding method due to the poor condition of the calves. They were of the opinion that some form of milk should be fed until the calves were at least 4 months of age. Elting and LaMaster (1934) demonstrated that calves may be weaned at 50 to 60 days of age and raised successfully on hay and grain. Ingham et al. (1930) suggested 30 to 60 days as the weaning period. Jones et al. (1931) indicated 30 to 50 days using about 160 lb. of whole milk and 90 lb. of reconstituted skimmilk. McCandlish (1939) on the basis of his review of the literature suggested a minimum whole milk allowance of at least 400 to 500 lb. spread over the first 4 to 5 weeks.

Savage and Crawford (1935) weaned Holstein calves that had received 350 lb. of whole milk at 7 weeks of age. They were able to obtain growth above the accepted normal using various experimental mixtures. They concluded that not more than 22% dry skimmilk was necessary in a calf starter mixture. When they tried the Bender and Perry (1930) limited-whole-milk (150 lb.) and blood-flour-concentrate mixture method they found that growth of these calves during the first 16 weeks was inferior to those given the 22% dried skimmilk ration. At the end of 26 weeks there was no difference in weight.

Lindsey and Archibald (1925) replaced whole milk with skimmilk at 7 to 10 days of age. They stated that skimmilk substitutes will replace skimmilk adequately. Four years later Lindsey and Archibald (1929) reiterated that dried skimmilk was the best substitute for liquid skimmilk in raising calves. They also claimed that calf meals were satisfactory but not adequate for rapid growth. Williams and Bechdel (1931) asserted that a calf starter should contain both dry skimmilk and blood flour.

EXPERIMENTAL

Selection and Assignment of Animals

Twenty-one Holstein calves consisting of 17 bulls and 4 heifers were placed on three milk replacers. The calves were obtained from the university herd and from three local dairymen. The calves were assigned at random to the various milk replacers as they became available. A slight adjustment in assigning calves was made with the last calves in order to obtain groups with comparable initial weight. Any calf apparently sick or abnormal during the first few days on experiment was removed and the next animal obtained was substituted in its place.

Feeding and Management

All calves were left with their dams for 48 hours after birth. They were then removed from their dams, weighed and usually fasted. However, in two cases calves that were hungry were not starved the full 24 hours; they thus received a full feeding the first day. The feeding schedule is shown in Table 1. Milk feeding was limited to a maximum of 56 lb. with the exception of the two calves mentioned above, and was discontinued entirely after the twenty-first day of life. Milk replacer feeding as a gruel at the rate of 0.5 lb. per day and *ad libitum* in dry form was started on the seventh day of age. No hay was fed at any time during the experimental period.

The amount of water fed daily was calculated to supply a total liquid intake of 1 lb. per 10 lb. of body weight. Adjustments were made weekly, if needed, on the basis of body weight changes. No changes in amount of water fed were made if it amounted to less than 2 lb. per day.

The calves were kept in individual pens bedded with wood shavings. They were taken off experiment at 60 days of age.

Table 1

Daily Feeding Schedule

Age (days)	Whole milk (lb.)	Replacer fed as gruel (lb.)	Replacer fed dry (lb.)
0-2	with cow	--	--
3	usually fasted	--	--
4-6	6	--	--
7-10	4	0.5	*ad libitum*
11-21	2	0.5	*ad libitum*
22-60	--	0.5	*ad libitum*

Feed Formulation

The formulas of the three milk replacers used in the experiment are presented in Table 2. Milk replacer 1 served as the basal ration. Milk replacer 2, which contained 5% dried whey, was used to study the supplementary effect of whey in an all vegetable milk replacement. In milk replacer 3 the 5% dried whey was replaced by 3.5% lactose (c.p.)

Table 2

Composition of Milk Replacers

Ingredients	Milk replacer 1	2	3
	%	%	%
Fine ground corn	51.6	47.1	47.1
Soybean flour (52.4%)	33.0	32.5	34.0
Distillers dried solubles	10.0	10.0	10.0
Dried whey	--	5.0	--
Lactose	--	--	3.5
Steamed bonemeal	1.5	1.5	1.5
Calcium carbonate	.5	.5	.5
Salt	.5	.5	.5
Aureofac*	2.8	2.8	2.8
Vitamin and trace mineral**	.1	.1	.1
Total	100.0	100.0	100.0

* Contained 1.8 gm. Aureomycin and 1.8 mg. B_{12} per lb.

**Mixture contains:

Vitamin A concentrate 20,000 U.S.P. units/ gm.	20 gm.
Irradiated yeast, 9,000 I.U. Vitamin D/gm.	5 gm.
Cobaltous sulfate ($CoSO_4 \cdot 7H_2O$)	3 gm.
Cupric sulfate ($CuSO_4 \cdot 5H_2O$)	2 gm.
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	11 gm.

to determine whether the lactose in whey is one of the necessary factor(s). The protein content of the ration was adjusted by varying the amount of corn and soybean flour.

Feed grade aureomycin was added at a level calculated to supply 50 mg. of aureomycin per lb. of feed. The particular product used also supplied 50 mcg. of vitamin B_{12} activity per lb. of feed.

The milk replacers were mixed in 100 lb. lots. The micro ingredients were premixed, then mixed into a larger quantity before being added to the final mixture. The mixed feed was kept in 30-gallon metal containers to protect it from moisture and contamination.

Measurements of Feed Effects

Body weight. The calves were weighed at the beginning of the experiment, two separate days each week during the experiment and at the end of the experiment. All weighings were made at approximately the same time of day.

Health and post mortem. The calves were observed daily with particular note being made of hair coat, condition of feces and alertness of the calf. Three calves were taken to the clinic for post mortem studies after having completed the experiment. Gross inspections were made of the alimentary tract and vital organs. Blood cell counts and hemoglobin determinations were also made on the three calves.

Feed consumption and analysis of feed. Daily records of feed consumption by the individual calves were kept. The feeds were analyzed using the accepted A.O.A.C. (1950) procedures. The results of chemical analyses made on the three milk replacers are presented in Table 3.

Table 3

Chemical Analyses of Milk Replacers

Constituent	Milk replacer 1	2	3
Water (%)	8.11	8.59	8.38
Ash (%)	6.31	6.64	5.92
Crude fiber (%)	2.80	2.80	2.79
Ether extract (%)	5.08	5.07	4.94
Crude protein (%)	26.94	26.69	25.37
Nitrogen-free extract (%)	50.76	50.21	52.57
Calcium (%)	.874	.884	.788
Phosphorus (%)	.790	.804	.736
Copper (%)	.0054	.0035	.0050
Iron (%)	.0236	.0214	.0233
Potassium (%)	1.10	1.18	1.06
Magnesium (%)	.214	.219	.206
Manganese (%)	.0021	.0019	.0019
Cobalt (ppm)	4.27	3.89	3.73
Carotene (ppm)	4.4	4.0	4.6

RESULTS

The average whole milk consumption for the three groups of calves varied from 50.7 to 54.9 lb. for the experimental period (Table 4). The difference was due to refusal of one or more feeds by some calves. Most refusals occurred at the first few feeds following the addition of milk replacer to the liquid, although in general little or no difficulty was encountered.

Table 4

Growth and Feed Consumption Data of Calves to 60 Days of Age

Replacer	1	2	3
No. of calves used	7	7	7
No. of calves died	0	0	0
Weight			
Average initial (lb.)	91.4	93.9	93.6
Average daily gain (lb.)	0.87	0.92	0.87
Standard error of mean (lb.)	0.08	0.05	0.07
Feed consumption per calf			
Whole milk (lb.)	54.9	51.9	50.7
Milk replacer (lb.)	108.2	117.5	112.9
Milk replacer/lb. gain (lb.)	2.21	2.26	2.37

The consumption of milk replacer varied more within groups than between groups. There was no significant difference between the three groups in feed consumption and feed efficiency. However, it was noted that consumption of milk replacer in the dry form was low during the first 20 to 30 days of age. Until such time when feed consumption increased the weight gains were also very low.

Growth data are summarized in Table 4 and presented in detail in Appendix Table 1. The average daily weight gains of the calves on milk replacers 1, 2 and 3 were 0.87±.08, 0.92±.05 and 0.87±.07 lb., respectively. Although the average daily gain of the group receiving replacer 2, containing 5% dried whey, was greater than that of the other groups the difference was not statistically significant. The calves in the dried whey group also were the most uniform in weight gains.

Growth curves for the three groups of experimental calves and the USDA standard for Holstein calves (Matthews and Fohrman, 1954) are presented in Fig. I. The growth curves show that there is little difference between the three replacer groups in growth over the experimental period. In all three groups the period of rapid weight gain began between 20 and 30 days of age.

The calves fed replacer 2, containing 5% dried whey, had the more costive feces, smoother haircoat and more alert appearance. No differences could be detected between calves on the basal ration and the one containing 3.5% lactose.

None of the calves died while on experiment nor were any calves sick. Slight plaquing and hyperkeratosis were observed in the rumens of the calves upon post mortem examination. The blood cell counts and hemoglobin values were normal.

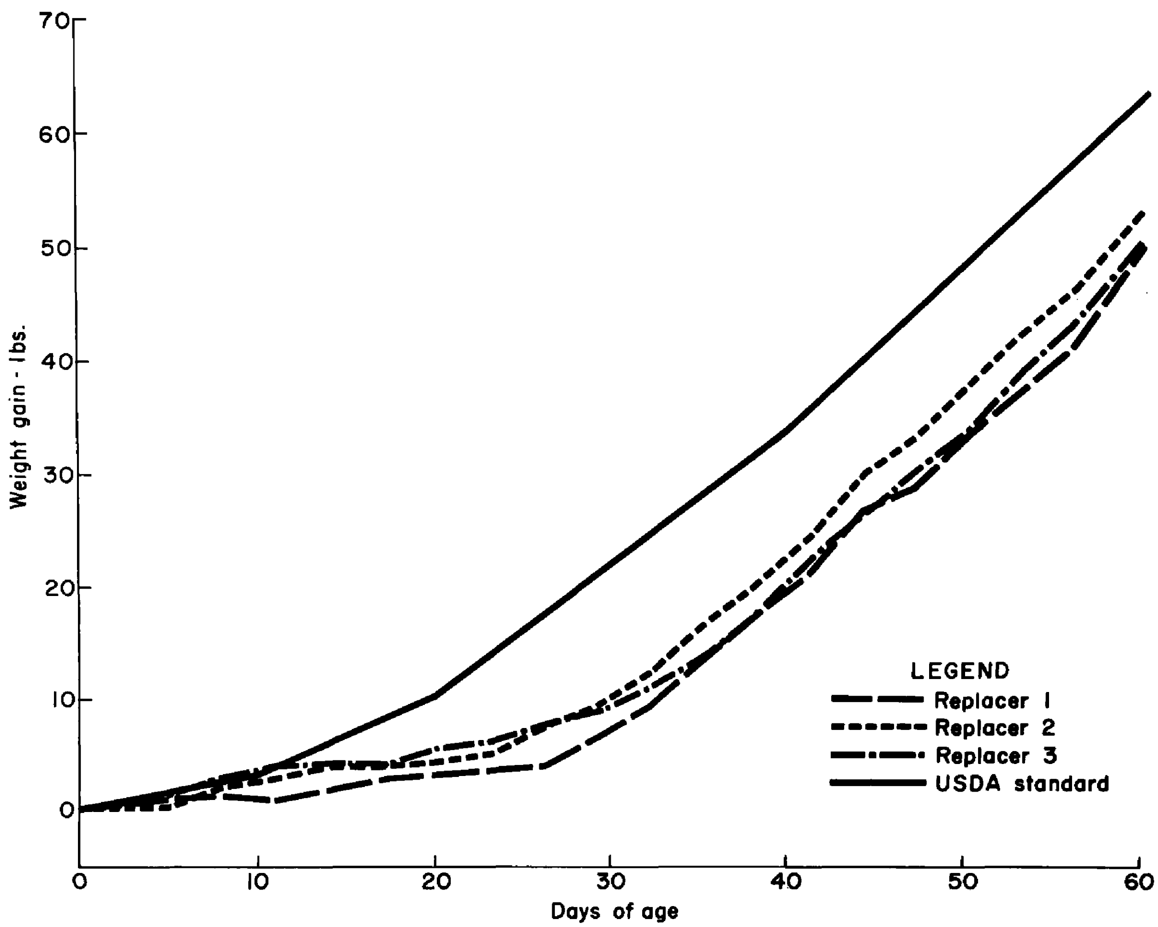


Fig. I. Growth curves

DISCUSSION

Inspection of the growth data in Table 4 shows that the least variation occurred in calves fed milk replacer 2, containing 5% dried whey. This is in agreement with previous work of Huffman et al. (1954).

An analysis of the growth curves in Fig. I indicates a difference in weight gains between the experimental calves and the USDA standard (Matthews and Fohrman, 1954) during the first 20 to 30 days of age. During this period the experimental calves gained an average of 8 to 10 lb. each compared to 22 lb. for calves on the USDA standard. Between 30 and 60 days the growth rates of the calves were equal.

The first 20 to 30 days of life is referred to as the "critical period". During this period the weight change of the experimental calves was negligible. This is in marked contrast with the continued increase in weight gains in the USDA standard. The standard was established with calves fed whole milk to 4 weeks of age followed by skimmilk to 6 months of age. In contrast, the experimental calves were fed a total of 50.7 to 54.9 lb. of whole milk each. The results indicate that the calves were unable to utilize the milk replacers satisfactorily during the first 30 days, although, after 30 days the growth curves of the calves fed replacers were parallel to that of the USDA standard. Similar results were reported by Stein et al. (1954) who obtained less growth when milk was replaced by milk replacers at 10 days of age.

The data indicate the necessity of feeding milk to prevent this period of little growth. However, Savage and Tailby (1911) and Krauss et al. (1935) reported that they could not distinguish between 2- or 3-year-old heifers which had been reared on large amounts of milk as compared to limited milk. This indicated that the critical period had a negligible effect as far as the mature animal was concerned provided a normal ration was fed after the experiment was completed.

The consumption of feed was closely related to the rate of growth. It was noted that during the first 20 to 30 days of age, when the growth rate was either nil or very low, replacer consumption was about one pound per day or less. The growth curves indicate that only enough milk replacer was consumed to satisfy the maintenance requirement of the calf. At approximately 25 days of age a rapid increase in feed consumption occurred and by 60 days of age the consumption was approximately 4 to 5 lb. per calf daily. The increase in feed consumption was also reflected by increased weight gain. The calves with the lowest average daily gains were those which did not increase their feed consumption until about 40 days of age. Although they were gaining weight rapidly at the end of the experiment the weight gains for the experimental period were less than the USDA standard.

At the same time that weight gains and feed consumption increased there was a marked change in the condition of the feces. Before the change occurred the odor and appearance of the feces were typical of a calf and afterwards more representative of those of a cow. This indicates that a physiological change may have occurred due to increased rumen function. It is postulated that the end of the critical period coincides with the beginning of rumen function as indicated by the change in odor of rumen contents (Kesler et al., 1951) and the decrease in blood sugar (Craine and Hansen, 1952; McCandless and Dye, 1950).

The most noticeable effects observed when dried whey was included in the ration were improved fecal condition, alertness and improved haircoat. It is possible that the effect of dried whey is mediated through the intestinal flora as evidenced by the improved condition of the feces.

In replacer 3, the 5% dried whey was replaced with 3.5% lactose to determine whether or not the lactose in whey was the factor producing the favorable effects. An inspection of the data indicates that 3.5% lactose in the vegetable milk replacer used in this study had no effect on weight gains or condition of the calf. Results with milk replacers 1 and 3 were similar in all respects. However, calves on both milk replacers 1 and 3 were less satisfactory than 2 in general appearance and condition of the feces. Although the feces of calves on milk replacer 1 and 3 were less costive than those of calves on milk replacer 2, there was no evidence of diarrhea as had been reported by Wallace et al. (1951) who used higher levels of lactose. The results in this experiment do not agree with those of Flipse et al. (1950) who reported a favorable effect with 5% lactose in a synthetic milk ration. The different results may be due to the types of rations fed.

The data indicate that a ration containing a special process soybean flour can produce satisfactory results in calf formulas. Although the method of processing used is not available it is probable that the availability of the protein was increased by a process similar to that proposed by Claudinin et al. (1948) which increases the availability of the amino acids, methionine and lysine.

The importance of processing was demonstrated by Noller and Huffman (1953) who found that calves reared on a milk replacer containing solvent extracted soybean oil meal had a longer critical period than calves reared on a milk replacer containing a special process soybean flour. The odor of the feces was less offensive after the critical period indicating that a change in the utilization of food had occurred. Carroll et al. (1952,1953) reported that in raw soybean meal the nitrogen passes farther down the intestinal tract before absorption than in the case of heated meal. The passage of the unabsorbed protein into the large intestine can result in "putrefaction" of protein. According to Schmidt (1907) this occurs exclusively in the large intestine. The absence of putrefaction would indicate absorption of the protein in the small intestine due either to an increase in the ability of the calf to utilize it or to a treatment which increased the availability of the soybean protein.

The milk replacers containing 10% distillers dried solubles produced better results than those reported by Huffman et al. (1954). However, in the present experiment the distillers solubles were a blend mixture compared to the single product used in the previous experiment. The milk replacers used in this study also differ from those used previously in type and amount of antibiotic. The rations used in the present investigation contained 50 mg. of aureomycin per pound of feed while the rations reported by Huffman et al. (1954) contained 10 mg. of bacitracin per pound of feed. The improvement in the present rations could be due to the effect of aureomycin. Knodt and Ross (1952) and Rusoff et al. (1951) reported increased growth with aureomycin in the diet.

The results of the blood cell counts and hemoglobin determinations indicate that the milk replacers contain sufficient blood forming constituents. Also, disease did not appear to be a factor as evidenced by normal differential white cell counts.

SUMMARY

Twenty-one Holstein calves were placed on three milk replacers--basal, basal with 5% dried whey and basal with 3.5% lactose. The calves were started on experiment at 3 days of age and taken off experiment at 60 days of age. The average whole milk consumption for the three groups of calves was 54.9, 51.9 and 50.7 lb., respectively, for the experimental period. Milk replacers were fed both as a gruel and <u>ad libitum</u> in dry form. No hay was fed during the experiment.

The average daily gains of the calves on the basal, whey and lactose rations were $0.87 \pm .08$, $0.92 \pm .05$ and $0.87 \pm .07$ lb., respectively. The differences were not statistically significant.

Growth patterns indicated the existence of a critical period in the life of the young calf from birth to approximately 25 days of age. The end of the critical period was characterized by increased growth, increased feed consumption and improved appearance of the calf.

Calves receiving the whey ration had the more costive feces, smoother haircoat and were more alert. The use of lactose appeared to have no benefit under the conditions of this experiment.

PART II

DIGESTIBILITY AND BALANCE STUDIES WITH MILK AND MILK REPLACERS

REVIEW OF LITERATURE

The Nutritive Value of Milk

Effect of processing. Among the many methods of food processing, heat has been widely employed. Food treated in this way must retain its palatability as well as most of its nutrients. It is generally known that the denaturation temperature varies with different proteins and the rate of denaturation increases with increase in temperature.

The effect of heat on the nutritive value and digestibility of various milks has been studied by a number of investigators. Among these were McCollum and Davis (1915) who observed a decrease in the nutritive value of protein when autoclaved milk was fed to rats. Whole and evaporated milk were compared by Nevens and Shaw (1932) in a paired feeding experiment with albino rats. The mean of 47 coefficients of protein digestibility for whole milk was 92.3 and the mean of 45 coefficients for evaporated milk was 88.4. A year later the same authors (1933a) were unable to find a significant difference in the apparent protein digestibility of two kinds of powdered milk but a significantly higher value was obtained for fresh whole milk. Fairbanks and Mitchell (1935) found that preheating in the spray-drying process lowered the biological value of the protein about 8%, although the digestibility of the milk protein was not significantly affected. Raising the temperature to scorching decreased the biological value further and lowered the digestibility at a rate which increased with the degree of scorching.

Henry and Kon (1938) used pairs of littermate female rats starting at 24 to 25 days of age to determine the biological value and true digestibility of raw and commercially sterilized milk. The biological values of raw and sterilized milk proteins were 84.3 and 79.1, respectively. The true digestibility of the proteins was 96.4 and 95.3%, respectively. When Anderson et al. (1940) fed raw milk to dogs they grew well and had normal reproductive functions. Poor results were observed with both pasteurized and evaporated milk. In an experiment with kids, Catel (1932) reported improved growth and utilization of fat, protein and carbohydrate with raw goat milk as compared to pasteurized goat milk. Cook et al. (1951b) observed that sterilization of milk decreased the growth of rats. They concluded that the degree of decrease in protein efficiency of the milk was in proportion to the severity of heat treatment and holding time.

Although some investigators reported decreases in the nutritive value of milk due to heat others were unable to substantiate these decreases. In an experiment with rats, Henry et al. (1939) were unable to demonstrate a significant difference in the biological value of the protein in spray dried, roller dried and evaporated milk. However, in this experiment, the evaporated milk was significantly less digestible than the spray-dried milk. A comparison of the nutritive value of unheated and autoclaved skimmilk in dogs and rats by Kraft and Morgan (1951) indicated that autoclaving had no effect on nitrogen retention in dogs, but in weanling rats the milk lost one-half to two-thirds of its growth efficiency. This dissimilarity in species is not in agreement with Schroeder et al. (1953) who state that the conflicting claims regarding the deleterious effect of heat cannot be attributed to the difference in species of experimental animals used. Rather, the variation in nutritive value of the milk is due to both the intensity and duration of heating.

Henry et al. (1937) could demonstrate no difference in the biological value and true digestibility between the proteins of raw and pasteurized milk. Hodson (1952), using the rat repletion method of protein evaluation, concluded that sterilization of evaporated milk did not affect the nutritive value of the protein. Whitnah (1943), using rats, and Schroeder et al. (1953), using dogs, also could find no nutritional difference between evaporated and fresh raw milk.

