UREA UTILIZATION BY THE YOUNG DAIRY CALF

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Gail D. Riegle

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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

MASTER OF SCIENCE

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ABSTRACT

A study was carried out to determine the ability of young calves to utilize milk replacers supplemented with urea. Twenty-four male Holstein calves were assigned to three milk replacer diets. A basal ration containing 10% crude protein was compared to rations containing 18% crude protein. One of the 18% crude protein rations was supplemented with milk proteins and urea supplied the supplemental protein in the other. The calves were weaned at ten days of age. At twenty days of age, the eight calves comprising each replacer group were randomly divided into sub-groups A and B, of four calves each. The calves in sub-group A were fed an increasing amount of milk replacer. The calves in sub-group B were fed lesser amounts of milk replacer but were allowed free access to a urea supplemented calf starter. Neither group were allowed hay during the study. Digestion studies were conducted on all calves at 15, 29, and 43 days of age. Chemical analyses were conducted to determine nitrogen balance, apparent protein digestibility, apparent dry matter digestibility, blood urea, and blood non-protein nitrogen values.

Calves fed the urea supplemented milk replacer were found to have significantly greater ($P \leq 0.01$) values for nitrogen balance, and apparent protein digestibility. Dry matter digestibility values increased with age for calves in sub-group B, fed the calf starter as a dry feed, and decreased with increasing age for calves that were continued on the gruel diet alone. Blood levels of urea nitrogen and non-protein nitrogen were found to consistantly decrease with age. In most instances the calves fed the urea supplemented milk replacer had greater blood urea nitrogen and blood non-protein nitrogen values than did the calves fed either of the other two experimental rations.

The data assembled from the digestion studies indicated that the young calf could utilize urea as a dietary source of nitrogen at 15 to 19 days of age.

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

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INTRODUCTION

Many studies have been carried out determining the relative value of urea as a dietary source of protein for mature ruminants. When properly fed, its generally favorable responses are well known and accepted. However, the age at which the young calf can efficiently begin to utilize urea has not been agreed upon.

Most workers agree that on a limited milk feeding program, the young dairy calf is mature in ruminal function; as measured by fatty acid production, at about six weeks of age. Other work has shown that the rate of ruminal development, measured by papillary development, is to a large extent determined by the relative amounts of milk offered in the calf's diet. When dry feeds were introduced into the young calf's diet to supplement or replace the milk being fed, some ruminal papillary development was measured at 12 to 20 days of age. The relative amount of the development was seemingly dependent on the amounts of forages or grains being consumed.

Recent research in urea feeding to young dairy calves indicated that under a limited milk feeding

program, the calf was able to utilize urea efficiently by 4 to 5 weeks of age. In this work no attempt was made to determine the earliest possible age at which the calf could begin to utilize the non-protein nitrogen supplied by urea.

The present research was designed to study the early utilization of dietary urea by the young dairy calf.

A REVIEW OF LITERATURE

The role of urea in ruminant nutrition has recently been extensively reviewed by Du Pont De Nemours and Company (1958), and in an earlier review by Reid (1953). The reviewers indicated the general acceptance of urea, when properly fed, as a source of dietary nitrogen for mature ruminants.

The use of urea as a source of protein for dairy heifers has been investigated by several workers. Lassiter et. al. (1958), working with dairy heifers, compared concentrate rations containing 3, 5, and 7% urea. They found a decrease in daily gain and feed consumption for each increase in the level of urea fed. Additional studies reported by Lassiter (1958) indicated that the heifers could utilize concentrate rations containing as much as 5% urea when sulfur supplementation was provided. They found that heifers fed concentrate rations containing 7% urea did not grow satisfactorily regardless of sulfur supplementation.

In tests conducted by Parham et. al. (1955), 19 to 33 months old heifers showed no significant decrease in gains when ammoniated molasses and urea sup-

plied 18% of the ration crude protein. However, more energy per unit of gain was required by the animals receiving urea.

Bartlett and Cotton (1933) reported that dairy heifers 7 to 17 months of age utilized urea as well as conventional vegetable proteins. They also observed that the urea supplemented heifers gained significantly more than heifers fed a low protein control ration.

However, Hart et. al. (1939) working with dairy heifers, observed that when 70% of the dietary nitrogen was in the form of urea, diuresis along with increased levels of blood urea occurred. These workers concluded that less efficient utilization of the urea protein was obtained. Most authors agree that when feeding urea to functionally mature ruminants urea nitrogen can replace up to 1/3 of the total protein in the ration without significantly reducing utilization efficiency.

Experimental data concerning the utilization of urea for dairy calves younger than 6 months of age are not as plentiful. Urea utilization by young dairy calves was studied by Brown et. al. (1958).

It was reported that a 12.1% protein equivalent calf starter (46.3% of the nitrogen supplied by urea) was adequate for above normal growth of calves fed a limited milk ration for 42 days. Nitrogen balance data indicate that nitrogen retention increased significantly with age. Also they found that the blood urea nitrogen and plasma protein levels were significantly higher at 2 days of age than 4, 8, or 12 weeks of age.

Earlier work by Brown et. al. (1956) compared a 6.7% crude protein calf starter with a 15.1% crude protein urea supplemented starter (urea contributing 54.2% of the total protein) and a 15.2% crude protein conventional milk protein supplemented starter. The calves grew at comparable rates during the first six weeks when milk was being fed, after which the calves on both supplemented rations grew significantly faster than the calves fed the low protein rations. Differences between the urea-supplemented and conventional protein groups as regards average daily gain, total starter consumption, or pounds of feed required per pound of gain were not significant. These workers observed that the calves on the urea ration digested a lower percentage of crude fiber than those fed the

conventional protein supplemented diet. Although the results of these two trials were influenced by the milk feeding, they indicate that a portion of the nitrogen requirements of the young calf can be supplied by the addition of urea to the ration.

Urea utilization trials on young non-ruminants generally have not given favorable results. Taylor and Ringer (1913) in their work with dogs, Hanson and Ferrin (1955) with hogs, and Liu et. al. (1955) also working with hogs reported that little if any nutritional benefits are derived from dietary urea. Braude (1942), in a study of rations utilizing synthetic proteins, also reported unfavorable results when urea was incorporated into swine rations.

An extensive study on urea utilization by swine, conducted by Hays et. al. (1957), demonstrated that when urea was incorporated into the diet, feed efficiency was significantly reduced, feed required per pound of gain increased linearly as the percentage of urea in the ration was increased, and the percent of nitrogen retained decreased as the level of urea in the diet was increased. The replacement of 10 or 20% of the protein with urea significantly reduced the rate

of gain.

Kress and Marcy (1940) fed urea to rats and reported almost complete recovery of the urea in the urine and feces.

Most studies of urea utilization in poultry have yielded negative results. Slinger et. al. (1952) reported that growth rates in chicks were not improved by the addition of urea to diets suboptimal in protein level.

Conversely, in tests conducted by Liu et. al. (1955) on growing swine, a small, but definite amount of urea labeled with N^{15} was absorbed into tissue proteins. Grafe et. al. (1913) reported that the addition of urea to the diets of swine increased nitrogen retention.

Rumen development and the utilization, digestibility, and retention of non-protein nitrogen has been studied extensively in recent years. Conrad and Hibbs (1953 and 1954) conducted several extensive studies concerning ruminal development by young dairy calves on high roughage diets. Their data indicated that feeding of high quality roughages to the very young calf enhances the development of types of bacteria

that are numerous in the mature rumen, and also increases the production of volatile fatty acids in the rumen. This work indicated that the rumen is functionally mature after 6 weeks of age.

According to Lengemann and Allen (1955), there are great differences in rumen contents between 1 and 2 month old calves. They report that the development of adult-like rumen function is gradual and starts early in the life of the calf. These workers found that many of the changes were dependent on the nature of the diet and the amount and kinds of bacteria ingested by the calf. Using fatty acid production as a measure of development, they observed a stabilization of the relative percentages of acetic, butyric, and propionic acids by the second month of age. They concluded that at 6 months of age the rumen contained percentages of the volatile fatty acid that were high enough to consider the rumen adult in function.

McCarthy and Kesler (1956), working with 1 to 15 weeks old Holstein calves, found that blood glucose decreases concurrent with increases in the levels of the blood volatile fatty acids with increasing age. This experiment showed a transition in the metabolites

involved in energy metabolism. At birth and for a short time afterward, the calf relies on glucose for its major energy needs. As the calf matures, the increase in volatile fatty acids is probably the result of increased rumen activity. It was found that all factors began to shift at 1 week of age. The levels of volatile fatty acids in the rumen fluid and the ability of this fluid to digest cellulose (by 1 week of age) indicated at least a partially functioning rumen had been developed. Blood volatile fatty acids underwent their largest increases in concentration during the first 6 weeks. At this stage the concentrations were sufficient to contribute considerably to the metabolic needs of the animal. These authors concluded that mature development of the rumen is completed at 5 to 6 weeks of age.

Kesler et. al. (1951) found a pronounced increase in weights of rumen contents and tissues between the ages of 32 and 42 days. It appeared that rumination had begun at 6 weeks of age.

That calves have at least a partially functioning rumen at an early age was also observed by Swanson et. al. (1958). It was reported that at 6 to 14 days

of age, 79% of the Holsteins and 64% of the Jerseys studied were ruminating. By 20 to 28 days all the Holsteins and 91% of the Jerseys were ruminating. Examination of rumen contents showed that 11 calves that were killed from 14 to 22 days of age had been ruminating normally and 6 that were killed from 12 to 15 days had not been ruminating effectively. It was reported that effective rumination commenced in the hand-fed calf before it was 3 weeks of age.

Work by Martin et. al. (1959) illustrated that the young calf was able to absorb volatile fatty acids from its digestive tract by 3 weeks of age. It was reported that while it is possible for the calf to absorb volatile fatty acids at an earlier age, the absorbing ability is enhanced by the developing rumen mucosa. It was also observed that if the young calf was fed a lactose-free diet, its blood sugar level remained constant as in the shole milk fed calves.