Since it was noted that heat may affect the nutritive value and digestibility of milk protein, the next step was to determine the mode of its action on the milk protein. Hodson (1954) suggested that for rat growth the amino acid deficiencies in evaporated milk proteins involved primarily the sulfur-containing amino acids. The effect on biological value of supplementing heat treated milk proteins with cystine and methionine was studied by Henry and Kon (1953). They found that the addition of 0.2% cystine increased the biological value of the milk proteins 5%, further addition of 0.4% DL-methionine increased the biological value another 5%. Methionine alone had the same effect as a combination of methionine and cystine.

Numerous investigators have studied the mode of action of heat on milk proteins. Block and Mitchell (1946) suggested that heating casein formed a peptide linkage between the epsilon-amino group of lysine and the free carboxyl group of one of the dicarboxylic amino acids. This complex was resistant to enzymatic digestion. Pader _et al._ (1948) showed that overheating of casein decreased the rate of lysine liberation. They indicated that the lysine may have been bound to other amino acids by a linkage which was unavailable to enzymes. The slow liberation indicated that the low biological value of lysine was not due to destruction but only to rate of availability. In experiments on the effect of heat treatment of milk, Cook _et al._ (1951a) found a significant decrease in protein efficiency of lactalbumin for rat growth when lactose was contained in the heat treated sample. In the absence of lactose the heat treatment had no effect. They observed no browning in heated lactose-free samples but a deep caramel color in samples containing lactose.

Significant changes in the nitrogen distribution of sterilized milk were reported by Menefee _et al._ (1941) and Shahani and Sommer (1951). These changes occurred as a result of the coagulation of albumin and globulin which freed the amino groups. The free amino groups were then capable of combining with sugar to form a protein-sugar complex. The formation of the protein-sugar complex was followed by Henry _et al._ (1948) using the Van Slyke method for free amino nitrogen. In their experiments they could account for the loss of one molecule of lactose for each free amino group destroyed.

Maillard (1912) first pointed out a reaction between the amino group of the amino acid and the carbonyl group of a sugar. Hill and Patton (1947) and Patton and Hill (1948) demonstrated that the deleterious effect of heat processing on the nutritive value of milk proteins may be due to the Maillard reaction. Henry _et al._ (1948) attributed much of the reduction in biological value of protein to the combination of lysine with lactose. When McInroy et al. (1949) autoclaved casein in the presence of dextrose, the casein did not support the growth of weanling albino rats. Similar treatment in the absence of dextrose had only a slight effect on the growth-promoting ability of casein. Schroeder et al. (1951) observed a decrease in nutritive efficiency of protein by 66 to 77% relative to the unheated protein when it was autoclaved in the presence of equimolar concentrations of lactose, maltose, xylose, or fructose.

Shipstead and Tarassuk (1953) reported that browning was unlikely if the moisture content of milk was below 4% and the storage temperature was low. The effect of browning and its associated changes in milk has been reviewed by Patton (1955).

Certain vitamins are known to be heat labile. The use of heat in milk processing would be expected to lower the vitamin content of the processed milk. Kon (1938) reported a marked decrease in the ascorbic acid content of milk by commercial sterilization. Sterilization of milk also caused a 30% destruction of the thiamine in the milk. The destruction of vitamin A and carotene by sterilization of milk was negligible (Gillam et al., 1938). The heat lability of pyridoxine in milk was determined by Tomarelli et al. (1955) using a microbiological assay and rat growth procedure. Heat destroyed much of the vitamin and decreased the biological response to the remaining vitamin.

Effect of storage. The effect of storage on the nutritive value of dried skimmilk was investigated by Henry and Kon (1945). They observed that prolonged storage decreased the biological value but had no effect on the true digestibility. The biological value of spray-dried skimmilk decreased from 88.5 at 18 months after manufacture to 71.1 some 36 months later (Henry et al., 1946).

Marked losses of arginine, histidine, lysine and methionine in discolored dried skimmilk samples were observed by Hodson and Krueger (1947). Samples which retained their white color lost only minor amounts of the amino acids. Henry and Kon (1948) attributed the decrease in nutritive value of dried skimmilk to the presence of moisture. They observed that on the addition of lysine to the experimental milk sample the biological value of the protein was equal to that of the control sample.

The storage of evaporated milk for 16 months at room temperature had no effect on the nutritive value of the protein (Hodson, 1952). However, storage for 5 years resulted in considerable loss of the nutritive value of the protein. Schroeder et al. (1953) reported that the digestibility and biological value of the milk proteins were not affected when milk was kept in frozen storage for 5 months.

The losses of seventeen amino acids in evaporated milk stored for long periods were studied by Hodson (1960). During 5 years of storage the milk lost 17% of the lysine, 17% of the histidine and 11% of the arginine. During the first 15 to 17 months the losses of the three amino acids were less than 4%. Webb et al. (1951) found that storage of evaporated milk for 2 years at 38°C. caused the following losses: tryptophane, 12%; lysine, 29%; histidine, 29%; and arginine, 28%. The use of this milk in rat growth experiments yielded substantiating results.

The Value of Milk and Vegetable Feedstuffs

It is generally known that the young calf cannot satisfactorily utilize certain types of feeds such as roughages before rumen function commences. From their studies with calves fed either dried skimmilk protein, casein or gelatin as the sole source of protein in the diet Blaxter and Wood (1952b) concluded that the young calf is dependent on its diet for its supply of essential amino acids.

Milk, a food especially designed by nature for the young mammal, is almost completely digested. Nevens and Shaw (1933b) demonstrated that the milk sugar of whole fresh milk was completely digested by rats, the fat about 99% and the protein about 91%. Murley et al. (1952) obtained digestibility coefficients of 95.4 for dry matter and 98.4 for carbohydrates in calves between the ages of 16 and 60 days. This again demonstrates the high degree of digestibility of milk by the young calf.

Some of the digestibility coefficients of milk obtained with calves, swine and rats are presented in Table 5. The data demonstrate the high degree of digestibility for milk and the uniformity between the three species in their ability to digest the various constituents of milk. An inspection of the table shows an approximate apparent digestibility for dry matter of 96%; crude protein, 94%; ether extract, 98%, excluding the low value for skimmilk; and 99% for the nitrogen-free extract.

Honcamp et al. (1932) have suggested that the nitrogen-containing substances in the milk condition its feeding value. About 90% of the milk protein was digested by ruminants and as much as 98% by swine. The nitrogen-free extract also was highly digested.

Table 5

Apparent Digestibility of Milk

Feedstuff	Animal	DM	CP	EE	NFE	Reference
		%	%	%	%	
Skimmilk	calves	98.3	95.2	99.7	100.0	Fingerling (1908)
Whole milk, cow's partly skimmed	$7\frac{1}{2}$-8 mo. calves	95.6	95.2	98.7	100.0	Hughes and Cave (1931)
Whole milk, cow's	5-14 day old calves	96.5	93.8	95.6	--	Blaxter and Wood (1952a)
Skimmilk	calves	98.0	96.0	38.0	100.0	Schneider (1947)
Whole milk, cow's	calves	--	93.3	--	--	Blackwood et al. (1936)
Whole milk, cow's	calves	--	94.3	--	--	Tomme and Taranenko (1939)
Colostrum and whole milk	1-17 day old calves	94.2	88.5	96.5	97.0	Parrish et al. (1953)
Whole milk, cow's, raw	pigs	95.0	95.7	95.8	97.3	Wellman (1914)
Whole milk, homogenized	pigs	97.3	97.7	97.4	97.0	Wellman (1914)
"Diafarin" skimmilk	pigs	95.5	94.3	88.6	98.4	Wellman (1914)
Whole milk, cow's, raw	rats	94.7	92.3	99.0	--	Nevens and Shaw (1932)
Whole milk, cow's evaporated	rats	93.2	88.4	99.0	--	Nevens and Shaw (1932)

Table 6

Apparent Digestibility of Various Feeds

Feedstuff	Animal	DM	CP	EE	CF	NFE	Reference
		%	%	%	%	%	
Corn grain, dif.	cattle	90.6	71.1	66.9	--	95.9	Forbes _et al._ (1931)
Corn grain, dif.	cattle	84.0	63.0	83.0	13.0	88.0	Schneider (1947)
Corn grain	cattle	83.7	64.0	80.0	--	90.8	Beach (1906)
Corn grain	cattle	87.0	75.0	87.0	19.0	91.0	Schneider (1947)
Corn grain	swine	--	93.2	64.0	68.8	93.0	Forbes _et al._ (1914)
Corn grain	swine	86.2	74.0	64.9	38.8	91.5	Grindley _et al._ (1917)
Soybean oil meal, expeller, dif.	cattle	86.8	88.3	88.0	111.0	83.8	Watson _et al._ (1936)
Soybean oil meal, solvent	cattle	85.6	90.2	-15.2	45.9	92.4	Forbes _et al._ (1940)
Soybean oil meal, hydraulic	cattle	84.4	88.7	79.5	12.1	91.7	Forbes _et al._ (1940)
Soybean oil meal, expeller	cattle	86.6	89.4	66.8	71.5	91.7	Forbes _et al._ (1940)
Soybean oil meal	sheep	88.6	95.1	70.3	64.2	91.0	Malkomesuis and Schramm (1930)
Soybean oil meal	sheep	86.8	83.9	87.3	--	98.1	Hamilton _et al._ (1928)
Soybean oil meal	swine	90.5	94.0	--	60.5	92.4	Kellner and Neumann (1910)

Table 6 (continued)

Feedstuff	Animal	DM	CP	EE	CF	NFE	Reference
		%	%	%	%	%	
Soybean oil meal	swine	--	91.7	53.0	100.0	85.5	Fingerling and Honcamp (1934)
Soybean oil meal	swine	--	88.7	100.0	61.2	94.0	Fingerling and Honcamp (1934)
Distillers dried solubles, corn and rye	cattle	73.0	74.3	64.4	62.5	88.4	Huffman _et al._ (1951)
Distillers dried solubles, corn	cattle	88.7	83.1	79.0	86.1	93.5	Huffman _et al._ (1951)
Distillers dried solubles	swine	83.0	60.0	-690.0	68.0	93.0	Mangold _et al._ (1947)
Calf meal, raw	9 wk.old calves	71.6	78.2	95.1	--	71.3	Archibald (1928)
Calf meal, cooked	9 wk.old calves	74.6	74.1	94.7	--	75.7	Archibald (1928)

A cross section of digestibility coefficients obtained for various concentrates with cattle, sheep and swine is presented in Table 6. Due to a paucity of values for calves it is impossible to make a direct comparison. The results of a digestion trial by Archibald (1928) with 9-month-old calves fed calf meals are presented in Table 6. The coefficients for the calf meals were lower than those obtained on the other feeds using older cattle, sheep or swine with the exception of the ether extract which was more digestible in the calf meal.

The use of filled milks in digestibility trials with calves was reported by DeMan (1951). He found that soybean oil, hydrogenated soybean oil and whole milk fat were 67, 75 and 96% digested. Again it demonstrates the higher digestibility of milk fat in comparison to vegetable fat. A beneficial effect was also noted by Jacobson et al. (1949) and Jarvis and Waugh (1949) when hydrogenated soybean oil was fed to calves in the place of regular soybean oil

An investigation of the utilization of nitrogen from pea-, rye-, and soya-flours and milk by the rat, pig, dog and rabbit was conducted by Lelu (1934). The results obtained with milk on the rabbit were variable; by the pig, dog and rat it was 96% utilized. The utilization of the flours was highest by the pig (90-96); intermediate by the dog (71-81), and lowest by the rat (66-77). Bondi and Birk (1952) reported that the addition of trichloracetic acid to pancreatic digests of plant protein feeds resulted in the formation of considerable precipitate. This did not occur with animal protein feeds.

Garrigus and Mitchell (1935) studied the effect on digestibility of grinding corn for pigs. Their results indicated a 13% increase in protein digestibility due to grinding. Heupke and Marx (1928) observed that the cells of the nut had to be destroyed or mechanically ruptured before fat was digested in the small intestine of mice. A similar result was also observed in man.

Carpenter (1951) concluded from his summary of rat data that the animal proteins were nutritionally superior to the vegetable proteins. He found that soybean oil meal was the only vegetable protein within the range of the animal proteins. Desikackar et al. (1946) reported that the biological value of cow's milk and soya milk was the same for the adult rat. The animal and vegetable feeds have the same general biological value for the ruminant (McNaught and Smith, 1947).

The effect of level of feeding on the digestibility and biological value of a feed was studied by Mitchell et al. (1932). They found that the lowest level of feeding used in a steer was associated with the most complete digestibility of all nutrients.

Digestion in the Young Calf

When the calf is born the milk it consumes passes directly into the omasum and abomasum via the esophageal groove. As the calf becomes older the use of the esophageal groove diminishes. The function of the esophageal groove in the young calf and adult animal was studied by Schalk and Amadon (1928). They reported that, during drinking, the water spurts from the cardia and is deposited in the front of the rumen and is later transferred to other parts of the rumen. They observed that water does not follow the esophageal groove into the omasum and abomasum and concluded that the esophageal groove functions only in the nursing calf.

Trautmann and Schmitt (1933) studied the passage of milk into the stomach in young goats fed a diet of milk and water. Swallowing was necessary for entrance of liquids into the esophageal groove. They also observed that the goat lost its ability to use the esophageal groove after weaning and the start of roughage consumption. Wise et al. (1942) reported that elevation of the neck was not a significant factor in promoting milk passage through the esophageal groove.

Espe and Cannon (1937) established that the psychic phase of gastric secretion was absent or of minor importance in calves. The changes produced in consumed milk prior to its entrance into the stomach of the calf were studied by Wise et al. (1940) using "sham feeding". They found an increase in rate of rennet coagulation, curd tension, hydrogen-ion concentration, lipolytic activity and cream volume.

The effect of curd tension on the digestibility of milk was studied by Espe and Dye (1932). In an adult dog, milk of low curd tension left the stomach in 1.7 to 1.8 hr. and a milk with a high curd tension took 2.3 to 2.8 hr. In a calf it took 4.0 hr. for milk with a low curd tension to leave the stomach as compared to 6.0 hr. for high curd tension milk. Doubling the curd tension of the milk increased the digestive period 30 to 65%. According to Espe and Cannon (1935) milk containing up to 6% fat tended to leave the stomach faster than skimmilk. Mortenson et al. (1935) reported that boiled milk left the abomasum of a calf faster than raw milk.

The inability of the young calf to utilize starch was demonstrated by Shaw et al. (1918). Calves at 4 to 7 days of age were able to digest only one-fifth of the starch consumed. At 3 to 4 weeks of age the calves were able to digest well over 90% of the starch in the ration. It seems that the meager ability of the calf to utilize starch at 4 to 7 days of age may be attributed to a shortage of starch-splitting enzymes. The increased efficiency of starch digestion at 3 to 4 weeks of age might be attributed to enzymes other than those in saliva. Dukes (1947) reported that the saliva of cattle does not contain an amylase.

The inability of the calf to utilize starch has stimulated the use of malt, containing the enzyme diastase, to help the calf digest the starch. Kellner (1926) credited Leibig with using wheat flour treated with malt in feeding calves. Kellner also described calf rations using malt. Hittcher (1909) reported the use of starch treated with malt to replace the butterfat in calf feeding. He used 7-day-old calves which were kept on experiment for 15 weeks. Although 15% of the calves died while on experiment he reported that calves fed starch treated with malt were slightly better the first 4 weeks of the experiment. Remer (1932) reported calf rearing experiments with dried potatoes supplemented with distillery malt. He observed no detrimental effects when feeding was commenced the first week and gradually increased to 400 gm. per head daily.

Minz and Schilf (1932) conducted experiments with rats fed by stomach tube and killed after one hour. The nature of the clot and degree of digestion were determined. They noted finer milk curd and a greater degree of digestion when malt preparations and extract of dried malt were fed to rats than when no malt was fed.

Pancreatin and papain concentrates have also been used in attempts to aid the calf in digesting feed. Conquest *et al.* (1938) produced an enzyme-treated milk which did not stay in the stomach as long as untreated milk. The calves were fed colored milk, killed after 7 hours and the amount of curd remaining in the stomach was determined. The calves fed normal milk retained 23% more curd in the stomach than calves receiving treated milk. Also the curd tension of the untreated milk was twice that of the enzyme-treated curd. The use of papain and pancreatin powder in calf replacement feeds was reported by Williams and Knodt (1951). The addition of papain or pancreatin powder resulted in poor growth and low feed consumption. Post-mortem examination of the two fatalities which occurred indicated dehydration and intestinal degeneration.

A study of the fat content of the feces of 14 calves was made by Howe (1921). During the first three days of life a readjustment in the metabolic activities of the calf was noted. He reported fairly complete digestion of the fat but a failure in absorption. He also found that the percentage of neutral fat decreased and the free fatty acids increased during the first week of life.

Nitrogen Metabolism

The quality of the protein in the diet of the young calf is very important before the rumen becomes functionally developed. Although the nitrogen in the ration may be adequate, the amount of food protein required depends on the amino acid composition of the protein and the relative availability of the amino acids. As the rumen develops, the quality of food protein required decreases due to synthesis of high quality protein by the rumen microorganisms.

The effect of a nitrogen-free diet on the digestibility of the various nutrients by calves was studied by Blaxter and Wood (1951a).

They found that as the digestibility coefficients of the dry matter decreased from 94.0 to 77.0 those of the dietary fat decreased from 91.7 to 44.9. The endogenous urinary nitrogen, which represented the minimum requirement for maintenance of nitrogen equilibrium, was 81.9 mg. per kg. body weight per day. It was noted that the output of urea plus ammonia decreased on a nitrogen-free diet. Later Blaxter and Wood (1951b) demonstrated that the metabolism of a calf on a starvation diet differed from that of a calf on a nitrogen-free diet. The effect of a sparing action by the nitrogen diet was shown by the increased urea plus ammonia excretion of calves on the starvation regime where the loss of urinary nitrogen was 250 mg. per kg. body weight. The authors pointed out that this was much greater than the value of 152 mg. in sheep (Morris and Ray, 1939), 162 mg. in the goat (Morris and Ray, 1939) and 90 mg. in the cow (Hutchinson and Morris, 1936; Morris and Ray, 1939).

In another experiment Blaxter and Wood (1951c) observed that urinary nitrogen increased at a constant rate with increasing intake of apparently digested nitrogen. This was irrespective of the amount of protein in the diet. The feeding of a lower level of protein increased the biological value of the protein. The decrease in biological value with the higher intakes of protein was attributed to the use of the protein for energy with the result that less nitrogen was retained in the tissues. At comparable intakes of energy the storage of nitrogen was greater for the diet high in protein. In a study of the value of cow's milk Blaxter and Wood (1952a) observed that body weight gain and nitrogen storage were linearly related to the intake of milk. The excretion of urinary nitrogen did not change with milk intake. The biological value increased with increased intake even at the higher levels. The calf with the higher basal metabolism stored about 40 percent less nitrogen. The increased loss of nitrogen could be accounted for by the increased excretion of urea-, ammonia- and amino-nitrogen. Blaxter and Wood (1952b) also conducted experiments with 4 calves given dried skimmilk, casein or gelatin as the sole source of protein. The calves were in positive nitrogen balance with the dried skimmilk and casein and in negative balance with the gelatin. The nitrogen balance was correlated with body weight changes. The biological value was 92.3 for dried skimmilk, 78.8 for casein and 29.5 for gelatin. These results were comparable to the biological value in the calf, rat and man when the skimmilk was taken as 100.

Carr _et al_. (1917) studied the effect of 5 different rations on the nitrogen retention of calves. They found that skimmilk gave the best results while a vegetable meal and vegetable-dried blood meal produced the poorest results.

Lofgreen _et al_. (1951) in their studies with calves observed an increase in biological value when the energy content of the ration was increased by the addition of non-nitrogenous feeds. Forbes and Yoke (1955) studied the effect of energy intake on biological value of the protein fed to rats. They observed that low levels of food intake depressed the biological value of the protein due to the increased use of the dietary protein for energy. The effect of energy intake on protein utilization has been studied in man (Werner, 1948), the mouse (Bosshardt _et al_., 1946), the rat (Barnes and Bosshardt, 1946) and the dog (Allison _et al_., 1946).

The field of carbohydrates and fats as they influenced protein utilization and metabolism in animals and man, was surveyed by Munro (1951).

He presented evidence that carbohydrates played a role in promoting utilization of dietary protein and also that nitrogen balance was affected by energy intake. He indicated that the feeding of carbohydrates to fasting animals reduced nitrogen output, but the feeding of fats had no effect until the fat stores were exhausted. Sunde (1955) fed diets containing 20 and 28% protein to chicks. The 20% protein diet produced the best results. Addition of 5 to 10% fat to the 28% protein diet produced comparable results. The author suggested that high levels of protein are detrimental to the chick unless accompanied by high levels of energy.

A value for metabolic nitrogen excretion of 0.45 gm. per 100 gm. dry matter intake was obtained by Hutchinson and Morris (1936). This value was obtained in experiments performed on goats, sheep and cows using a low nitrogen diet. Blaxter and Wood (1951a) obtained a value of 0.43 gm. which is in close agreement with Hutchinson and Morris (1936). A much lower value was reported by Lofgreen and Kleiber (1953) who arrived at a figure of 0.27 gm. per 100 gm. dry matter intake. They claim that their value is valid because it was determined under conditions of normal intake of protein and total energy.

From a study on the effect of fiber on the utilization of dietary protein by rats Rutherford and Crampton (1955) concluded that the source as well as the amount of fiber influenced the apparent digestibility of protein.

Calcium and Phosphorus Metabolism

The importance of calcium and phosphorus for the young growing calf is indicated by the fact that about 70% of the body ash consists of these two elements. Approximately 99% of the calcium and 80% of the phosphorus in the body are present in the bones and teeth.

Blaxter and Wood (1952a) determined that the storage of calcium and phosphorus in the young calf was linearly related to the amount of milk ingested. At an intake of 2.5 times maintenance 92% of the milk calcium and 80% of the milk phosphorus were retained in the tissues. Archibald and Bennett (1935) found that the retention of phosphorus was greater when dairy heifers had an intake of 3.25 gm. than on 1.8 gm. per 100 lb. body weight. According to Huffman et al. (1933) 10 to 21 gm. of phosphorus daily met the requirements of cattle from 18 months to first calving. They also indicated that 6 to 12 gm. calcium daily met the calcium requirement of a calf from birth to 2 years of age. Ellenberger et al. (1951) slaughtered 16 calves at 90 days of age which had gained 139.6 lb. from birth to time of slaughter. The calves ate an average of 6.63 gm. calcium and 5.71 gm. of phosphorus per 100 lb. body weight daily. They utilized 47.8% of the calcium and 36.9% of the phosphorus. The calcium and phosphorus content of their bodies were normal. Assuming 50% utilization, the authors suggested a minimum allowance of 6.32 gm. calcium and 4.20 gm. phosphorus per 100 lb. body weight daily. The National Research Council (1950) recommended 8 gm. calcium and 6 gm. phosphorus daily for a 100 lb. growing calf. Converse (1954) determined the calcium requirement as being 7.7 to 7.2 gm. daily from birth to 6 months of age for 4 Holstein and 4 Jersey calves, respectively. He reported that this amount of calcium was adequate for growth but not for gestation. It may have been affected by the abnormally small amount of hay fed.

The calcium maintenance requirement of the bovine was determined by Hansard (1954) using radioactive calcium. He determined that the maintenance requirement per 100 lb. body weight for calcium increased from 0.5 gm. at 10 days of age to 2 gm. at 6 months of age. From 6 months of age to maturity it remained relatively constant.

Blackwood *et al.* (1936) working with calves and Lasby and Palmer (1935) with rats concluded that there was no difference in calcium and phosphorus retention between rations of raw and pasteurized milk. Willard and Blunt (1927) in experiments with children observed more favorable results with evaporated than pasteurized milk.

Causeret (1953) noted decreased calcium retention with increased water consumption. Fat intake apparently has no effect on calcium retention (Fuqua and Patton, 1953). Lactose appears to increase calcium retention in the rat (Outhouse *et al.*, 1935; Fournier, 1954) and glucose has no effect (Schreier and Mechtold, 1952).

EXPERIMENTAL PROCEDURE

Experimental Design

Three experiments were conducted in this investigation. A 4 x 4 Latin square consisting of 4 animals, 4 periods and 4 treatments was used in experiments 1 and 3. The design of experiments 1 and 3 and the ages of the calves at the time of each fecal and urine collection are shown in Tables 7 and 8. In experiment 1, 5-day preliminary periods and 2-day collection periods were used. In experiment 3, the preliminary periods consisted of 4 days and the collection periods 4 days. Experiment 2 consisted of two calves on continuous 2-day collection periods. The 2-day values were combined into 4-day periods on the basis of calf age. The calf on raw whole milk was placed on experiment at 8 days of age but developed diarrhea and had to be removed from the experiment temporarily at 10 days of age. It was placed on experiment again at 14 days of age but at 26 days it again had to be removed due to diarrhea. The calf fed evaporated milk was placed on experiment at 10 days of age and taken off experiment at 32 days of age.

Selection and Assignment of Calves

Ten male calves were used in the three experiments. The 4 calves in experiment 1 consisted of two Holsteins, one Guernsey and one Ayrshire. In experiments 2 and 3 only Holstein calves were used. The calves were obtained from the university herd and local farmers when 2 to 4 days of age and assigned to the experiment randomly. A calf which was sick or refused to eat was removed from the experiment and the next calf substituted in its place. Any data collected on calves taken off experiment were discarded.

Feeding and Management

The calves were placed in individual pens on heavy metal screens to prevent the ingestion of bedding. They were not allowed access to roughage. Due to the absence of bedding the pens were heated with overhead heat lamps. Whole milk feeding with open pails at the rate of 4 lb. twice daily was initiated as soon as the calves would drink. On the sixth day of age the calves were placed on the experimental rations for the first period. The first fecal and urine collection period for each calf commenced on the tenth day of age.

The composition of the various rations fed is presented in Table 9. It should be noted that during periods when a replacer was fed, 2 lb. of evaporated milk was replaced by 0.5 lb. of replacer. The calves were fed at the same time each morning and evening throughout the experiment. In experiment 3, calf C-925 was fed less than the usual amount during the first period to insure complete consumption of the ration. In the same experiment the amount of feed fed calf C-923 was increased during the fourth period due to the poor condition of the calf. Calves with diarrhea were removed from the experiment.

Table 7

Experimental Design of Experiment 1
Showing the Age of Calves and Rations Fed

Period	Age in Days	Calf C-899	C-900	C-902	C-906
1	10-12	Evap.	Repl.* 5	Repl. 6	Repl. 4
2	17-19	Repl. 5	Repl. 4	Evap.	Repl. 6
3	24-26	Repl. 6	Evap.	Repl. 4	Repl. 5
4	31-33	Repl. 4	Repl. 6	Repl. 5	Evap.

*Repl.--milk replacer.

Table 8

Experimental Design of Experiment 3
Showing the Age of Calves and Rations Fed

Period	Age in days	Calf C-922	C-923	C-925	C-926
1	10-14	W.M.	Repl.* 7	Evap.	Repl. 8
2	18-22	Repl. 7	Repl. 8	W.M.	Evap.
3	26-30	Evap.	W.M.	Repl. 8	Repl. 7
4	34-38	Repl. 8	Evap.	Repl. 7	W.M.

*Repl.--milk replacer.

Table 9

Composition of Daily Rations

Ration	Ingredient: Whole Milk	Evaporated Milk	Water	Milk Replacer
	lb.	lb.	lb.	lb.
Whole milk	8	--	--	--
Evaporated milk	--	4	4	--
Milk replacer	--	2	6	0.5

Table 10

Composition of Milk Replacers
Used in Experiments 1 and 3

Ingredients	Milk Replacer 4	5	6	7	8
Ground corn	57.2	53.2	44.2	57.4	53.4
Soybean flour (52.4%)	40.0	34.0	38.0	40.0	34.0
Distillers dried solubles	--	10.0	--	--	10.0
Rolled oats	--	--	15.0	--	--
Steamed bonemeal	1.5	1.5	1.5	1.5	1.5
Calcium carbonate	0.5	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Baciferm -- 5*	0.2	0.2	0.2	--	--
Vitamin and trace mineral**	0.1	0.1	0.1	0.1	0.1
Total	100.0	100.0	100.0	100.0	100.0

* Contained 5 gm. bacitracin per lb.

**Mixture contained:

Vitamin A concentrate 20,000 U.S.P. units/gm.	20 gm.
Irradiated yeast, 9,000 I.U. Vitamin D/gm.	5 gm.
Cobaltous sulfate ($CoSO_4 \cdot 7H_2O$)	3 gm.
Cupric sulfate ($CuSO_4 \cdot 5H_2O$)	2 gm.
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	11 gm.

Table 11

Chemical Analyses of Feeds
Used in Experiments 1 and 3

Feed	DM	Ash	CF	EE	CP	NFE	Ca	P
	%	%	%	%	%	%	%	%
Replacer 4	89.45	5.20	2.09	4.28	25.50	52.37	.743	.674
Replacer 5	88.54	5.35	2.21	4.30	24.28	52.19	.706	.667
Replacer 6	89.67	5.41	1.97	4.77	26.20	51.32	.747	.693
Replacer 7	87.81	5.21	2.00	4.28	24.31	52.02	.721	.651
Replacer 8	87.01	5.69	2.04	4.92	23.75	50.61	.882	.746
Whole milk, Period 1	11.84	.67	--	3.60	3.26	4.31	.123	.096
Whole milk, Period 2	11.67	.64	--	3.40	3.25	4.38	.123	.096
Whole milk, Period 3	11.40	.64	--	3.50	3.05	4.21	.123	.096
Whole milk, Period 4	11.73	.60	--	3.40	3.27	4.46	.123	.096
Evap. milk Lot 1	26.25	1.51	--	9.96	6.08	8.70	.238	.188
Evap. milk Lot 2	25.82	1.49	--	7.78	6.28	10.27	.238	.188
Evap. milk Lot 3	25.19	1.44	--	7.89	7.12	8.74	.238	.188

Formulation of Milk Replacers

The composition of the milk replacers used in experiments 1 and 3 is presented in Table 10. Milk replacers 4 and 5 are comparable to milk replacer 7 and 8, respectively, with the exceptions of the type of distillers dried solubles used and the use of antibiotic in experiment

1 but not in experiment 3. The protein content was adjusted by varying the amounts of ground corn and soybean flour.

To facilitate the use of milk replacers as gruels, the corn, distillers dried solubles and rolled oats were finely ground. The trace ingredients were premixed before being added to the final mixture. The mixed feeds were stored in metal containers to prevent contamination.

The chemical analyses of the feeds used are presented in Table 11.

Collection of Feces and Urine

Feces were collected using 8 x 3 x 15 inch pliofilm bags (Safelon, product of Safeway Products Division, Yorkville Paper Co., Inc., New York) (Emery, 1951). The bags were prepared with cellulose tape as shown in Fig. II. The long strips of cellulose tape were placed on first then crossed by smaller pieces to prevent tearing when the long tapes were cut to form the flap. Care was taken not to cut the cross tapes. After the bag was taped and cut as indicated in Fig. I and II the tail opening was made by cutting a square hole, the approximate size of the tail, and reinforcing with cellulose tape (Fig. III).

The calves were prepared by clipping the entire area back of the hip bones and flank down to the hook. The undersides of the calves were also clipped. A web strap $1\frac{1}{2}$ inches wide and approximately 9 inches long was attached to the undersides of the calves (Fig. IV) with branding cement (product of Nebraska Salesbook Co., Lincoln, Nebraska) (Hobbs et al., 1950). Another strap was attached to the backs of the calves with branding cement as shown in Fig. V.

The bag was attached by passing the tail through the tail opening and passing the bag under the back strap, folding over the strap and taping down with strips of cellulose tape (Fig. VI). The lower flap (Fig. VII) was attached by passing the flap between the lower strap and the body, folding back and winding with cellulose tape. Care was taken to fit the bag snugly without undue strain. The bag was removed by cutting with scissors.

After being removed, the bag was weighed with its contents, cut open and the contents placed in a glass jar. The glass jars containing the feces were kept in a refrigerator and the contents dried immediately after collection of the last sample.

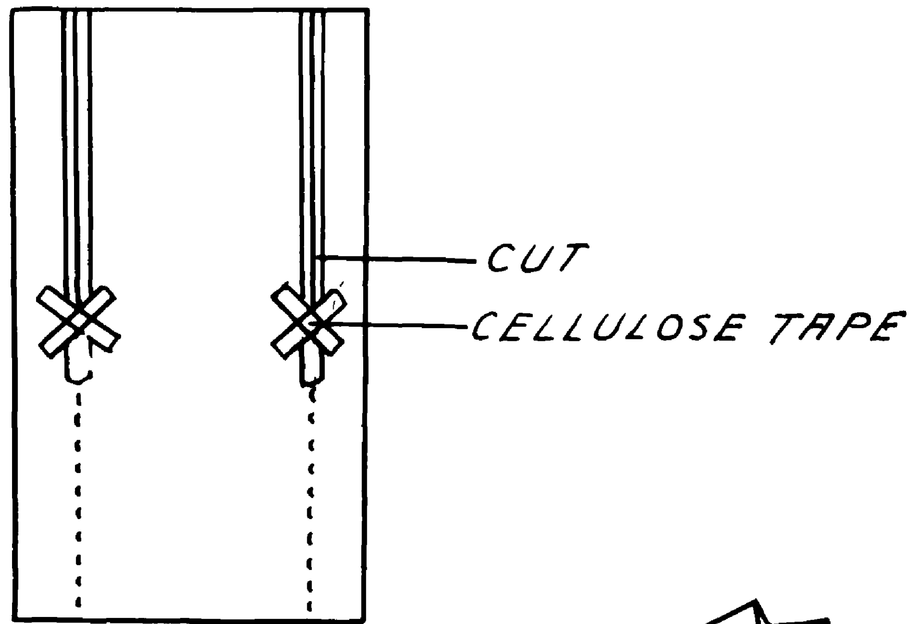
The bags were checked 4 times a day. During periods of replacer feeding it was often necessary to change the bags 4 times daily. However, during milk feeding periods once a day was usually sufficient.

During the collection periods the calves were kept in metal cages 36 in. wide, 30 in. high and 48 in. deep (product of Geo. H. Wahmann Mfg. Co., Baltimore, Md.). The calves stood on a heavy coarse-mesh screen with a finer screen and a urine funnel and drain below. The two screens and funnel were removable.

The urine was collected in a glass carboy containing 20 ml. of concentrated hydrochloric acid. At the end of the collection period the urine was measured and samples saved for chemical analysis. The urine samples were refrigerated until analyzed.

Fig. II   Preparation of bag before cutting flap

Fig. III Finished bag


CUT
CELLULOSE TAPE

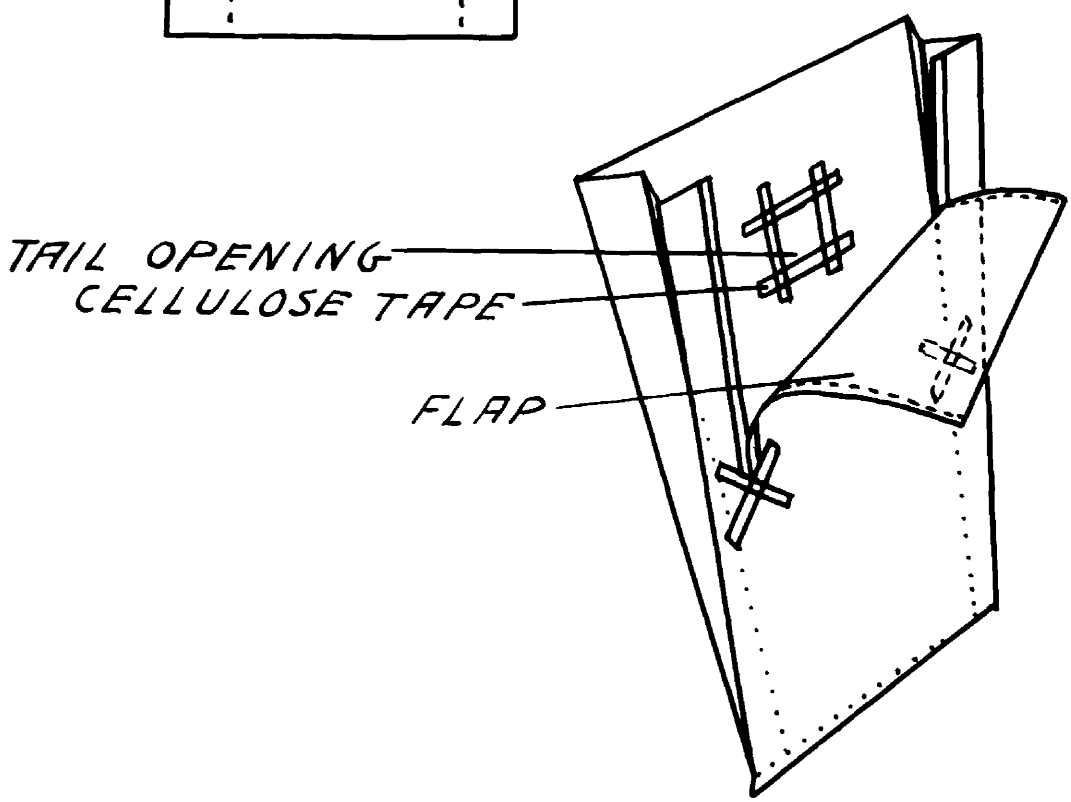
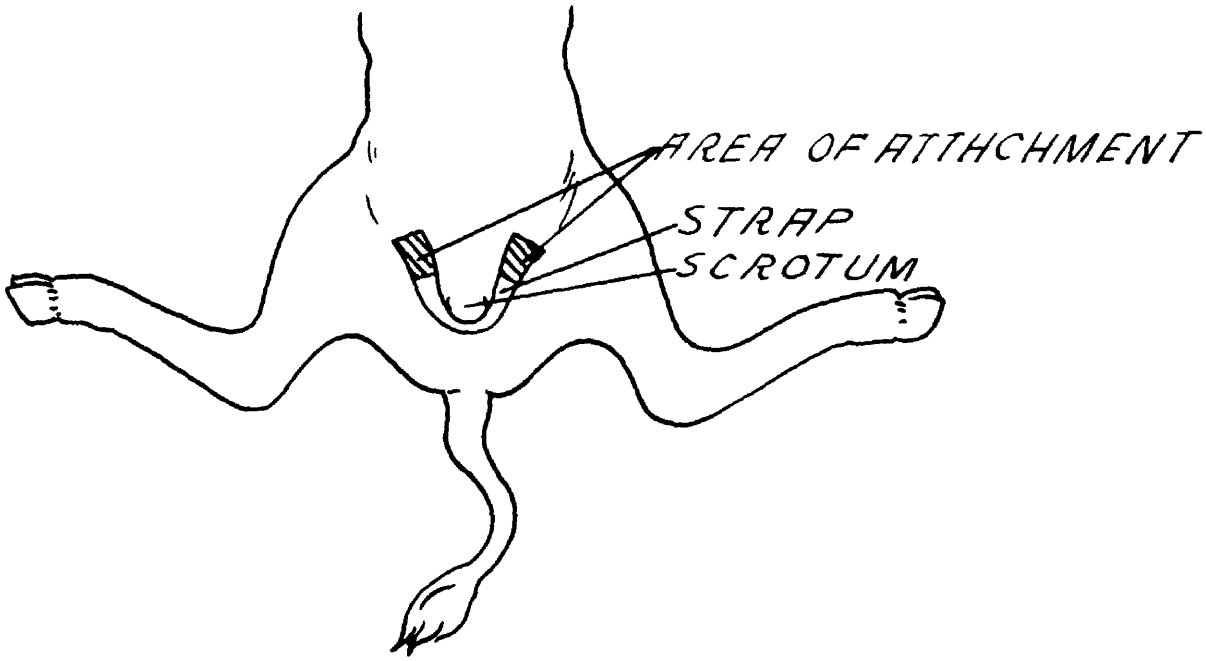

TAIL OPENING
CELLULOSE TAPE
FLAP

Fig. IV Position of lower strap

Fig. V Position of top strap


AREA OF ATTHCHMENT
STRAP
SCROTUM

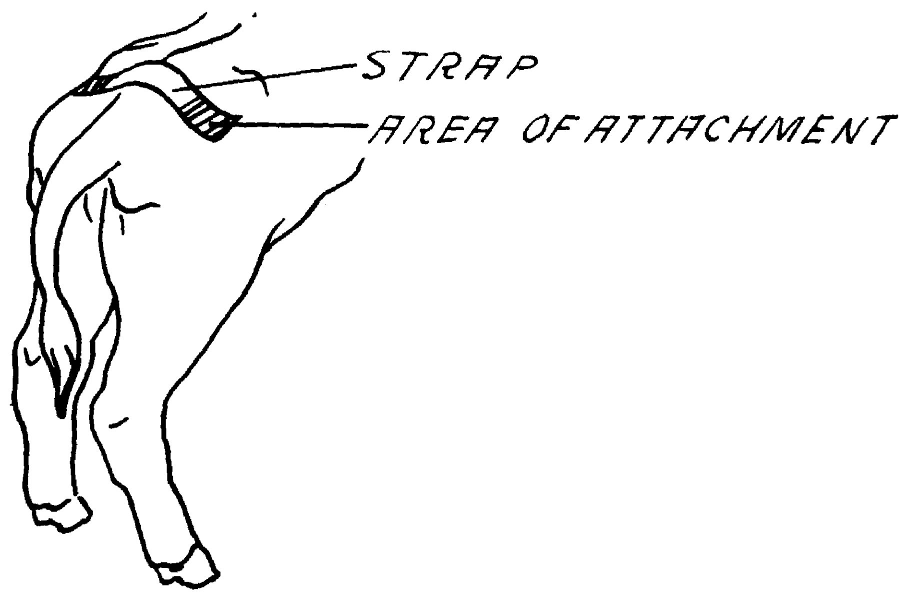
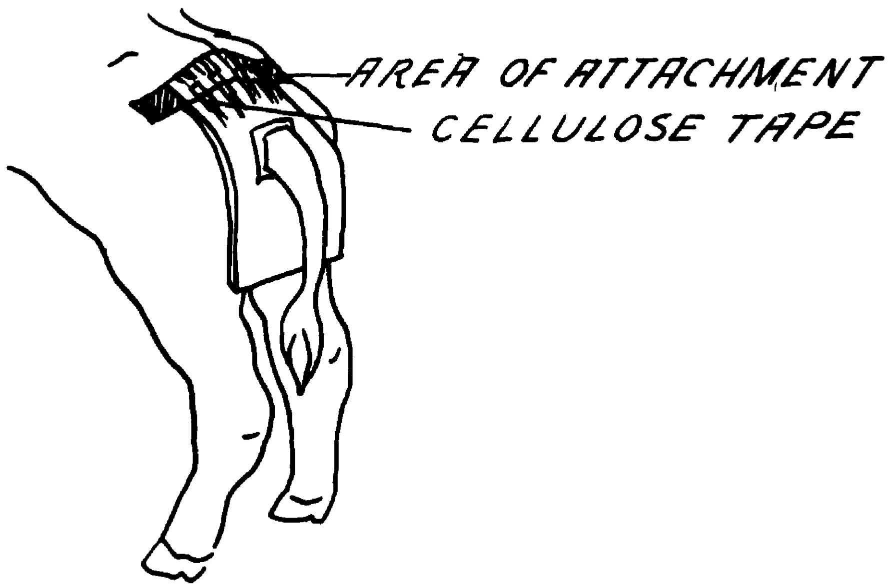
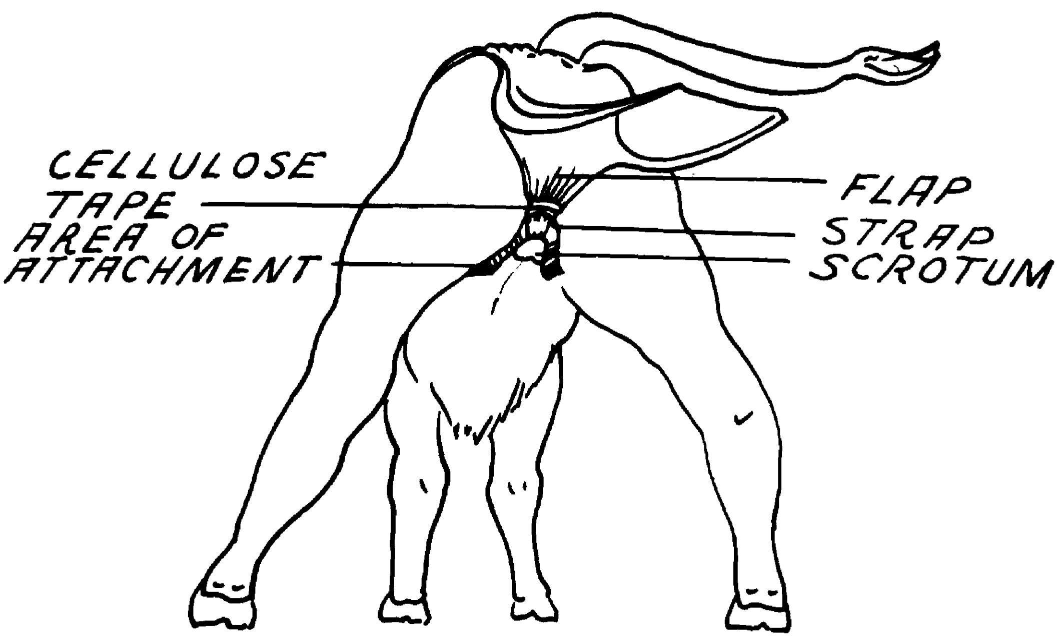

STRAP
AREA OF ATTACHMENT

Fig. VI Attachment of pliofilm bag to top strap

Fig. VII Attachment of pliofilm bag to lower strap


AREA OF ATTACHMENT
CELLULOSE TAPE


CELLULOSE TAPE
AREA OF ATTACHMENT
FLAP
STRAP
SCROTUM

Analytical Procedures

Milk replacers: Dry matter, crude fiber, nitrogen, ether extract, ash, calcium and phosphorus (A.O.A.C., 1950).

Milk: Nitrogen (Kjeldahl), fat (Babcock), total solids (Mojonnier), wet ash for calcium and phosphorus (Brenner and Harris, 1939) using selenium oxychloride as a catalyst, calcium (modification of Shohl and Pedley, 1922) and phosphorus (modification of Fiske and Subbarow, 1925).

Feces: Dry matter, crude fiber, nitrogen, ether extract, ash, calcium and phosphorus (A.O.A.C., 1950).

Urine: Nitrogen (Kjeldahl), wet ash for calcium and phosphorus (Brenner and Harris, 1939) using selenium oxychloride as a catalyst, calcium (modification of Shohl and Pedley, 1922) and phosphorus (modification of Fiske and Subbarow, 1925).

Statistical analyses: (Snedecor, 1946).

Calculation: The coefficients of apparent digestibility of the milk replacers were determined by difference. Nitrogen, calcium and phosphorus balances were calculated on the milk replacer ration as fed which included the evaporated milk.

RESULTS

Experiment 1

The coefficients of apparent digestibility obtained in this experiment, using 5-day preliminary periods and 2-day collection period, are presented in Table 12. The average apparent digestibilities for evaporated milk were: dry matter, 89.5; crude protein, 79.1; ether extract, 91.4; and nitrogen-free extract, 97.0%. The average coefficients of apparent digestion for the milk replacers were: dry matter, 51.4; crude protein, 20.4; crude fiber, -12.1; and nitrogen-free extract, 70.8. The apparent digestibility of the ether extract for the milk replacers was not calculated since the digestibility of the replacers was determined by difference and the ether extract content of milk was considerably greater than that in the milk replacers. Digestibility data for individual animals for each period are presented in Appendix Table 2.

Analyses of variance of these results (Table 13) indicated significant differences among the various feeds in the apparent digestibility of the dry matter and nitrogen-free extract portions. The differences due to animals and periods were not statistically significant.

The coefficients of apparent digestion of the dry matter are presented by periods in Fig. VIII and Appendix Table 2. The dry matter of the evaporated milk was 81% digested by a 10- to 12-day-old calf and an average of 93.3% by 17- to 34-day-old calves. In contrast, the mean dry matter digestibility of the milk replacers increased from 32.9% for 10- to 12-day-old calves to 64.9% for the 24- to 34-day-old calves.

The crude protein of the evaporated milk was 60.1% digested by the 10- to 12-day-old calf and an average of 85.6% by 17- to 34-day-old calves (Fig. IX and Appendix Table 2). The digestibility values for the crude protein of the milk replacers were much lower and more variable. The nitrogen-free extract (Fig. X) was the most digestible nutrient in both the evaporated milk and in the milk replacers. In the evaporated milk it was equally as digestible the first period as in later periods. However, the nitrogen-free extract of the milk replacers was less digestible during the first period and reached a maximum in the third period.

An average positive nitrogen balance of 3.69 gm. daily was obtained on the evaporated milk compared to the negative values with the milk replacer rations (Table 12). Nitrogen retention on the evaporated milk was lower in the first period than in succeeding periods (Appendix Table 3). For the milk replacers the nitrogen balance tended to be negative for the first two periods and positive during the other two periods.

Studies on the calcium metabolism (Appendix Table 4) of the calves indicate that they were in positive balance at all times. Calves fed the evaporated milk retained an average of 59.7% of their calcium intake while calves fed the milk replacer rations retained an average of 31.4% of their calcium intake. Calcium retention varied among periods.

The data on phosphorus metabolism show that calves fed evaporated milk retained an average of 54.5% of their phosphorus intake compared to an average of 31.1% for calves receiving the milk replacer rations. The retention of phosphorus was low during the first two periods in calves receiving the milk replacer ration (Appendix Table 5).

Table 12

Average Digestibilitiy Coefficients, Daily Balances
and Their Standard Errors--Experiment 1

Feed	Digestibility					Balance/day		
	DM	CP	EE	CF	NFE	N	Ca	P
	%	%	%	%	%	gm.	gm.	gm.
Evaporated milk	89.5	79.1	91.4	--	97.0	3.69	2.58	1.86
Replacer 4	56.6	24.9	*	-10.0	72.0	-0.63	1.20	1.05
Replacer 5	51.6	27.2	*	-9.1	69.2	-1.19	1.18	1.01
Replacer 6	46.1	9.0	*	-17.2	71.3	-1.34	1.22	0.95
Standard error of mean	7.66	17.09	--	--	5.36	1.75	0.42	0.23

* not determined

Table 13

Analyses of Variance--Experiment 1
F values

Source	df	DM	CP	NFE	N	Ca	P
Periods	3	2.94	1.16	2.43	3.20	.26	1.18
Animals	3	.37	.95	1.47	1.26	.88	1.38
Treatments	3	6.47*	2.80	6.00*	1.87	2.78	3.43
Error	6						

* Need 4.76 for P = .05

Table 14

Dry Matter Digestibility of Whole Milk
and Evaporated Milk--Experiment 2

Age of calves	Whole milk	Evaporated milk
Days	%	%
8-10	96.5	--
10-14	--*	81.6
14-18	92.0	90.4
18-22	95.9	93.4
22-26	96.3	93.4
26-30	--**	90.3
30-32	--	92.3

* no samples due to diarrhea

**taken off experiment due to diarrhea

Table 15

Average Digestibility Coefficients, Daily Balances and Their Standard Errors--Experiment 3

Feed	Digestibility					Balance/day		
	DM	CP	EE	CF	NFE	N	Ca	P
	%	%	%	%	%	gm.	gm.	gm.
Whole milk	94.8	90.1	97.8	--	97.1	7.36	3.64	2.12
Evaporated milk	86.7	76.9	88.1	--	94.9	3.20	1.74	0.87
Replacer 7	59.1	25.3	69.1	-4.4	77.3	-0.07	1.54	0.61
Replacer 8	55.1	17.7	24.0	6.2	78.2	-2.29	1.60	0.49
Standard error of mean	6.63	10.4	--	--	4.21	1.54	0.33	0.33

Experiment 2

A comparison of the apparent dry matter digestibilities of raw whole milk and evaporated milk by two calves is presented in Table 14. The coefficients of dry matter digestibility averaged 95.2 for the raw whole milk and 90.3 for the evaporated milk. The dry matter of the evaporated milk was 81.6% digestible during the 10- to 14-day age period and 90.4% during the 14- to 18-day age period. The dry matter of the whole milk was more digestible throughout the experiment. The missing values were due to sudden onset of diarrhea which interfered with feces collection.

Experiment 3

The mean coefficients of apparent digestibility of the feeds used in this experiment, using 4-day preliminary periods and 4-day collection periods are presented in Table 15 and individual data in Appendix Table 6. The average coefficients of raw whole milk were: dry matter, 94.8; crude protein, 90.1; ether extract, 97.8; nitrogen-free extract, 97.1. The corresponding average coefficients for the evaporated milk were 86.7, 76.9, 88.1 and 94.9, respectively. In comparison, the average apparent digestibility of the milk replacers was as follows: dry matter, 57.1; crude protein, 21.5; ether extract, 46.5; crude fiber, 0.9; nitrogen-free extract, 77.8%. In all cases the values for the milk replacers were lower than those obtained with milks. This was particularly true of the crude protein portion of the feed.

When an analysis of variance was made it was found that the variance in apparent digestibility among feeds was significant for the dry matter and nitrogen-free extract and highly significant for the crude protein (Table 16). The variance among animals was not significant. Crude protein digestibility also varied significantly among periods.

The coefficients of apparent digestion of the dry matter in the various feeds are shown by periods in Fig. XI. The curves show that the apparent digestibility of the dry matter of raw whole milk was high, averaging 94.8%, with little variation due to period. That of the evaporated milk was lower during the first period but reached its maximum value by the second period. The dry matter digestibility of the milk replacers was low during the first period, increased during the second period and reached its maximum in the third period (26 to 30 days of age). The average coefficients for the dry matter of the milk replacers were 25.0, 52.5, 77.2 and 72.7, respectively, for the four consecutive periods.

The apparent digestibilities of crude protein by periods are presented in Fig. XII and Appendix Table 6. The crude protein of the raw whole milk was 81.2, 92.8, 93.2, and 93.0% digested in the four consecutive periods. The corresponding values for the evaporated milk were 56.5, 80.7, 82.7, and 87.8%. The meancoefficients of digestibility for the crude protein of the milk replacers were -26.5, 8.7, 55.6 and 48.2, respectively, for the four consecutive periods.

In all four feeds the nitrogen-free extract was the most digestible nutrient (Fig. XIII) as was found in Experiment 1. The apparent digestibility of the nitrogen-free extract of the raw whole milk and evaporated milk were 97.1 and 94.9%, respectively, with little variation due to period. In contrast, the nitrogen-free extract of the milk replacers for the four consecutive experimental periods averaged 57.9, 80.4, 85.9 and 87.2%, respectively.

The coefficients of digestibility for the dry matter, crude protein and nitrogen-free extract for the four feeds were averaged for the third and fourth period. The results are shown in Fig. XIV. The data show that there is very little difference between the two milk replacers in the apparent digestibility of the dry matter, crude protein and nitrogen-free extract. The evaporated milk was less digestible than the raw whole milk but the differences were smaller than when all four periods were considered. The largest difference occurred between the milks and milk replacers in apparent crude protein digestibility.

Analysis of variance of the nitrogen balance data indicated significant differences among feeds (Table 16). The daily nitrogen balance on raw whole milk averaged +7.36 gm., evaporated milk, + 3.20 gm., and the two milk replacers averaged -1.18 gm. Nitrogen retention also varied significantly with periods, as occurred with crude protein digestion. Negative nitrogen balance was obtained with evaporated milk during the first period and with milk replacers during the first two periods (Appendix Table 7).

Calcium retention was significantly greater for calves fed raw whole milk than for those fed the evaporated milk or milk replacer rations (Appendix Table 8). The calves fed raw whole milk retained 3.6 gm. or 81.6% of their calcium intake compared to an average of 1.6 gm. or 39% by calves fed either evaporated milk or milk replacer rations. Marked variations in calcium retention were observed among periods.

The phosphorus balance was also significantly affected by ration (Appendix Table 9). Calves fed raw whole milk retained 60.9% of the phosphorus intake compared to 25.5% retained by calves receiving evaporated milk and 19.2% and 14.2% by the calves receiving milk replacers. The retention of phosphorus by calves receiving evaporated milk was negative during the first period. Low or negative phosphorus balances were observed during the first two periods when milk replacers were fed.

Table 16

Analyses of Variance--Experiment 3
F Values

Source	df	DM	CP	NFE	N	Ca	P
Periods	3	4.29	5.08*	2.14	5.03*	.28	.90
Animals	3	.83	.61	1.37	.28	1.21	.48
Treatments	3	8.94*	12.14**	6.26*	7.44*	9.28*	5.12*
Error	6						

* Need 4.76 for P = .05

**Need 9.78 for P = .01

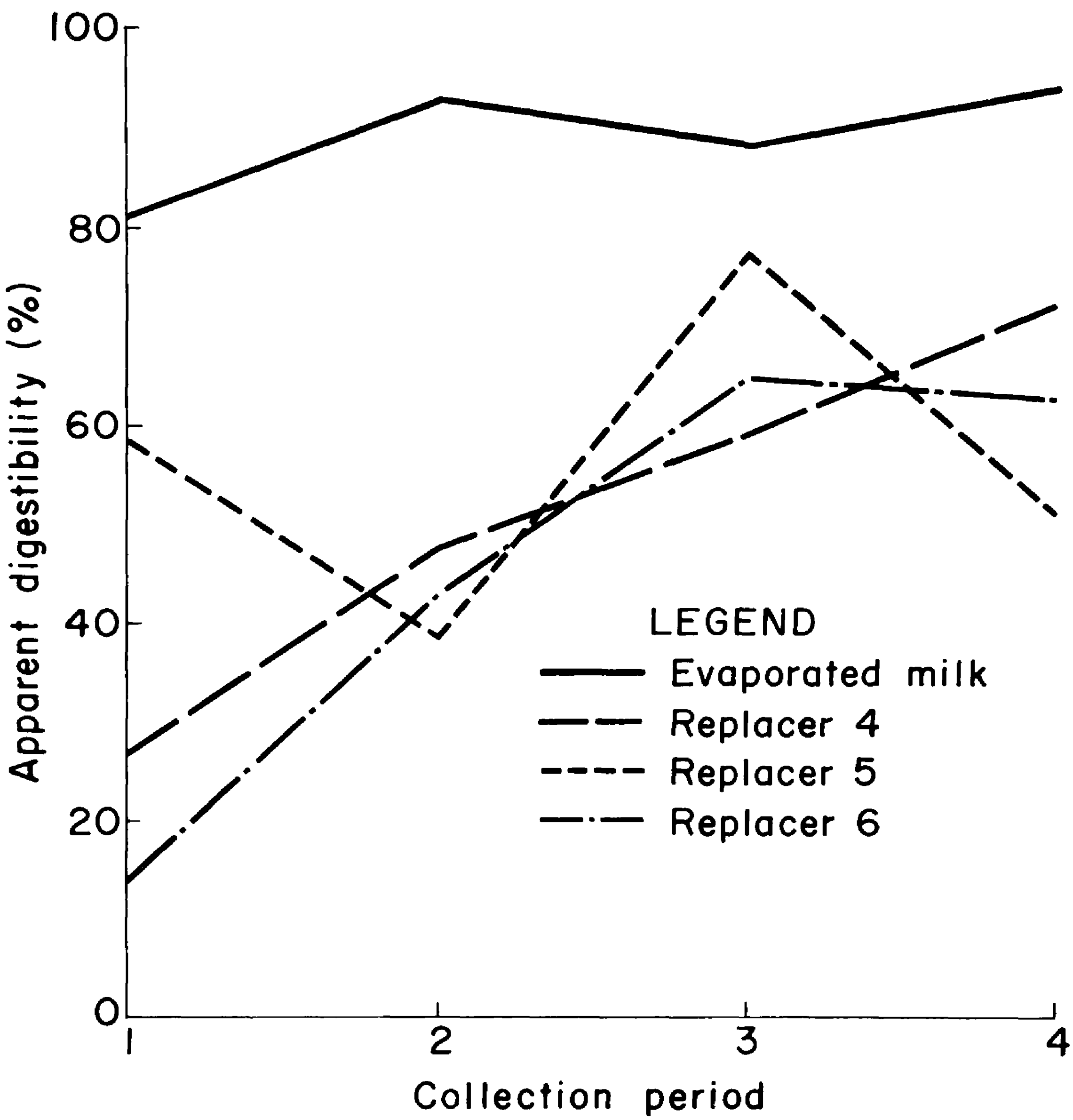


Fig. VIII. Apparent dry matter digestibilities by periods--Experiment 1

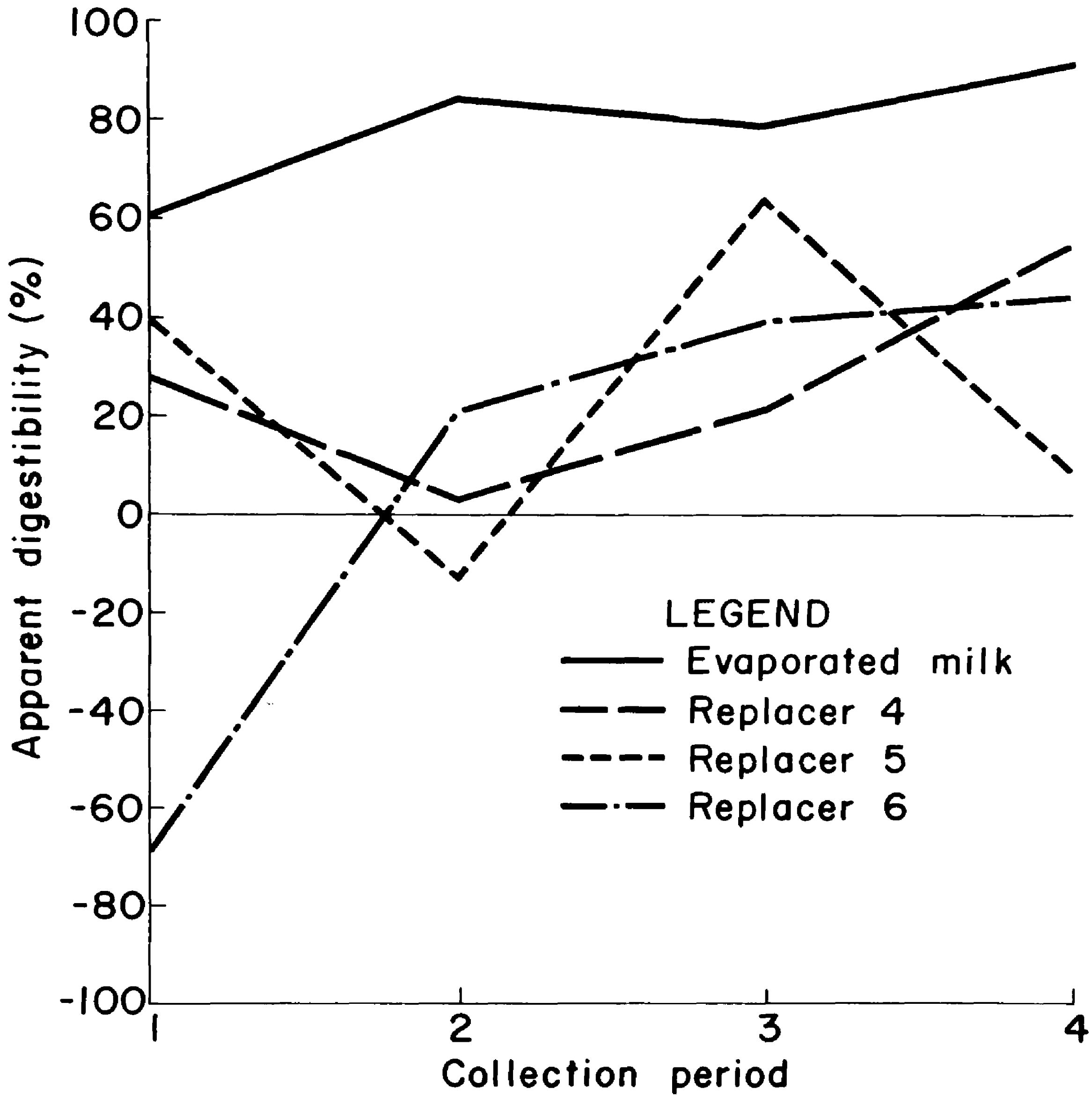


Fig. IX. Apparent crude protein digestibilities by periods--Experiment 1

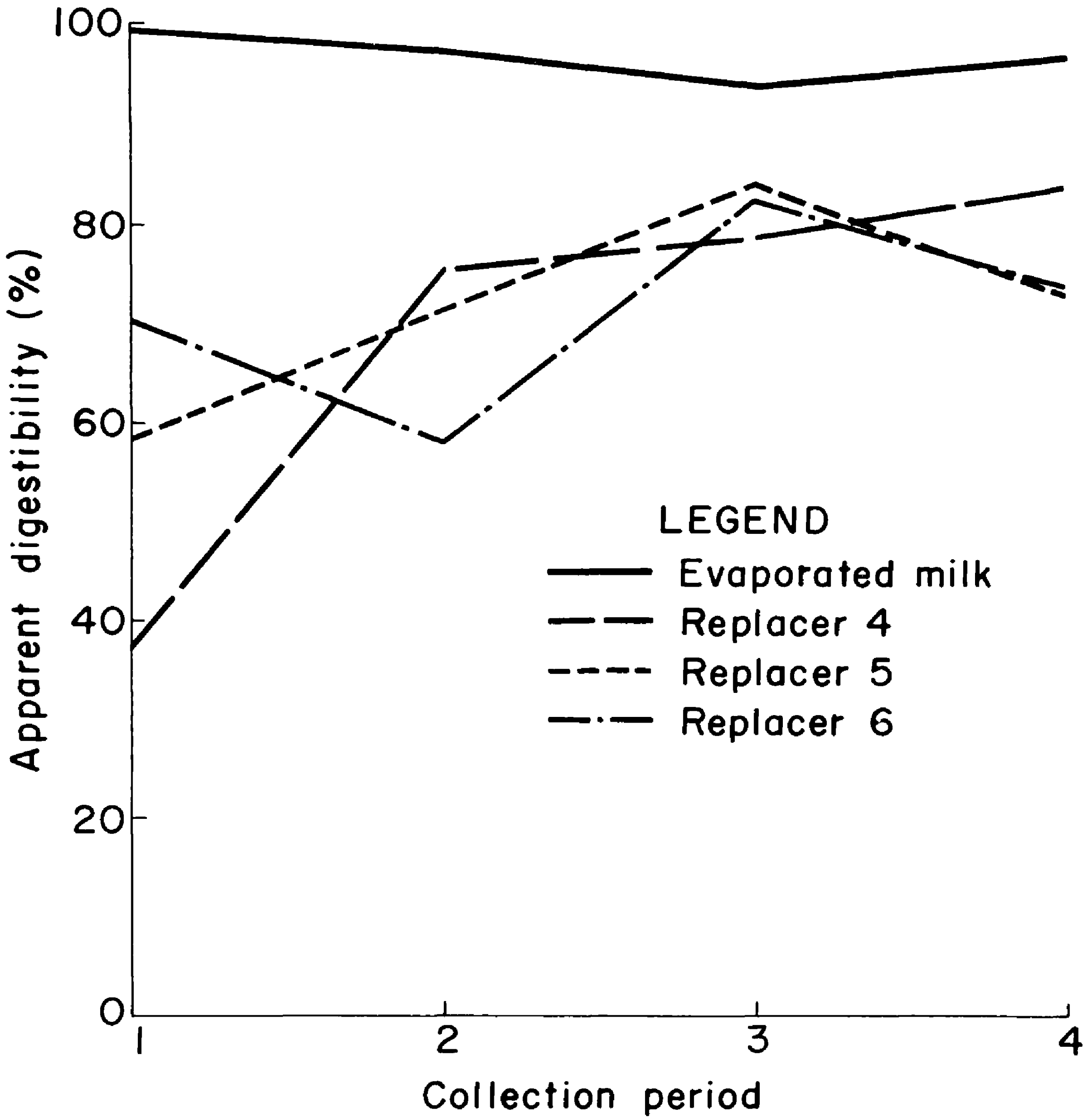


Fig. X. Apparent nitrogen-free extract digestibilities by periods--Experiment 1

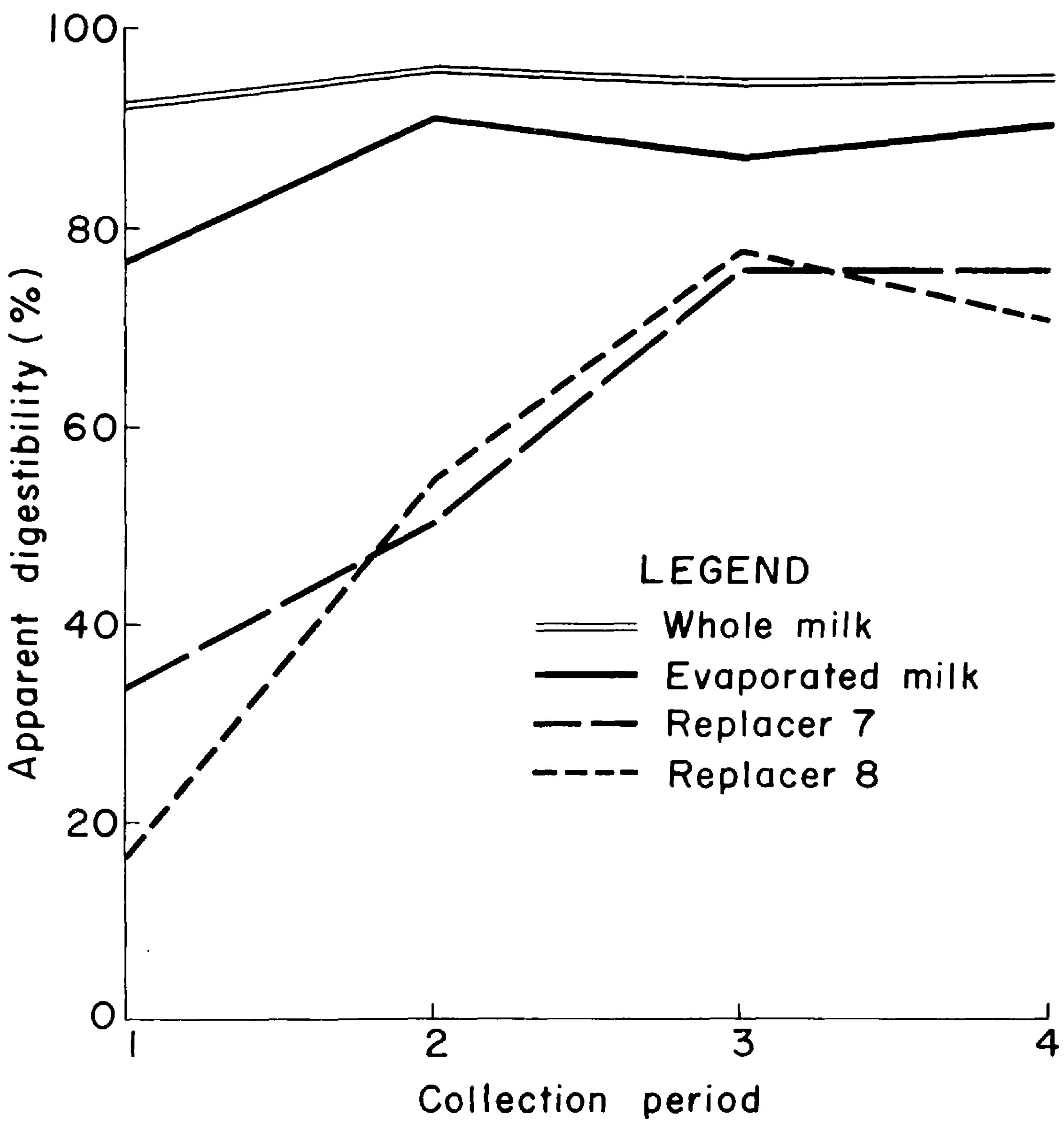


Fig. XI. Apparent dry matter digestibilities by periods--Experiment 3

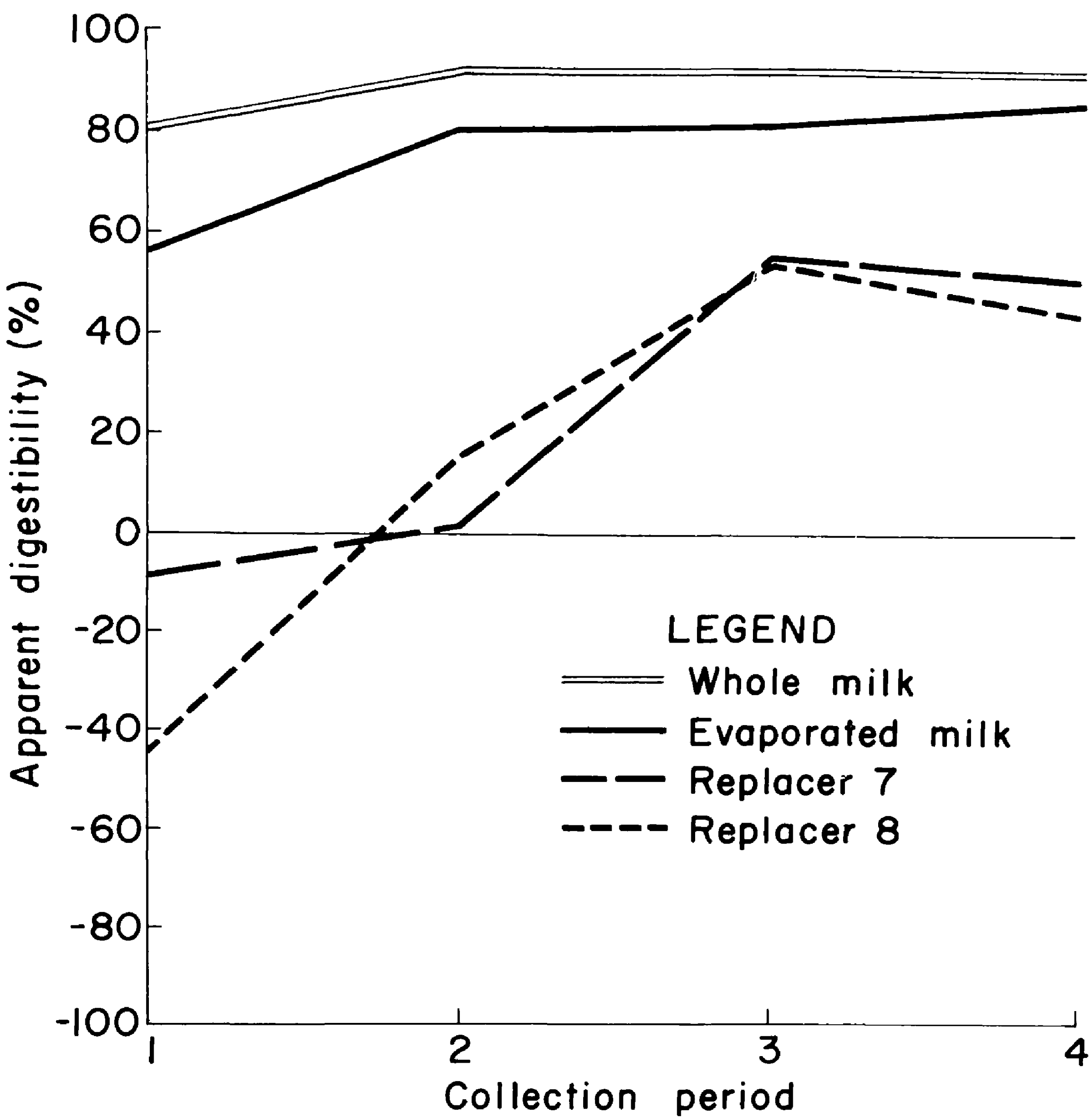


Fig. XII. Apparent crude protein digestibilities by periods--Experiment 3

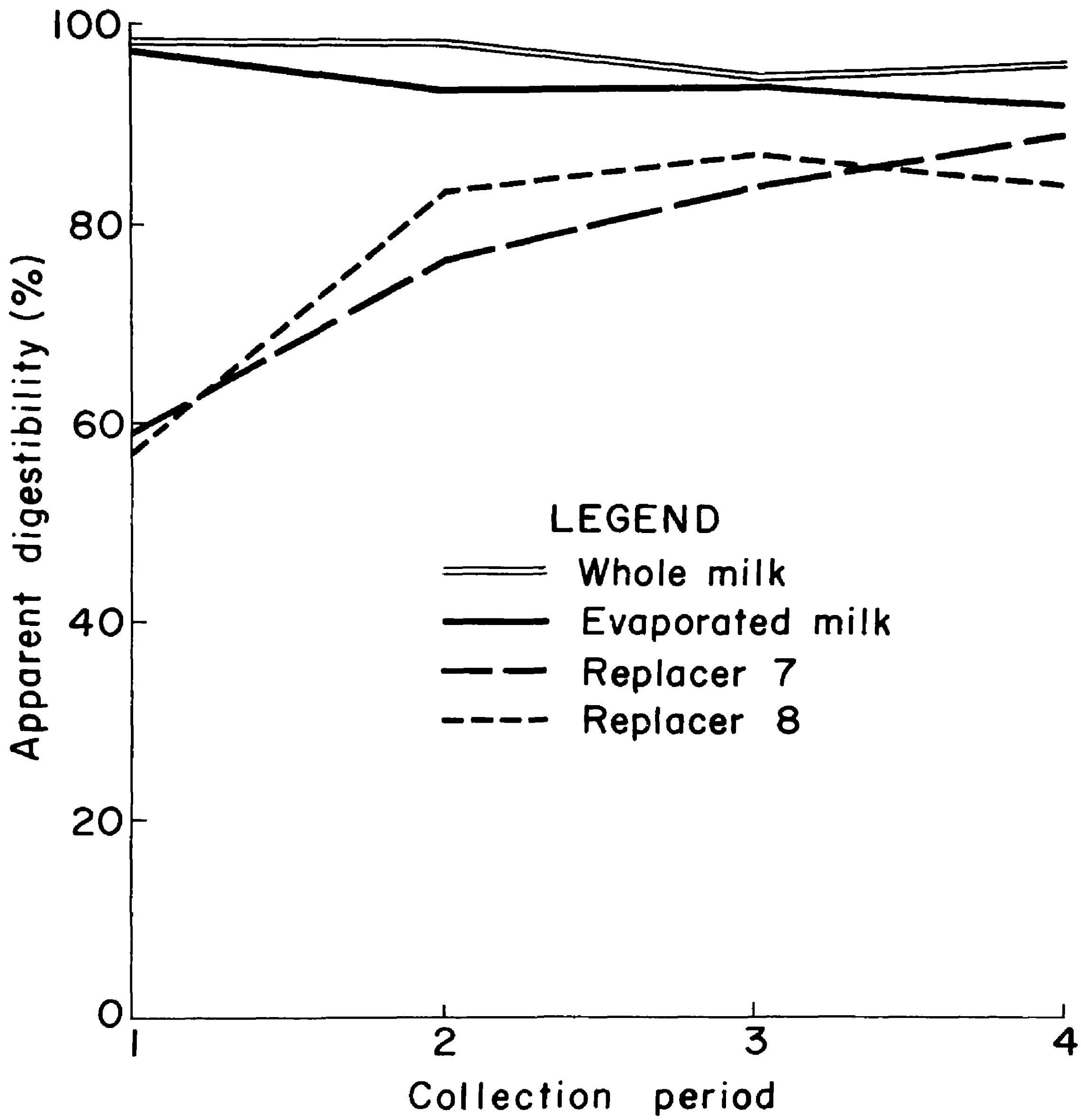


Fig. XIII. Apparent nitrogen-free extract digestibilities by periods--Experiment 3

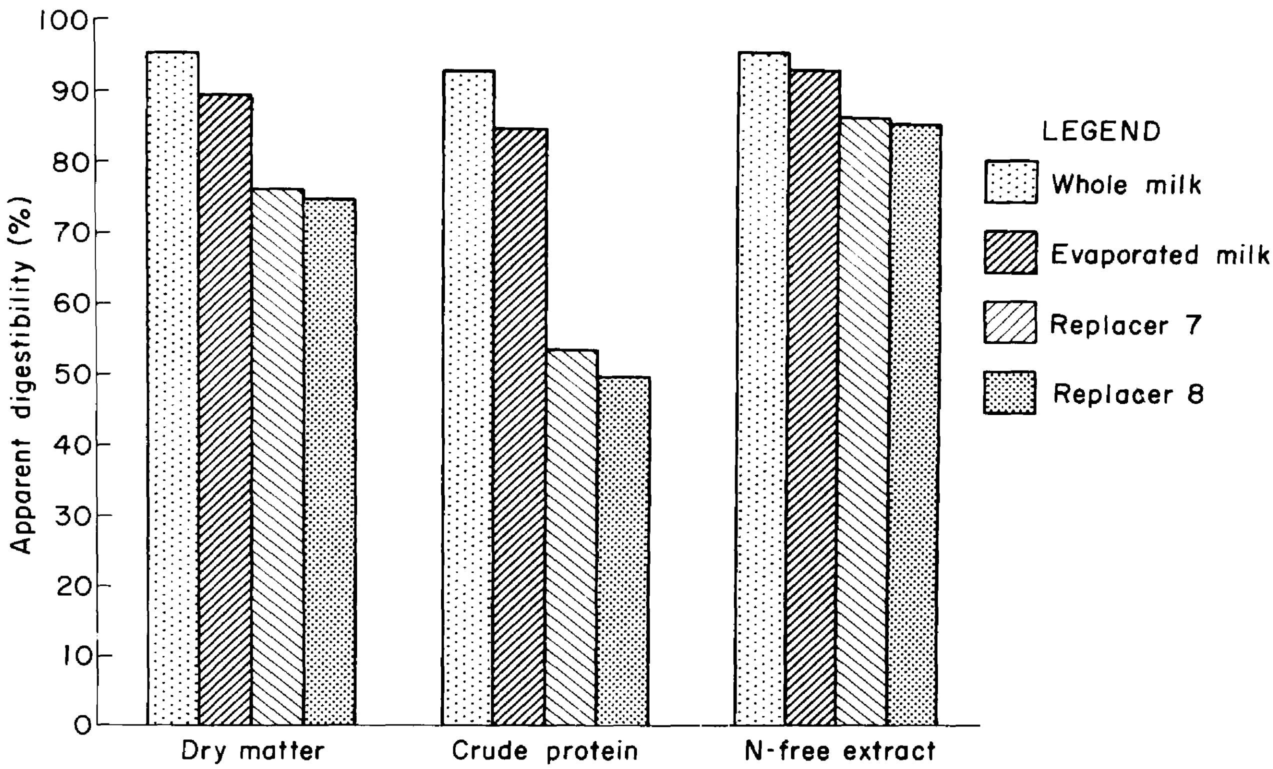


Fig. XIV. Apparent digestibilities of dry matter, crude protein and nitrogen-free extract of raw whole milk, evaporated milk and milk replacers by 26- to 38-day-old calves--Experiment 1

DISCUSSION

A search of the literature had disclosed a paucity of data on the relation of age to digestion in the calf. Besides determining the apparent digestibility of the feed, experiments 1 and 3 were also designed to give a measure of the relationship of age to the digestibility of the feeds. In experiment 1, 2-day fecal collections were made beginning at 10, 17, 24 and 31 days of age. In experiment 3, using 4-day collection periods, the corresponding ages were 10, 18, 26 and 34 days.

The technique devised for the collection of feces from young calves satisfied the requirements of this investigation. This method embraced freedom of movement by the calves, low cost, and ease of attaching and removing the bags. One difficulty observed with this method of fecal collection was possible leakage of laxative feces from the bag when the calf was lying down. In general very little difficulty was encountered when the feces were costive and the bags were changed 4 times daily.

The apparent digestibilities of three milk replacers and evaporated milk were studied in experiment 1. Evaporated milk was used both as the control and to supply the milk portion of the replacer rations. The data in Table 12 indicate significant differences between the coefficients of digestion for evaporated milk and the milk replacers. However, the coefficients of digestion for the evaporated milk were lower than those reported for whole milk by Blaxter and Wood (1952a) in calves and Wellman (1914) in pigs. Parrish et al. (1953) using 1- to 17-day-old calves also observed higher values for whole milk with the exception of the crude protein which was equal to the crude protein in the present investigation. The milk replacers used in this study were significantly less digestible than the evaporated milk (Table 12) and subject to marked variations among periods. The variations were believed to be due to the shortness of the collection period. The evidence suggested that 2-day collection periods were insufficient for valid results when milk replacers were fed. A marked decrease in the variations occurred after 4-day collection periods were adopted. A 2-day collection period seemed to be adequate when evaporated milk was fed.

Experiment 2 was conducted to compare the apparent dry matter digestibility of evaporated and raw whole milk in a continuous trial with two calves. It was found throughout the experiment that the apparent dry matter digestibility of the evaporated milk was lower than that of raw whole milk (Table 14). The average coefficient of dry matter digestion of raw whole milk was 95.2 which is in agreement with the results reported by Wellman (1914), Hughes and Cave (1931), Blaxter and Wood (1952a) and Parrish et al. (1953). In comparison, the dry matter of the evaporated milk was 81.6% digested by a 10- to 14-day-old calf in the first experiment. In the following collection period (14 to 18 days of age) the apparent dry matter digestibility of the evaporated milk had increased to 90.4% which is comparable to that of the evaporated milk in the first experiment. These results indicate that the dry matter of the evaporated milk is less digestible in the young calf than is that of raw whole milk.

A comparison of raw whole milk, evaporated milk and two milk replacers was made in experiment 3, using 4-day collection periods, in an attempt to decrease the variations observed in experiment 1. The average coefficients of apparent digestibility of the dry matter, ether extract and nitrogen-free extract of raw whole milk were 94.8, 97.8 and 97.1, respectively (Table 15). Similar values were reported by Wellman (1914) with pigs, Hughes and Cave (1931) with 7½- to 8-month-old calves, Parrish et al. (1953) with 1- to 17-day-old calves and Blaxter and Wood (1952a) with with 5- to 14-day-old calves. The apparent digestibility of the dry matter for the raw whole milk is also in agreement with the value obtained for the raw whole milk in experiment 2. The average apparent digestibility of 90.1% for the crude protein of raw whole milk is lower than the values cited by Wellman (1914), Hughes and Cave (1931) and Blaxter and Wood (1952a). However, as can be seen in Fig. XII, the low average value is due to the low apparent digestibility of the crude protein during the first period. In the following periods the values were equal to those reported by the investigators mentioned above. Parrish et al. (1953) also observed low crude protein digestibilities for colostrum and whole milk in calves between the ages of 3 and 8 days. They reported apparent crude protein digestibilities of 83% at 3 to 4 days of age and 86% at 5 to 8 days of age. In 14- to 17-day-old calves it had increased to 93% which is in agreement with the results in experiment 3.

A comparison of evaporated and raw whole milk data for experiment 3 (Table 15) indicates that evaporated milk is less digestible than raw whole milk under the conditions of this experiment. The apparent digestibility of the crude protein portion of the evaporated milk was noticeably lower than that in raw whole milk and also slightly lower than that in the evaporated milk in experiment 1. In their experiments with rats, Nevens and Shaw (1932) also observed a lower crude protein digestibility in evaporated milk than in whole milk. However, Henry and Kon (1938) and Fairbanks and Mitchell (1935), using rats, were unable to demonstrate a difference between the crude protein digestibilities of evaporated and whole milk. A later experiment by Kraft and Morgan (1951) suggested a possible difference between animals in their ability to utilize the protein of heated milk. These authors reported that heating of skimmilk had no effect on nitrogen retention in dogs but a marked decrease occurred when fed to weanling rats. The lower values for the evaporated milk as compared to raw whole milk in the present investigation suggest that young calves, at the ages used, may not be physiologically equivalent to the animals used by most investigators. The evaporated milk values were consistently lower, although the differences were small. This suggestion is not in agreement with Schroeder <u>et al</u>. (1953) who claim that differences attributed to species of experimental animals used are in reality due to the intensity and duration of heat used in processing the milk. However, it should be noted that in the present investigation 3 different lots of evaporated milk were used. The results for all 3 lots were consistently lower than those for raw whole milk.

Inspection of the coefficients of digestibility in experiment 3 (Table 15) reveals that the milk replacer values are lower than are those for the milks. Again as in experiment 1 the crude protein in the milk replacers was considerably less digestible than the crude protein in the milks. Less difference occurred in the nitrogen-free extract portion. The crude fiber of the milk replacers in experiment 3 appeared to be indigestible, a finding which agrees with the results in experiment 1. This suggests that crude fiber has little or no value in the nutrition of the young calf before the rumen begins to develop unless its presence stimulates rumen development. McCandlish (1923) had previously suggested that bulk in the diet stimulated the development of the alimentary tract in the young calf.

The ether extract values for the milk replacers were of little value because the ether extract portion of the milk replacers was small in comparison to that in the milk fed with them. Since the milk replacer digestibilities were determined by difference, any error in the milk value would be magnified out of proportion in the ether extract digestibility for the milk replacers.

The digestibilities of the various feeds as they might be affected by age of the calf were studied in experiments 1 and 3. When the coefficients of apparent digestibility of the dry matter, crude protein and nitrogen-free extract for experiment 1 were plotted graphically by periods (Fig. VIII, IX and X), it was noted that the digestibility coefficients varied with age of the calf. The values obtained in experiment 3 (Fig. XI, XII and XIII) were similar to those in experiment 1, but the results with milk replacers were less variable among periods. This was believed to be due to the longer collection period. The results in experiment 3 demonstrate that the digestibility of raw whole milk varies little with age of the calf. In contrast, evaporated milk is not as digestible by the 10- to 14-day-old calf as by the 18- to 22-day-old calf, a difference essentially attributable to the lowered digestibility of the crude protein in the evaporated milk.

The digestibility patterns also indicate that the calves were unable to utilize the milk replacers satisfactorily until the third period, when they were approximately 25 days of age (average for experiments 1 and 3). These results substantiate the conclusion in Part I that the end of the critical period in the life of the young calf is approximately 25 days of age. This was indicated by the increased feed consumption, increased weight gain and improved general appearance of the calves. The age cited is also in agreement with Shaw et al. (1918) who reported that 4- to 7-day-old calves were able to digest only one-fifth of the starch consumed but at 21 to 28 days of age they were able to digest well over 90 percent of the starch in the ration. It was suggested in Part I that the increased ability of the calves to utilize the milk replacers at approximately 25 days of age may be due to the development of rumen function. However, the data on crude fiber digestion (Tables 12 and 15) suggest that the increased ability of the calf to utilize milk replacers may not be due to increased rumen function. As the rumen develops the apparent digestibility of the crude fiber would be expected to increase as occurred with the other components of the milk replacers. However, in experiments 1 and 3 the apparent crude fiber digestibility was essentially zero during the third and fourth periods. It is suggested that the improved utilization of milk replacers by calves at approximately 25 days of age may be due to some unidentified physiological change.

An inspection of the data in Fig. XIV indicates that in 26- to 38-day-old calves the apparent digestibilities of raw whole and evaporated milk are similar for dry matter, crude protein and nitrogen-free extract. The apparent digestibilities of the two milk replacers were almost identical, and they were significantly less digestible than the milks. The apparent digestibilities of the milk replacers were compared with those obtained on calf meals with 9-month-old calves by Archibald (1928). The coefficients for the crude protein of the milk replacers were considerably lower, dry matter slightly higher and the nitrogen-free extract noticeably higher than those of the calf meals. On the basis of this comparison it appears that crude protein is less digestible by 26- to 38-day-old calves than by 9-month-old calves. The dissimilarities cited could be in part due to differences in the composition of the rations fed.

A limiting factor in the nutrition of the young calf until approximately 25 days of age appears to be the lower apparent crude protein digestibility in the milk replacers. In experiments 1 and 3 (Appendix Tables 3 and 7) the average daily urinary nitrogen excretion was similar for all rations. However, fecal nitrogen varied from 1.8 gm. in the raw whole milk ration and 3.8 gm. in the evaporated milk ration to 10.5 gm. in the milk replacer rations. Since the dry matter intake on all diets was essentially the same the metabolic fecal nitrogen excretion should be fairly constant among the rations. Some increase in metabolic fecal nitrogen may occur due to the physical state of the milk replacers as compared to that of the milks. It is postulated that the increased fecal nitrogen observed in calves receiving the milk replacer rations primarily represented undigested protein which could not be assimilated by the calf. The failure of digestion might be attributable to a lack of sufficient enzymes for splitting the protein molecules.

The decreased apparent crude protein digestibility and the increased fecal nitrogen excreted by calves on evaporated as compared to raw whole milk may be due to the effect of heat on the milk protein during processing. This has been indicated by Pader et al. (1948) who reported that heating of casein decreased lysine liberation. The decreased liberation of lysine might be attributed to the formation of a linkage which was enzyme resistant. Fairbanks and Mitchell (1935) also indicated that the use of increasing amounts of heat decreased the digestibility of the milk protein.

Calcium retention was variable both between experiments and periods. It was observed that calcium retention varied little with age. However, calcium retention by calves fed raw whole milk was greater than by calves fed evaporated milk or milk replacer rations. This suggests that the calcium of raw whole milk is more efficiently utilized by the young calf than that of the evaporated milk or milk replacer ration.

Urine analyses indicate a low urinary calcium excretion by the calf (Appendix Tables 4 and 8). In experiment 1 the urinary calcium excretion amounted to 2.8% of the total calcium excreted. In experiment 3 it was 1.9% of the total calcium excreted. These values are similar to the 2% urinary calcium reported by Blackwood et al. (1936) and lower than the 5% found by Blaxter and Wood (1952a).

Analyses of data on phosphorus balances (Appendix Tables 5 and 9) also showed marked variations. Marked variations in calcium and phosphorus balances were also noted by Blackwood et al. (1936). It was observed that phosphorus retention was lower the first two periods than during the last two periods. Phosphorus retention tended to vary to some degree with nitrogen retention.

The data presented in this investigation indicate that raw whole milk is readily digested and utilized by the young calf. Apparently the young calf is not able to digest and assimilate evaporated milk as readily as raw whole milk, although the differences are small. The data also show that milk replacers of the type used in this investigation are of little value to the calf until approximately 25 days of age. Thereafter these feeds were considerably more digestible, although not as digestible as comparable feeds by adult animals.

SUMMARY

Ten male calves were allotted to three experiments. Two groups of four 10-day-old calves each were assigned to 4 x 4 Latin square metabolism experiments. Fecal collections were made utilizing a simplified bag technique. The apparent digestibilities of the dry matter and other feed constituents of five milk replacers, evaporated milk and raw whole milk were determined. Nitrogen, calcium and phosphorus balances were determined. The effect of age of the calves on the apparent digestibility of the various feeds was studied. One experiment was conducted with two calves to compare the digestibility of evaporated and raw whole milk in a continuous trial.

The variability of the milk replacer data in the first experiment indicated the inadequacy of 2-day fecal and urine collection periods. The 4-day collection periods used in the third experiment appeared to be sufficient.

The mean coefficient of apparent dry matter digestion of raw whole milk was 94.8; crude protein, 90.1; ether extract, 97.8; and nitrogen-free extract, 97.1. The dry matter of evaporated milk was 76.8% digested by a 10- to 14-day-old calf and an average of 90.0% by 19- to 38-day-old calves. The average apparent dry matter digestibility of the milk replacers increased from 25.0% for 10- to 14-day-old calves to an average of 75.4% for 26- to 38-day-old calves. Similar increases in digestibility with increased age of the calves were noted for the crude pro-

tein and nitrogen-free extract fractions. The most digestible fraction was the nitrogen-free extract and the least digestible the crude protein.

The crude protein of the raw whole milk was slightly less digestible by the 10- to 14-day-old calf than in subsequent periods. For the evaporated milk it was low for the 10- to 14-day-old calf and at its maximum value by 19 to 22 days of age. During the first collection period the crude protein of the milk replacers was considerably less digestible than that of the milks. It attained its maximum value by 26 days of age.

Between the ages of 26 and 38 days the evaporated milk was slightly less digestible than the raw whole milk. The different milk replacers were approximately equally digestible but were significantly less so than the milks. This was most noticeable in the crude protein fraction.

Crude fiber was essentially indigestible throughout the experiments.

The percentage and actual amount of nitrogen, calcium and phosphorus retained was greater for calves fed raw whole milk than those fed the evaporated milk or milk replacer rations. Nitrogen and phosphorus balances were low or negative in 10- to 22-day-old calves fed the milk replacer rations. The older calves had positive balances.

The data indicate that the milk replacers used in this investigation were not satisfactorily utilized by the calf until it was approximately 25 days of age.

LITERATURE CITED

Allison, J. B., J. A. Anderson, and R. D. Seeley. 1946. The determination of the nitrogen balance index in normal and hypoproteinemic dogs. Ann. N. Y. Acad. Sci. 47:245-271.

Anderson, H. D., C. A. Elvehjem, and J. E. Gonce, Jr. 1940. A comparison of the nutritive values of raw, pasteurized and evaporated milks for the dog. J. Nutr. 20:433-443.

Archibald, J. G. 1928. Calf meal studies. I. Laboratory experiments in the improvement of physical condition. II. Feeding experiments with cooked and uncooked meals. J. Dairy Sci. 11:119-135.

Archibald, J. G., and E. Bennett. 1935. The phosphorus requirements of dairy heifers. J. Agr. Res. 51:83-96.

Armstrong, D. G., T. R. Preston, and R. H. Armstrong. 1954. Digestibility of a sample of pasture grass by calves. Nature 174:1182-1183.

Ascroft, D. W. 1933. Effect of milk products on pH of intestinal contents of domestic fowl. Poultry Sci. 12:292-298.

Association of Official Agricultural Chemists. 1950. Official Methods of Analysis of the Association of Official Agricultural Chemists. 7th Ed. Washington, D. C.

Barnes, R. H., and D. K. Bosshardt. 1946. The evaluation of protein quality in the normal animal. Ann. N. Y. Acad. Sci. 47:273-296.

Beach, C. L. 1906. The facility of digestion of foods a factor in feeding. Conn. Agr. Expt. Sta. Bull. 43:1-23.

Bechdel, S. I. 1917. Studies in veal production. Pa. Agr. Expt. Sta. Rpt. pp. 337-347.

Becker, R. B., P. T. Dix Arnold, and S. P. Marshall. 1951. Development of the bovine stomach during fetal life. J. Dairy Sci. 34:329-332.

Bender, C. B., and J. W. Bartlett. 1929. A study of the factors affecting the growth of dairy heifers. J. Dairy Sci. 12:37-48.

Bender, C. B., and E. J. Perry. 1930. The New Jersey dry-fed calf mixture. N. J. Agr. Expt. Sta. Ext. Bull. 73:1-4.

Blackwood, J. H., and S. Morris, and N. C. Wright. 1936. The nutritive value of raw and pasteurized milk for calves. The assimilation and retention of nitrogen, phosphorus and calcium. J. Dairy Res. 7: 228-237.

Blaxter, K. L., and W. A. Wood. 1951a. The nutrition of the young Ayrshire calf. 1. The endogenous nitrogen and basal energy metabolism of the calf. Brit. J. Nutr. 5:11-25.

Blaxter, K. L., and W. A. Wood. 1951b. The nutrition of the young Ayrshire calf. 3. The metabolism of the calf during starvation and subsequent realimentation. Brit. J. Nutr. 5:29-55.

Blaxter, K. L., and W. A. Wood. 1951c. The nutrition of the young Ayrshire calf. 4. Some factors affecting the biological value of protein determined by nitrogen balance methods. Brit. J. Nutr. 5:55-67.

Blaxter, K. L., and W. A. Wood. 1952a. The nutrition of the young Ayrshire calf. 5. The nutritive value of cow's whole milk. Brit. J. Nutr. 6:1-12.

Blaxter, K. L., and W. A. Wood. 1952b. The nutrition of the young Ayrshire calf. 7. The biological value of gelatin and of casein when given as the sole source of protein. Brit. J. Nutr. 6:56-71.

Block, R. J., and H. H. Mitchell. 1946. The correlation of the amino-acid composition of proteins with their nutritive value. Nutr. Abs. and Rev. 16:249-278.

Bondi, A., and Y. Birk. 1952. A difference in in vitro pancreatic digestion between animal and plant protein feeds. Nature 170:673.

Bosshardt, D. K., W. Paul, K. O'Doherty, and R. H. Barnes. 1946. The influence of caloric intake on the growth utilization of dietary protein. J. Nutr. 32:641-651.

Bowman, D. E. 1944. Fractions derived from soybeans and navy beans which retard tryptic digestion of casein. Proc. Soc. Exptl. Biol. Med. 57:139-140.

Brenner, M. W., and P. L. Harris. 1939. Improved method for the wet ashing of biological materials. Chemist Analyst 28:55-56.

Brown, D. C., J. Read, and H. S. Willard. 1953. Slacked lime as a preventive of scours for whey-fed calves. J. Dairy Sci. 36:319-324.

Cannon, P. R., and B. W. McNease. 1923. Factors controlling intestinal bacteria. The influence of hydrogen-ion concentration on bacterial types. J. Infectious Dis. 32:175-180.

Carpenter, K. J. 1951. The relative nutritional values of animal and vegetable proteins for animals. Brit. J. Nutr. 5:243-249.

Carr, R. H., and G. Spitzer, R. E. Caldwell, and O. H. Andersen. 1917. The efficiency of certain milk substitutes in calf feeding. J. Biol. Chem. 28:501-509.

Carroll, R. W., G. W. Hensley, and W. R. Graham, Jr. 1952. The site of nitrogen absorption in rats fed raw and heat-treated soybean meals. Science 115:36-39.

Carroll, R. W., G. W. Hensley, C. L. Sittler, E. L. Wilcox, and W. R. Graham, Jr. 1953. Absorption of nitrogen and amino acids from soybean meal as affected by heat treatment or supplementation with aureomycin and methionine. Arch. Biochem. Biophys. 45:260-269.

Catel, W. 1932. Uber den einfluss roher und autoklavierter Milch auf Wachstum und Stoffwechsel (Tierversuche). (Influence of raw and autoclaved milk on growth and metabolism (animal experiments). Monatsschr. f. Kenderheilk. 53:14-17. (Nutr. Abs. Rev. 2:359, 1932)

Causeret, J. 1953. Influence de la consommation' d'eau sur l'elimination intestinale et renale due calcium. (Effect of water consumption on the calcium excretion by the intestine and kidney.) Compt. Rend. Acad. Sci. 237:664-665. (Nutr. Abs. Rev. 24:383, 1954)

Claudinin, D. R., W. W. Cravens, C. A. Elvehjem, and J. G. Halpin. 1946. Deficiencies in overheated soybean oil meal. Poultry Sci. 25:399.

Claudinin, D. R., W. W. Cravens, C. A. Elvehjem, and J. G. Halpin. 1947. Deficiencies in over-heated soybean oil meal. Poultry Sci. 26:150-156.

Claudinin, D. R., W. W. Cravens, C. A. Elvehjem, and J. G. Halpin. 1948. The relationship between time and temperature to the nutritive value of soybean oil meal. Poultry Sci. 27:370-371.

Conrad, H. R., and J. W. Hibbs. 1953. The effect of rumen inoculations and the ratio of hay to grain eaten on digestion and nitrogen retention in high roughage fed calves. J. Dairy Sci. 36:600.

Conrad, H. R., and J. W. Hibbs. 1954. A high roughage system for raising calves based on early rumen development. IV. Synthesis of thiamine and riboflavin in the rumen as influenced by the ratio of hay to grain fed and initiation of dry feed consumption. J. Dairy Sci. 37:512-522.

Conrad, H. R., J. W. Hibbs, and W. D. Pounden. 1954. The influence of the ration and early rumen development on the volatile fatty acid content of rumen juice and blood sugar levels in high roughage fed calves. J. Dairy Sci. 37:664.

Conrad, H. R., J. W. Hibbs, W. D. Pounden, and T. S. Sutton. 1950. The effect of rumen inoculations on the digestibility in young calves. J. Dairy Sci. 33:585-592.

Conquest, V., A. W. Turner, and H. J. Reynolds. 1938. Soft curd milk produced with pancreatic concentrate. J. Dairy Sci. 21:361.

Converse, H. T. 1954. Calcium requirements of dairy cattle. U. S. Dept. Agr. Tech. Bull. 1092:1-25.

Cook, B. B., A. F. Morgan, B. Singer, and J. Parker. 1951a. The effect of heat treatment on the nutritive value of milk proteins. II. Rat growth studies with casein and lactalbumin and their lactose derivatives. J. Nutr. 44:63-81.

Cook, B. B., A. F. Morgan, E. O. Weast, and J. Parker. 1951b. The effect of heat treatment on the nutritive value of milk proteins. J. Nutr. 44:51-61.

Craine, E. M., and R. G. Hansen. 1952. The short-chain fatty acids of the peripheral blood of goats. J. Dairy Sci. 35:631-636.

Daniel, F. K., and E. H. Harvey. 1947. Some observations on the nutritional value of dialyzed whey solids. J. Nutr. 33:429-436.

Davis, H. P., and G. W. Trimberger. 1946. Distillers by-products and soybean meal in dry calf starters for calves on limited quantities of milk. Nebr. Agr. Expt. Sta. Res. Bull. 142:1-29.

DeMan, T. J. 1951. Kalveropfokproef met Gehydurde Soya-Olie. Tijdschr. Diergeneesk. 76:175.

Desikachar, H. S. R., S. S. De, and V. Subrahmanyan. 1946. Studies on the nutritive value of soya milk. I. Nutritive value of the protein. Ann. Biochem. Exptl. Med. 6:49-56.

Dukes, H. H. 1947. The Physiology of Domestic Animals. 6th ed. George Banta Publishing Co. Menasha, Wis. p. 272.

Duncan, D. L. 1955. The physiological effects of lactose. A review. Nutr. Abs. Rev. 25:309-320.

Dye, J. A., and D. Orsini. 1952. Glycemic levels and rumen development in calves. Fed. Proc. 11:39.

Ellenberger, H. B., J. A. Newlander, and C. H. Jones. 1951. Effects of feeding different grades of hay and cod-liver oil concentrate to dairy cattle. I. From birth to 90 days of age. Vt. Agr. Expt. Sta. Bull. 564:1-48.

Elting, E. C., and J. P. LaMaster. 1934. Raising dairy calves by a limited milk feeding plan. S.C. Agr. Expt. Sta. Bull. 293:1-19.

Emery, R. S. 1951. Digestion of corn oil and milk fat by the dairy calf. M. S. Thesis, Colorado A. and M. College, Fort Collins, Colo.

Espe, D. L., and C. Y. Cannon. 1935. The relation of the fat content of milk to the passage of the milk curd from the stomach of the calf. J. Dairy Sci. 18:141-147.

Espe, D. L., and C. Y. Cannon. 1937. Gastric secretion in ruminants. Am. J. Physiol. 119:720-723.

Espe, D. L., and J. A. Dye. 1932. Effect of curd tension on the digestibility of milk. Am. J. Dis. Children 43:62-69.

Fairbanks, B. W., and H. H. Mitchell. 1935. The nutritive value of skimmilk powders, with special reference to the sensitivity of milk proteins to heat. J. Agr. Res. 51:1107-1121.

Fingerling, G. 1908. Beiträge zur Physiologie der Ernährung wachsender Tiere. 1. Ersatz von Vollmilch durch Magernilch mit und ohne Surrogate bei Saugkälbern. Landw. Vers. Sta. 68:141-188.

Fingerling, G., und F. Honcamp. 1934. Uber den Wert der Holzzuckerhefe als Futtermittel. I. Mitteilung: Der Nährwert der Holzzuckerhefe auf Grund von Stoffwechsel-und Respirations-versuchen met Schweinen und Weiderkauern. Landw. Vers. Sta. 118:263-342.

Fischer, J. E., and T. S. Sutton. 1949. Effects of lactose on gastrointestinal motility. A review. J. Dairy Sci. 32:139-162.

Fiske, C. H., and Y. Subbarow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375-400.

Flipse, R. J., C. F. Huffman, H. D. Webster, and C. W. Duncan. 1950. Carbohydrate utilization in the young calf. I. Nutritive value of glucose, corn syrup and lactose as carbohydrate sources in synthetic milk. J. Dairy Sci. 33:548-556.

Forbes, E. B., F. M. Beegle, C. M. Fritz, and J. E. Mensching. 1914. A chemical study of the nutrition of swine. Ohio Agr. Expt. Sta. Bull. 271:225-261.

Forbes, E. B., W. W. Braman, M. Kriss, and R. W. Swift. 1931. The metabolizable energy and net energy values of corn meal when fed exclusively and in combination with alfalfa hay. J. Agr. Res. 43:1015-1026.

Forbes, E. B., J. W. Bratzler, and C. E. French. 1940. The utilization of certain feeding stuffs by cattle. Pa. Agr. Expt. Sta. Bull. 391:1-14.

Forbes, R. M., and M. Yoke. 1955. Effect of energy intake on the biological value of protein fed to rats. J. Nutr. 55:499-506.

Fournier, P. 1954. L'effect protecteur du lait vis-a-vis de la resorption des os de la rate allaitante. Compt. Rend. Acad. Sci. 238:391-393.

Fuqua, M. E., and M. B. Patton. 1953. Effect of three levels of fat intake on calcium metabolism. J. Amer. Dietetic Assoc. 29:1010-1013.

Garrigus, W. P., and H. H. Mitchell. 1935. The effect of grinding on the digestibility of corn by pigs and on its content of metabolizable energy. J. Agr. Res. 50:731-735.

Gillam, A. E., K. M. Henry, S. K. Kon, and P. White. 1938. The effect of commercial sterilization on the nutritive value of milk. III. Effect of the vitamin A and carotene content of milk. J. Dairy Res. 9:17-21.

Grindley, H. S., W. J. Carmichael, and C. I. Newlin. 1917. Digestion experiments with pigs with special reference to the influence of one feed upon another, and to the individuality of pigs. Ill. Agr. Expt. Sta. Bull. 200:55-94.

Ham, W. E., and R. M. Sandstedt. 1944. A proteolytic inhibiting substance in the extract from unheated soybean meal. J. Biol. Chem. 154:505-506.

Hamilton, T. S., H. H. Mitchell, and W. G. Kummlade. 1928. The digestibility and metabolizable energy of soybean products. Ill. Agr. Expt. Sta. Bull. 303:239-295.

Hansard, S. L., C. L. Comar, and M. P. Plumlee. 1954. The effects of age upon calcium utilization and maintenance requirements in the bovine. J. Animal Sci. 13:25-36.

Hathaway, I. L., G. W. Trimberger, and H. P. Davis. 1943. The use of dried whey and blood meal in the raising of calves on limited amounts of milk. Nebr. Agr. Expt. Sta. Res. Bull. 132:1-19.

Hayward, H. 1902. The rearing of calves on milk substitutes. Pa. Agr. Expt. Sta. Bull. 60:3-12.

Hayward, J. W., H. Steenbock, and G. Bohstedt. 1936. The effect of heat as used in the extraction of soybean oil upon the nutritive value of the protein of soybean oil meal. J. Nutr. 11:219-234.

Henry, K. M., J. Houston, S. K. Kon, and L. W. Osborne. 1939. The effect of commercial drying and evaporation on the nutritive properties of milk. J. Dairy Res. 10:272-293.

Henry, K. M., and S. K. Kon. 1938. The effect of commercial sterilization on the nutritive value of milk. II. Biological value and digestibility of the proteins (nitrogen) of milk. J. Dairy Res. 9:5-11.

Henry, K. M., and S. K. Kon. 1945. Changes on storage in the biological value of the proteins of dried skim milk. Biochem. J. 39:XXVI-XXVII.

Henry, K. M., and S. K. Kon. 1948. Deterioration on storage of dried skim milk. IV. Changes in the biological value of the proteins. J. Dairy Res. 15:341-356.

Henry, K. M., and S. K. Kon. 1953. The effect of cystine and methionine, added separately or together, on the biological value of the proteins of dried skimmilk. Brit. J. Nutr. 7:29-33.

Henry, K. M., S. K. Kon, C. H. Lea, and J. C. D. White. 1948. Deterioration on storage of dried skimmilk. III. Physical, chemical and palatability changes in the stored powders. J. Dairy Res. 15:298-340.

Henry, K. M., S. K. Kon, and S. J. Rowland. 1946. Studies of the biological value of the proteins of dried skimmilk: Value as an addition to bread; tests with young and older rats; effects of storage. J. Dairy Res. 14:403-414.

Henry, K. M., S. K. Kon, and M. B. Watson. 1937. The effect of commercial pasteurization on the biological value and digestibility of the proteins of milk. Milk and Nutrition. Part 1, Reading, England. pp. 37-44. (Nutr. Abs. Rev. 7:112, 1937)

Heupke, W., und A. V. Marx. 1928. Untersuchungen über Verdauung aus geschlossenen Pflanzenaellen u. ihre Bedeutung für Physiologie u. Pathologie der Verdauung beim Menschen. VI. Fettverdauung aus rohem Pflazengewebe. (Fat digestion from raw plant tissue.) Arch. Verdauungskrankh. 44:23-31. (Bio. Abs. 4:728, 1930)

Hibbs, J. W., and W. D. Pounden. 1948. The influence of the ration and early rumen development on the changes in the plasma carotenoids, vitamin A and ascorbic acid of young dairy calves. J. Dairy Sci. 31:1055-1061.

Hill, E. G., and A. R. Patton. 1947. The Maillard reaction in microbiological assay. Science. 105:481-482.

Hittcher. 1909. Cited by Savage, E. S., and C. M. McCay. 1942. The nutrition of calves: A review. J. Dairy Sci. 25:595-650.

Hobbs, C. S., S. L. Hansard, and E. R. Barrick. 1950. Simplified methods and equipment used in separation of urine from feces eliminated by heifers and by steers. J. Animal Sci. 9:565-570.

Hodson, A. Z. 1950. Amino acid content of evaporated milk on prolonged storage. Ind. Eng. Chem. 42:694-695.

Hodson, A. Z. 1952. Nutritive value of milk proteins. I. Stability during sterilization and storage of evaporated milk as determined by the rat repletion method. Food Res. 17:168-171.

Hodson, A. Z. 1954. Nutritive value of milk proteins. II. Stability during sterilization of evaporated milk as determined by the rat growth method. Food Res. 19:224-230.

Hodson, A. Z., and G. M. Krueger. 1947. Changes in the essential amino acid content of the proteins of dry skim milk on prolonged storage. Arch. Biochem. 12:51-55.

Honcamp, F., W. Helms, P. H. Malkomesius, C. Eichler, und M. Suchsse. 1932. Über die Verwendung und Verwertung von Molkereirückstanden als Futtermittel in der landwirtschaftlichen Nutzviehhaltung. Biedermanns Zentralbl. Agrikulturchen. 4:323-352. (Bio. Abs. 9:623, 1935)

Howe, P. E. 1921. The fat content of feces of young calves. Am. J. Dis. Children 21:57-64.

Huffman, C. F., C. W. Duncan, and E. J. Benne. 1951. The digestibility of distillers grain solubles by dairy cattle. Proc. 6th Distillers Feed Conf., Cincinnati, Ohio. pp. 18-23.

Huffman, C. F., C. W. Duncan, C. S. Robinson, and L. W. Lamb. 1933. Phosphorus requirement of dairy cattle when alfalfa furnishes the principle source of protein. Mich. Agr. Expt. Sta. Tech. Bull. 134:1-75.

Huffman, C. F., C. H. Noller, and J. A. Williams. 1954. Distillers dried solubles in milk replacers. Proc. 9th Distillers Feed Conf., Cincinnati, Ohio. pp. 12-16.

Hughes, J. S., and H. W. Cave. 1931. Coefficients of digestibility of the constituents of milk and the balance of calcium and phosphorus in calves on a milk diet. J. Nutr. 4:163-169.

Hutchinson, J. C. D., and S. Morris. 1936. The digestibility of dietary protein in the ruminant. I. Endogenous nitrogen excretion on a low nitrogen diet and in starvation. Biochem. J. 30:1682-1694.

Ingham, L. W., D. Meade, and M. H. Berry. 1930. Calf feeding investigations. I. Raising dairy calves on nurse cow, whole milk, remade skim milk, and calf meal. Md. Agr. Expt. Sta. Bull. 319:277-302.

Jacobson, N. L., C. V. Cannon, and B. H. Thomas. 1949. Filled milks for dairy calves. I. Soybean oil versus milk fat. J. Dairy Sci. 32:429-434.

Jarvis, R. N., and R. K. Waugh. 1949. Cottonseed oils in purified and skim milk diets for calves. J. Dairy Sci. 32:665-670.

Jones, I. R., P. M. Brandt, and F. D. Wilson. 1931. Raising calves on dry calf meals. Ore. Agr. Expt. Sta. Bull. 290:6-30.

Jukes, T. H., and W. L. Williams. 1953. Nutritional effects of antibiotics. Pharmacol. Rev. 5:381-420.

Kellner, O. 1926. The Scientific Feeding of Animals. Translated by W. Goodwin, The Mayflower Press, Plymouth, England. pp. 226-230.

Kellner, O., und R. Neumann. 1910. Futterungsversuche mit Schweinen über die Verdaulichkeit getrockneter Kartoffeln und des entfettoten Sojabohnenmehls. Landw. Vers. Sta. 73:235-240.

Kesler, E. M., and C. B. Knodt. 1951. B-vitamin studies in calves. I. The relation between age of calf and levels of thiamine, riboflavin and nicotinic acid found in the digestive tract. J. Dairy Sci. 34:145-148.

Kesler, E. M., M. Ronning, and C. B. Knodt. 1951. Some physical characteristics of the tissue and contents of the rumen, abomasum and intestines in male Holstein calves of various ages. J. Animal Sci. 10:969-974.

Kline, O. L., J. A. Keenan, C. A. Elvehjem, and E. B. Hart. 1932. Lactose in nutrition. J. Biol. Chem. 98:121-131.

Knodt, C. B. 1953. Antibiotics in the growth of ruminant animals. Antibiotics and Chemotherapy 3:442-448.

Knodt, C. B., and E. B. Ross. 1952. The value of various levels of aureomycin in milk replacements for dairy calves. J. Dairy Sci. 35:493.

Kon, S. K. 1938. The effect of commercial sterilization on the nutritive value of milk. VII. Conclusions. J. Dairy Res. 9:207.

Kraft, R. A., and A. F. Morgan. 1951. The effect of heat treatment on the nutritive value of milk proteins. IV. The biological value of unheated and autoclaved dried skim milk. J. Nutr. 45:567-581.

Krauss, W. E., C. F. Monroe, and C. C. Hayden. 1935. Dry feed systems of raising calves. Ohio Agr. Expt. Sta. Bimon. Bull. 173:45-51.

Lasby, H. A., and L. S. Palmer. 1935. Nutritional anemia, calcium, phosphorus and nitrogen balance and bone composition of rats fed raw versus pasteurized milk. J. Dairy Sci. 18:181-192.

Lassiter, C. A., D. M. Seath, G. M. Bastin, and R. F. Elliott. 1953. Grain distillers dried solubles in a limited whole milk feeding program for calves. Proc. 8th Distillers Feed Conf., Cincinnati, Ohio. pp. 38-44.

Leighton, R. E. 1955. Personal communication

Lelu, P. 1934. L'utilisation digestive comparée des matieres albuminoides chez diverses espéces animales. Compt. Rend. Acad. Sci. 198:2022-2024.

Lindsey, J. B. 1904. Raising dairy calves without milk. Mass. Agr. Expt. Sta. Rpt. pp. 80-86.

Lindsey, J. B. 1915. Substitutes for milk in the rearing of dairy calves. Mass. Agr. Expt. Sta. Bull. 164:49-65.

Lindsey, J. B., and J. G. Archibald. 1925. Milk substitutes in the rearing of young calves. Mass. Agr. Expt. Sta. Bull. 223:43-51.

Lindsey, J. B., and J. G. Archibald. 1929. Milk substitutes in the growing of young calves. Mass. Agr. Expt. Sta. Bull. 247:329-330.

Lindsey, J. B., and J. G. Archibald. 1931. Milk substitutes in the growing of young calves. Mass. Agr. Expt. Sta. Bull. 271:271-272.

Lofgreen, G. P., and M. Kleiber. 1953. The metabolic fecal nitrogen excretion of the young calf and the true digestibility of casein. J. Nutr. 49:183-190.

Lofgreen, G. P., J. K. Loosli, and L. A. Maynard. 1951. The influence of energy intake on the nitrogen retention of growing calves. J. Dairy Sci. 34:911-915.

Maillard, L. C. 1912. "Action des acides amines sur les sucres; formation des melanoidins par vois methodique." Comp. Rend. Acad. Sci. 154:66-68.

Malkomesius, Ph., und W. Schramm. 1930. Uber Sojabohnen extraktions--rückstände verschiedener Gewinnungsweise. Landw. Vers. Sta. 110:33-47.

Mangold, E., H. Stotz, J. Schmidt, J. Kliesch, und H. Schmalenbach. 1939. Untersuchungen über verwend-barkeit der von blanckenburgschen Trockenschlempe bei der Schweinemart. Z. Tierernähr. Futtermittelk. 3:147-155. Cited by Schneider, B. H. 1947. Feeds of the World: Their Digestibility and Composition. Jarrett Printing Co., Charleston, W. Va.

Mann, S. O., F. M. Masson, and A. E. Oxford. 1954. Effect of feeding aureomycin to calves upon the establishment of their normal rumen microflora and microfauna. Brit. J. Nutr. 8:246-252.

Marshall, S. P., P. T. Dix Arnold, and R. B. Becker. 1950. Postpartum development of bovine stomach compartments and observations on some characteristics of their contents. J. Dairy Sci. 33:379.

Matthews, C. A., and M. H. Fohrman. 1954. Beltsville growth standards for Holstein cattle. U. S. Dept. of Agr. Tech. Bull. 1099:1-50.

Maynard, L. A., L. C. Norris, and W. E. Krauss. 1925. Rearing calves by the use of calf-meal gruel. N. Y. (Cornell) Agr. Expt. Sta. Bull. 439:1-23.

McCandless, E. L., and J. A. Dye. 1950. Physiological changes in intermediary metabolism of various species of ruminants incident to functional development of the rumen. Am. J. Physiol. 162: 434-445.

McCandlish, A. C. 1923. Studies in the growth and nutrition of dairy calves. V. Milk as the sole ration for calves. J. Dairy Sci. 6: 54-66.

McCandlish, A. C. 1939. Skimmilk powder for calves and a comparison of various supplemental feeds. West Scotland Agr. Coll. Res. Bull. 7:1-64.

McCollum, E. V., and M. Davis. 1915. The cause of the loss of nutritive efficiency of heated milk. J. Biol. Chem. 23:247-252.

McGilliard, A. D., M. Ronning, E. R. Berousek, and C. L. Norton. 1952. The influence of aureomycin and cud inoculation on the growth of dairy calves. J. Dairy Sci. 35:493.

McInroy, E. E., H. K. Murer, and R. Thiessen, Jr. 1949. The effect of autoclaving with dextrose on the nutritive value of casein. Arch. Biochem. 20:256-260.

McMeekan, C. P. 1954. Good rearing of dairy stock. New Zealand Dept. Agr. Bull. 228:1-31.

McNaught, M. L., and J. A. B. Smith. 1947. The role of the microflora of the alimentary tract of herbivora with special reference to ruminants. 4. Nitrogen metabolism in the rumen. Nutr. Abs. and Rev. 17:18-31.

Mead, S. W., W. M. Regan, and J. W. Bartlett. 1924. A study of the factors affecting the growth of dairy heifers. J. Dairy Sci. 7:440-459.

Melnick, D., B. L. Oser, and S. Weiss. 1946. Rate of Enzymic Digestion of proteins as a factor in nutrition. Science 103:326-329.

Menefee, S. G., O. R. Overman, and P. H. Tracy. 1941. The effect of processing on the nitrogen distribution in milk. J. Dairy Sci. 24:953-968.

Michels, J. 1908. Rolled oats as a partial substitute for milk in calf feeding. N. C. Agr. Expt. Sta. Bull. 199:12-15.

Mills, R., H. Breiter, E. Kempster, B. McKey, M. Pickens, and J. Outhouse. 1940. The influence of lactose on calcium retention in children. J. Nutr. 20:467-476.

Minz, R., und E. Schilf. 1932. Uber Gerinnung und Verdaulichkeit der Milch bei Zusatz von Malz enthaltneden Nahrungsstoffen. (Clotting and digestibility of milk to which foodstuffs containing malt have been added.) Ztschr. J. Ernährung 2:311-314. (Nutr. Abs. and Rev. 2:703, 1933)

Mitchell, H. H., T. S. Hamilton, F. J. McClure, W. T. Haines, J. R. Beadles, and H. P. Morris. 1932. The effect of the amount of feed consumed by cattle on the utilization of its energy content. J. Agr. Res. 45:163-191.

Morris, S., and S. C. Ray. 1939. The fasting metabolism of ruminants. Biochem. J. 33:1217-1230.

Morrison, H. B., R. S. Hulce, and G. C. Humphrey. 1922. Economical rations for dairy calves. Wis. Agr. Expt. Sta. Bull. 339:133-134.

Morrison, H. B., R. S. Hulce, and G. C. Humphrey. 1924. Raising dairy calves economically. Wis. Agr. Expt. Sta. Bull. 362:96-99.

Morse, F. W. 1898. The cost of raising calves. N. H. Agr. Expt. Sta. Bull. 58:157-166.

Mortenson, F. N., D. L. Espe, and C. Y. Cannon. 1935. Effect of heating milk on the time which the curds remain in the abomasum of calves. J. Dairy Sci. 18:229-238.

Munro, H. H. 1951. Carbohydrate and fat as factors in protein utilization and metabolism. Physiol. Rev. 31:449-488.

Murley, W. R., N. L. Jacobson, and R. S. Allen. 1952. The effect of aureomycin supplementation on growth and feed utilization of young dairy calves. J. Dairy Sci. 35:846-856.

National Research Council. 1950. Recommended nutrient allowances for dairy cattle. Natl. Res. Council, Washington, D. C.

Nevens, W. B., and D. D. Shaw. 1932. The effect of dairy manufacturing processes upon the nutritive value of milk. I. The apparent digestibility of fresh whole milk and evaporated milk. J. Nutr. 5:485-494.

Nevens, W. B., and D. D. Shaw. 1933a. The effect of dairy manufacturing processes upon the nutritive value of milk. II. The apparent digestibility of fresh whole milk and of powdered whole milk. J. Nutr. 6:139-150.

Nevens, W. B., and D. D. Shaw. 1933b. The relative digestibility by rats of the milk of five breeds of dairy cattle. J. Agr. Res. 46: 463.472.

Noller, C. H., and C. F. Huffman. 1953. Preliminary calf feed report--replacing whole milk at an early age. Proc. 8th Distillers Feed Conf., Cincinnati, Ohio. pp. 45-50.

Norton, C. L. and H. D. Eaton. 1946. Dry calf starters for dairy calves. N. Y. (Cornell) Agr. Expt. Sta. Bull. 835:1-32.

Osborne, T. B., and L. B. Mendel. 1917. The use of soybean as food. J. Biol. Chem. 32:369-387.

Otis, D. H. 1905. Experiments with hand-fed calves. Kan. Agr. Expt. Sta. Bull. 126:163-198.

Outhouse, J., J. Smith, I. Twoney, and M. Thorp. 1935. The influence of lactose, sucrose, and vitamin D on the mineral metabolism of rats. J. Home Econ. 27:541.

Pader, M., D. Melnick, and B. L. Oser. 1948. Factors affecting the availability of lysine in heat-processed casein. J. Biol. Chem. 172:763-769.

Parrish, D. B., E. E. Bartley, D. U. Burris, and R. T. McIntyre. 1953. Properties of the colostrum of the dairy cow. VIII. Digestibility of colostrum and milk by calves during the early postnatal days of life. J. Dairy Sci. 36:489-494.

Parrish, D. B., and F. C. Fountaine. 1952. Contents of the alimentary tract of calves at birth. J. Dairy Sci. 35:839-845.

Patton, A. R., and E. G. Hill. 1948. Inactivation of nutrients by heating with glucose. Science 107:68-69.

Patton, S. 1955. Browning and associated changes in milk and its products: A Review. J. Dairy Sci. 38:457-478.

Pelissier, C. L., S. T. Slack, G. W. Trimberger, K. L. Turk, and J. K. Loosli. 1954. Cud inoculation of dairy calves facts to improve growth. Farm Research 20:No. 2.

Pounden, W. D., and J. W. Hibbs. 1947. Some possible relationships between management, fore-stomach contents and diarrhea in the young dairy calf. J. Dairy Sci. 30:582-583.

Pounden, W. D., and J. W. Hibbs. 1948. The influence of the ration and rumen inoculation on the establishment of certain microorganisms in the rumen of young calves. J. Dairy Sci. 31:1041-1050.

Reid, R. L. 1953. Studies on the carbohydrate metabolism of sheep. 6. Inter-relations between changes in the distribution of levels of glucose and in the levels of volatile fatty acid in the blood of lambs. Australian J. Agr. Res. 4:213-223.

Remer, N. 1932. Uber die Beifütterung von Kohlenhydraten an Saugkalber unter Berucksichtigung der Milcheweissausnutung. (Supplementary feeding of carbohydrates to sucking calves with reference to the utilization of milk protein.) Biedermanns Zentralbl., B. Tierernährung. 3:463-506. (Nutr. Abs. and Rev. 2:178, 1932)

Richter, C. P. 1948. Effect of galactose on the utilization of fat. Science 108:449-450.

Riesen, W. H., D. R. Claudinin, C. A. Elvehjem, and W. W. Cravens. 1947. Liberation of essential amino acids from raw properly heated, and overheated soybean oil meal. J. Biol. Chem. 167:143-150.

Riggs, L. K., and A. Beaty. 1947. Some unique properties of lactose as a dietary carbohydrate. J. Dairy Sci. 30:939-950.

Robinson, C. S., and C. W. Duncan. 1931. The effect of lactose and the the acid-base value of the diet on the hydrogen-ion concentration of the intestinal contents of the rat and their possible influence on calcium absorption. J. Biol. Chem. 92:435-447.

Robinson, C. S., C. F. Huffman, and M. F. Mason. 1929. The results of the ingestion of certain calcium salts and of lactose. J. Biol. Chem. 84:257-267.

Rojas, J.,B. S. Schweigert, and I. W. Rupel. 1948. The utilization of lactose by the dairy calf fed normal or modified milk diets. J. Dairy Sci. 31:81-87.

Rupel, I. W. 1929. Raising the dairy calf. Wis. Agr. Expt. Sta. Bull. 404:16-18.

Rusoff, L. L., A. V. Davis, and J. A. Alford. 1951. Growth-promoting effect of aureomycin on young calves weaned from milk at an early age. J. Nutr. 45:289-300.

Rutherford, E. B., and E. W. Crampton. 1955. Effect of fiber on utilization of dietary protein. Fed. Proc. 14:448.

Savage, E. S., and C. H. Crawford. 1935. Dry concentrates as a partial substitute for whole milk in calf rations. N. Y. (Cornell) Agr. Expt. Sta. Bull. 622:1-29.

Savage, E. S., and G. W. Tailby, Jr. 1909. Substitutes for skimmed milk in raising calves. N. Y. (Cornell) Agr. Expt. Sta. Bull. 269:491-517.

Savage, E. S., and G. W. Tailby, Jr. 1911. Substitutes for skimmed milk in raising calves. N. Y. (Cornell) Agr. Expt. Sta. Bull. 304: 1-32.

Schabinger, J. R., and C. B. Knodt. 1948. Value of distillers dried solubles and distillers dried grains with solubles in the rations of dairy calves. J. Animal Sci. 7:434-439.

Schalk, A. F., and R. S. Amadon. 1928. Physiology of the ruminant stomach. Study of the dynamic factors. N. D. Agr. Expt. Sta. Bull. 216:1-64.

Schantz, E. J., C. A. Elvehjem, and E. B. Hart. 1938. The relation of fat to the utilization of lactose in milk. J. Biol. Chem. 122: 381-390.

Schmaltz. Cited by Martin, P., and W. Schauder. 1938. Anatomie der Haustiere (The Anatomy of Domestic Animals.) Schieckhardt and Ebner, Stutgart, Germany. p.173.

Schmidt, A. 1907. Cited by Cuthbertson, D. P., and A. T. Phillipson. Chap. 14. Microbiology of Digestion. Bourne, G. H., and G. W. Kidder, 1953, Editors. Physiology and Biochemistry of Nutrition: Part II. Academic Press, New York. p. 153.

Schneider, B. H. 1947. Feeds of the World: Their Digestibility and Composition. Jarrett Printing Co., Charleston, W. Va. pp. 299.

Schreier, K., und R. G. Mechtold. 1952. Uber den Einfluss of Glucose auf den Kalkstoffwechsel. (The effect of glucose on calcium metabolism.) Klin. Wochenschr. 30:567-568.

Schroeder, L. J., M. Iacobellis, and A. H. Smith. 1953. Heat processing and the nutritive value of milk and milk products. J. Nutr. 49:549-561.

Schroeder, L. J., R. A. Stewart, and A. H. Smith. 1951. The nutritive effect of heating lactalbumin in the presence of various reducing sugars. J. Nutr. 45:61-74.

Seekles, L., and E. Wegelin. 1952. Valorisation du petit lait dont la teneur en sel et en lactose est diminuee, comme source de proteine dans l'alimentation dew aminaux. (Value of whey with a diminished salt and lactose content as a source of protein in the feeding of animals.) IX Congr. Intermaz. Ind. Agrar., Rome, C. P. 22:1-14. (Nutr. Abs. Rev. 23:198, 1953)

Shahani, K. M., and H. H. Sommer. 1951. The protein and non-protein nitrogen fractions in milk. III. The effect of heat treatments and homogenization. J. Dairy Sci. 34:1035-1041.

Shaw, R. H., T. E. Woodward, and R. P. Norton. 1918. Digestion of starch by the young calf. J. Agr. Res. 18:575-578.

Shipstead, H., and N. P. Tarassuk. 1953. Chemical changes in dehydrated milk during storage. J. Agr. and Food Chem. 1:613-616.

Shohl, A. T., and F. G. Pedley. 1922. A rapid and accurate method for calcium in urine. J. Biol. Chem. 50:537-544.

Shoptaw, L. 1936. Soybean flour as a substitute for cows milk in feeding dairy calves. J. Dairy Sci. 19:95-99.

Slack, S. T., and K. L. Turk. 1951. The nutritive value of dried distillers corn solubles for dairy calves as determined by feeding, digestion and palatability trials. J. Dairy Sci. 34:505.

Snedecor, G. W. 1946. Statistical methods. 4th ed. Iowa Sate College Press, Inc. Ames, Iowa.

Stein, J. F., and C. B. Knodt. 1954. Further studies on the use of soyflour and whey solubles in milk replacement formulas for young dairy calves. J. Dairy Sci. 37:655-656.

Stein, J. F., C. B. Knodt, and E. B. Ross. 1954. Use of special processed soybean flour and whey solubles in milk replacement formulas for dairy calves. J. Dairy Sci. 37:373-379.

Stokstad, E. L. R. 1954. Antibiotics in animal nutrition. Physiol. Rev. 34:25-51.

Sunde, M. L. 1955. Relationship between protein level and energy level in chicks. Fed. Proc. 14:451-452.

Tomarelli, R. M., E. R. Spence, and F. W. Bernhart. 1955. Biological availability of B_6 of heated milk. J. Agr. and Food Chem. 3: 338-341.

Tomme and Taranenko. 1939. Cited by Blaxter, K. L., and W. A. Wood. 1952. The nutrition of the young Ayrshire calf. 5. The nutritive value of cow's whole milk. Brit. J. Nutr. 6:1-12.

Trautmann, A., und J. Schmitt. 1933. Beiträge zur Physiologie des Wiederkäuermagens. 3. Über den Schlundrinnenreflex bei kleinen Weiderkauern. Wiss. Arch. Landw. Abt. B. Tierernähr. u. Tierzucht 9:1-10.

Trimberger, G. W., and H. P. Davis. 1944. Protein supplements in dry calf starters for calves on limited quantities of milk. Nebr. Agr. Expt. Sta. Res. Bull. 134:1-24.

Wallace, H. D., J. K. Loosli, and K. L. Turk. 1951. Substitutes for fluid milk in feeding dairy calves. J. Dairy Sci. 34:256-264.

Warner, R. G., H. F. Bernholdt, C. H. Grippin, and J. K. Loosli. 1953. The influence of diet on the development of the ruminant stomach. J. Dairy Sci. 36:599.

Watson, C. J., J. C. Woodward, W. M. Davidson, G. W. Muir, and C. H. Robinson. 1936. The digestibility of Canadian feeding stuffs--soybean oil meal. Sci. Agr. 17:22-30.

Webb, B. H., E. F. Deysher, and F. E. Potter. 1951. Effect of storage temperature on properties of evaporated milk. J. Dairy Sci. 34: 1111-1118.

Wellman, O. 1914. Fütterungsversuche an Kälbern und Ferkeln mit Vollmich und korrigierter Magermilch. Landw. Jahrb. 46:499-626.

Werner, S. C. 1948. Some effects upon nitrogen balance of the independent variation of protein and calories in man. J. Clin. Invest. 27:561.

Whitnah, C. H. 1943. Nutritive value of milk protein. Food Res. 8: 89-94.

Willard, A. C., and K. Blunt. 1927. A comparison of evaporated with pasteurized milk as a source of calcium, phosphorus, and nitrogen. J. Biol. Chem. 75:251-262.

Williams, J. B., and C. B. Knodt. 1950. The further development of milk replacements for dairy calves. J. Dairy Sci. 33:809-814.

Williams, J. B., and C. B. Knodt. 1951. The supplementation of milk replacements with enzymes and other products. J. Dairy Sci. 10: 975-980.

Williams, P. S., and S. I. Bechdel. 1931. Dry skim milk rations vs. blood-flour rations for calf raising. Pa. Agr. Expt. Sta. Bull. 266:20-21.

Wise, G. H. 1941. Investigations with dairy cattle and dairy products. 54th Ann. Rpt. S. C. Agr. Expt. Sta. pp. 84-87.

Wise, G. H., G. W. Anderson, and P. G. Miller. 1942. Factors affecting the passage of liquids into the rumen of the dairy calf. II. Elevation of the head as milk is consumed. J. Dairy Sci. 25:529-536.

Wise, G. H., P. G. Miller, and G. W. Anderson. 1940. Changes observed in milk "sham fed" to dairy calves. J. Dairy Sci. 23:997-1011.

Van Poucke, R. F., F. W. Hill, R. A. Zuercher, and N. E. Rodgers. 1947. Studies on the value of whey products in early calf nutrition. J. Animal Sci. 6:491.

Young, F. B. 1953. Response of dairy calves to whole milk replacements containing dried whey product, dried skimmilk and fat. J. Dairy Sci. 36:600.

APPENDIX

Appendix Table 1

Individual Growth and Feed Consumption Data

		Body Weight				Feed Consumption		
Milk Replacer	Calf No.	Initial Wt. (lb.)	Final Wt. (lb.)	Gain (lb.)	Ave. Daily Gain (lb.)	Whole Milk (lb.)	Milk Replacer (lb.)	Milk Replacer /Gain (lb./lb.)
1	CS-161	78	123	45	.79	42	100.25	2.23
	-162	79	123	44	.77	52	102.25	2.32
	-163	100	139	39	.68	52	102.25	2.64
	-167	86	160	74	1.30	64	137.00	1.85
	-180	94	139	45	.79	55	103.00	2.29
	-183	107	158	51	.88	60	104.00	2.04
	-184	96	147	51	.88	59	107.00	2.10
2	CS-170	88	150	62	1.09	56	125.00	2.02
	-171	80	132	52	.91	54	113.50	2.18
	-172	82	132	50	.88	52	123.00	2.46
	-173	119	176	57	1.00	53	145.00	2.54
	-179	116	153	37	.65	45	95.75	2.59
	-182	85	141	56	.98	50	123.00	2.20
	-185	87	141	54	.95	53	97.50	1.81
3	CS-174	108	152	44	.77	49	117.50	2.67
	-175	85	132	47	.82	50	109.50	2.33
	-176	101	133	32	.57	46	107.00	3.34
	-177	88	139	51	.89	53	120.00	2.35
	-178	100	157	57	1.00	54	126.50	2.22
	-181	87	152	65	1.16	47	115.00	1.77
	-186	86	136	50	.88	56	95.00	1.90

Appendix Table 2

Coefficients of Apparent Digestibility of Feeds by Individual Animals for each Period--Experiment 1

Period	Feed	Animal	Digestibility Coefficients				
			DM	CP	EE	CF	NFE
1	Evap.	C-899	81.0	60.1	77.1	--	99.1
2	Evap.	C-902	93.2	84.7	95.6	--	97.7
3	Evap.	C-900	88.8	79.6	95.2	--	94.3
4	Evap.	C-906	95.0	92.2	97.5	--	97.1
Average			89.5	79.1	91.4	--	97.0
1	4	C-906	26.8	27.9	--	-42.5	37.5
2	4	C-900	47.5	3.5	--	8.1	75.9
3	4	C-902	59.5	21.6	--	-8.6	79.0
4	4	C-899	72.7	55.9	--	6.6	84.3
Average			56.6	24.9	--	-10.0	72.0
1	5	C-900	58.0	39.1	--	-0.6	58.3
2	5	C-899	65.0	-13.3	--	-11.8	71.8
3	5	C-906	77.9	64.6	--	-5.8	84.3
4	5	C-902	51.5	9.1	--	-21.9	73.9
Average			51.6	27.2	--	-9.1	69.2
1	6	C-902	13.9	-68.9	--	-14.7	70.1
2	6	C-906	42.6	20.5	--	-47.8	58.1
3	6	C-899	65.0	39.8	--	-12.2	82.8
4	6	C-900	63.0	44.8	--	2.9	74.2
Average			46.1	9.0	--	-17.2	71.3

Appendix Table 3

Daily Nitrogen Balances--Experiment 1

Period	Ration	Animal	Intake	Output			Balance
				Feces	Urine	Total	
				gm.	gm.	gm.	gm.
1	Evap.	C-899	17.88	7.28	10.21	17.49	0.39
2	Evap.	C-902	17.88	2.80	9.32	12.12	5.76
3	Evap.	C-900	17.88	3.71	8.25	11.97	5.91
4	Evap.	C-906	17.29	1.37	13.22	14.59	2.70
Average			17.73	3.79	10.25	14.04	3.69
1	4	C-900	18.20	10.31	16.11	26.42	-8.22
2	4	C-899	18.20	10.33	7.78	18.12	0.08
3	4	C-906	18.20	9.12	8.11	17.23	0.96
4	4	C-902	18.20	4.79	8.75	13.55	4.65
Average			18.20	8.64	10.19	18.83	-0.63
1	5	C-906	17.76	9.01	7.93	16.94	0.81
2	5	C-900	17.76	11.38	11.30	22.69	-4.93
3	5	C-902	17.46	4.91	13.79	18.70	-1.24
4	5	C-899	17.46	8.70	8.20	16.90	0.55
Average			17.61	8.50	10.30	18.80	-1.19
1	6	C-902	18.45	19.71	8.45	28.17	-9.71
2	6	C-906	18.16	8.85	10.21	19.07	-0.90
3	6	C-899	18.45	7.58	9.79	17.37	1.08
4	6	C-900	18.45	5.96	8.31	14.28	4.17
Average			18.38	10.53	9.19	19.72	-1.34

Appendix Table 4

Daily Calcium Metabolism--Experiment 1

Period	Ration	Animal	Intake	Output			Balance	Retained
				Feces	Urine	Total		
			gm.	gm.	gm.	gm.	gm.	%
1	Evap.	C-899	4.32	0.91	0.07	0.98	3.33	77.2
2	Evap.	C-902	4.32	0.78	0.10	0.88	3.44	79.6
3	Evap.	C-900	4.32	3.22	0.04	3.26	1.06	24.6
4	Evap.	C-906	4.32	1.76	0.07	1.83	2.50	57.8
Average			4.32	1.67	0.07	1.74	2.58	59.7
1	4	C-900	3.85	3.70	0.09	3.79	0.06	1.4
2	4	C-899	3.85	2.57	0.05	2.63	1.22	31.7
3	4	C-906	3.85	2.08	0.02	2.10	1.74	45.3
4	4	C-902	3.85	2.05	0.02	2.07	1.78	46.2
Average			3.85	2.60	0.05	2.65	1.20	31.2
1	5	C-906	3.76	2.44	0.09	2.53	1.23	32.8
2	5	C-900	3.76	2.82	0.09	2.91	0.85	22.6
3	5	C-902	3.76	2.30	0.07	2.37	1.39	37.0
4	5	C-899	3.76	2.40	0.10	2.50	1.26	33.5
Average			3.76	2.49	0.09	2.58	1.18	31.4
1	6	C-902	3.86	2.20	0.14	2.34	1.52	39.3
2	6	C-906	3.86	3.26	0.00	3.26	0.59	15.4
3	6	C-899	3.86	2.79	0.07	2.86	0.99	25.7
4	6	C-900	3.86	2.07	0.04	2.11	1.74	45.2
Average			3.86	2.58	0.06	2.64	1.22	31.6

Appendix Table 5

Daily Phosphorus Metabolism--Experiment 1

Period	Ration	Animal	Intake	Output			Balance	Retained
				Feces	Urine	Total		
			gm.	gm.	gm.	gm.	gm.	%
1	Evap.	C-899	3.41	0.75	0.72	1.47	1.94	56.9
2	Evap.	C-902	3.41	0.41	0.52	0.93	2.48	72.7
3	Evap.	C-900	3.41	1.53	0.50	2.04	1.37	40.2
4	Evap.	C-906	3.41	0.72	1.05	1.78	1.63	47.9
Average			3.41	0.85	0.70	1.55	1.86	54.5
1	4	C-900	3.20	2.08	1.06	3.14	0.06	1.9
2	4	C-899	3.20	1.59	0.64	2.23	0.97	30.3
3	4	C-906	3.20	1.04	0.75	1.79	1.41	44.1
4	4	C-902	3.20	1.05	0.41	1.46	1.74	54.1
Average			3.20	1.44	0.71	2.15	1.05	32.8
1	5	C-906	3.22	1.52	0.75	2.27	0.95	49.5
2	5	C-900	3.22	1.75	0.76	2.50	0.72	22.4
3	5	C-902	3.22	1.10	0.99	2.09	1.13	35.1
4	5	C-899	3.22	1.33	0.64	1.98	1.24	38.5
Average			3.22	1.42	0.78	2.21	1.01	31.4
1	6	C-902	3.28	1.89	0.75	2.64	0.64	19.5
2	6	C-906	3.28	1.94	0.79	2.73	0.55	16.8
3	6	C-899	3.28	1.41	0.67	2.09	1.19	36.3
4	6	C-902	3.28	1.19	0.68	1.87	1.41	43.0
Average			3.28	1.61	0.72	2.33	0.95	29.0

Appendix Table 6

Coefficients of Apparent Digestibilities of Feeds by Individual Animals for each Period--Experiment 3

Period	Feed	Animal	Digestibility Coefficients				
			DM	CP	EE	CF	NFE
1	W.M.	C-922	92.5	81.2	96.5	--	98.2
2	W.M.	C-925	96.2	92.8	97.9	--	98.0
3	W.M.	C-923	95.0	93.2	98.6	--	95.2
4	W.M.	C-926	95.6	93.0	98.0	--	96.8
Average			94.8	90.1	97.8	--	97.1
1	Evap.	C-925	76.8	56.5	72.3	--	97.4
2	Evap.	C-926	91.1	80.7	96.5	--	95.0
3	Evap.	C-922	87.9	82.7	87.3	--	94.4
4	Evap.	C-923	91.1	87.8	96.1	--	92.9
Average			86.7	76.9	88.1	--	94.9
1	7	C-923	33.8	-8.5	-1.0	-.2	58.9
2	7	C-922	50.2	1.7	48.9	-3.9	76.8
3	7	C-926	76.3	56.3	128.6	-8.0	84.0
4	7	C-925	76.0	51.6	100.2	-1.5	89.5
Average			59.1	25.3	69.1	-4.4	77.3
1	8	C-926	16.3	-44.5	-110.9	0.0	56.8
2	8	C-923	54.8	15.7	-7.5	7.6	83.9
3	8	C-925	78.1	54.9	124.8	13.5	87.7
4	8	C-922	71.2	44.8	89.7	3.8	84.8
Average			55.1	17.7	24.0	6.2	78.3

Appendix Table 7

Daily Nitrogen Balances--Experiment 3

Period	Ration	Animal	Intake	Output			Balance
				Feces	Urine	Total	
				gm.	gm.	gm.	gm.
1	W.M.	C-922	17.96	3.44	7.73	11.17	6.78
2	W.M.	C-925	17.91	1.31	9.98	11.29	6.61
3	W.M.	C-923	16.85	1.16	8.66	9.82	7.02
4	W.M.	C-926	18.06	1.28	7.74	9.02	9.04
Average			17.69	1.80	8.53	10.33	7.36
1	Evap.	C-925	13.10	5.82	11.55	17.37	-4.27
2	Evap.	C-926	17.46	3.44	9.50	12.94	4.52
3	Evap.	C-922	17.46	3.09	10.42	13.52	3.94
4	Evap.	C-923	21.83	2.72	10.52	13.00	8.58
Average			17.46	3.76	10.50	14.26	3.20
1	7	C-923	17.56	13.45	7.68	21.14	-3.58
2	7	C-922	17.56	10.40	8.44	18.84	-1.28
3	7	C-926	17.56	5.40	9.24	14.64	2.91
4	7	C-925	17.56	5.36	10.54	15.91	1.65
Average			17.56	8.65	8.98	17.63	-0.07
1	8	C-926	17.35	16.34	8.97	25.31	-7.96
2	8	C-923	17.35	8.98	14.45	23.43	-6.08
3	8	C-925	17.35	5.43	10.37	15.80	1.55
4	8	C-922	18.72	6.02	9.44	15.46	3.25
Average			17.70	9.19	10.80	19.99	-2.29

Appendix Table 8

Daily Calcium Metabolism--Experiment 3

Period	Ration	Animal	Intake	Output Feces	Output Urine	Output Total	Balance	Retained
			gm.	gm.	gm.	gm.	gm.	%
1	W.M.	C-922	4.46	0.43	0.02	0.45	4.01	89.9
2	W.M.	C-925	4.46	0.58	0.01	0.59	3.87	86.8
3	W.M.	C-923	4.46	1.43	0.09	1.52	2.95	66.1
4	W.M.	C-926	4.46	0.60	0.11	0.71	3.75	84.1
Average			4.46	0.76	0.06	0.82	3.64	81.6
1	Evap.	C-925	3.24	2.24	0.01	2.25	0.99	30.6
2	Evap.	C-926	4.32	1.34	0.06	1.40	2.92	67.6
3	Evap.	C-922	4.32	2.92	0.02	2.94	1.38	31.9
4	Evap.	C-923	5.40	3.73	0.00	3.73	1.67	30.9
Average			4.32	2.56	0.02	2.58	1.74	40.3
1	7	C-923	3.80	2.59	0.05	2.64	1.16	30.5
2	7	C-922	3.80	2.55	0.01	2.56	1.24	32.6
3	7	C-926	3.80	1.43	0.03	1.46	2.34	61.6
4	7	C-925	3.80	2.36	0.02	2.38	1.42	37.5
Average			3.80	2.23	0.03	2.26	1.54	40.5
1	8	C-926	4.16	2.75	0.10	2.85	1.31	31.5
2	8	C-923	4.16	3.19	0.02	3.21	0.95	22.8
3	8	C-925	4.16	1.90	0.04	1.94	2.22	53.4
4	8	C-922	4.50	2.53	0.06	2.59	1.91	42.4
Average			4.25	2.59	0.05	2.64	1.61	37.9

Appendix Table 9

Daily Phosphorus Metabolism--Experiment 3

Period	Ration	Animal	Intake	Output Feces	Output Urine	Output Total	Balance	Retained
			gm.	gm.	gm.	gm.	gm.	%
1	W.M.	C-922	3.48	0.22	0.63	0.86	2.62	75.3
2	W.M.	C-925	3.48	1.67	1.59	1.76	1.72	49.5
3	W.M.	C-923	3.48	0.35	1.26	1.61	1.87	53.7
4	W.M.	C-926	3.48	0.20	1.02	1.22	2.26	65.0
Average			3.48	0.23	1.13	1.36	2.12	60.9
1	Evap.	C-925	2.56	1.12	1.72	2.84	-0.28	-10.9
2	Evap.	C-926	3.41	0.75	1.06	1.81	1.60	47.0
3	Evap.	C-922	3.41	1.06	1.54	2.60	0.81	23.6
4	Evap.	C-923	4.26	1.69	1.22	2.91	1.35	31.8
Average			3.41	1.15	1.39	2.54	0.87	25.5
1	7	C-923	3.18	1.47	1.36	2.83	0.35	11.1
2	7	C-922	3.18	1.46	1.58	3.04	0.14	4.5
3	7	C-926	3.18	0.85	1.01	1.86	1.32	41.6
4	7	C-925	3.18	1.15	1.42	2.57	0.61	19.3
Average			3.18	1.23	1.34	2.57	0.61	19.2
1	8	C-926	3.40	1.79	1.73	3.52	-0.12	-3.6
2	8	C-923	3.40	1.58	1.72	3.30	0.10	2.7
3	8	C-925	3.40	0.97	1.46	2.43	0.97	28.5
4	8	C-922	3.66	1.19	1.44	2.63	1.03	28.3
Average			3.46	1.38	1.59	2.97	0.49	14.2