Flatt and co-workers (1958) introduced plastic and cellulose sponges into young calves' rumens. The sponges alone did not induce papillary development of the rumen, but when solutions of purified preparations of the sodium salts of acetic, propionic, butyric, and

lactic acids were introduced, marked development was stimulated. These authors concluded that the end-products of rumen fermentation, rather than the coarse nature of food cause rumen papillary development.

Sander et. al. (1959) added sodium acetate, sodium propionate, sodium butyrate, sodium chloride, and glucose to the rumens of young dairy calves and observed the effects on rumen mucosal development. The administration of sodium butyrate or sodium propionate caused marked development, however, adding sodium acetate, sodium chloride, or glucose caused very little mucosal development. It was hypothesized that rumen papillary development was a result of the metabolism of certain compounds by the rumen wall and their effect on blood flow supplying the rumen.

Development of rumen papillary epithelium was used as a criterium for rumen function by Flatt et. al. (1956). It was reported that milk-fed calves had the least rumen development when compared to animals fed solid feeds.

Brownlee (1956) also studied papillary development as a measure of rumen development. Newborn and

week-old calves kept on a milk diet did not show development of rumen papillae for 13 weeks. In contrast, week-old calves on a diet of milk plus hay, grass, or concentrates gave an increasing amount of papillary development. Since it was also found that calves kept on a milk diet, increased the weight of their rumen contents as much as 6 times the original weight and, did not have any papillary development, weight of rumen contents considered alone, is not a true measure of rumen development. Roughage alone was not a factor in determining the rate of development of rumen papillae. It was reported that the development was determined by the energy value of the foods or the rapidity with which they were broken down into absorbable fractions.

In further studies by Lengemann and Allen (1959), liberal milk feeding delayed the establishment of adult-like rumen microflora content as compared to limited milk fed calves. A rapid decrease in the aerobic bacterial types, an increase in total numbers of bacteria, and the establishment of protozoa types were apparent within the first 3 weeks of age. The total numbers of bacteria were low until the animals had

become established on diets containing solid feeds. Calves that were continued on milk diets consistantly showed high aerobic bacteria counts. Conversely, the calves that were fed solid feeds at an early age, developed mature levels of protozoa by 5 weeks of age. These calves achieved an acetic acid content of 63 mM per liter between the 6th and 7th week, 18.1 mM per liter of propionic acid by the 3rd week, and 14.5 mM of butyric acid per liter by the 4th week.

Harrison et. al. (1957) investigated retrogression of the reticulo-rumen when calves were changed from a hay-grain ration to a milk diet. When this substitution was made on 3 months old calves, the reticulo-rumen and omasum retrogressed to an undeveloped condition similiar to that of a milk fed calf. This work along with Conrad's (1953 and 1954) demonstrates an influence of diet ingredients upon rumen development and function.

The digestibility, retention and utilization of urea and other non-protein nitrogen compounds have recently been studied extensively by various researchers.

Wegner (1941) reported that the rate of urea conversion to protein within the rumen decreased when the

crude protein content of the ration exceeded 12%. The extent of urea conversion was decreased when the crude protein level of the ration exceeded 18%.

Meiske (1955) observed no difference in growth or weight gain resulting from feeding urea in combination rations to growing lambs.

King (1957) reported that when molasses was supplemented with urea, the digestibility of the molasses in the supplemented rations was considerably increased.

Belasco (1955) reported that the amount and type of carbohydrate used for energy affected urea utilization and the distribution of volatile fatty acids. These data indicated that the addition of starch to the fermentation resulted in better urea utilization and higher fatty acid production than cellulose. Starch introduced in vitro yielded more valeric, butyric, and acetic acids, and less propionic acid than cellulose. The amount of propionic acid produced was in direct proportion to the amounts of cellulose, urea utilization was as extensive as achieved by starch addition. When either starch or dextrose was introduced at high levels, cellulose digestion was inhibited. This was most pronounced with dextrose.

Dextrose added at high levels also gave sharp increases in levels of valeric and butyric acids which were compensated by decreases in levels of production of propionic and acetic acids.

Earlier work reported by Belasco (1954) indicated ammonium salts of formate, alpha-keto-glutarate, malate, and especially succinate and lactate produced higher rates of nitrogen utilization and lower free ammonia levels than urea or other ammonium salts studied. Belasco (1954) postulated that these salts enter into some biosynthetic process stimulatory to nitrogen fixation by rumen microflora. Using cellulose digestion and the lowering of free ammonia levels as indications of availability, Belasco (1954) reported that quanidine salts, carbonates, hydrochloride, and acetate were effective as sole nitrogen sources in vitro. When amides were introduced, they also produced low levels of free ammonia in the system along with a supply of biologically available nitrogen formed by normal ruminal bacterial growth.

Bell et. al. (1957) working with lambs reported a significantly greater digestibility of crude protein and lower digestibility of ether extract for

urea supplemented rations as compared to cottonseed meal supplemented rations.

Byers (1957) studied digestion of cows fed all corn rations with and without urea supplementation. When urea replaced 3.5% of the ground shelled corn for lactating cows, the digestibility coefficients for dry matter, protein, fiber, and nitrogen-free extract all favored the urea ration. However, only the increase in protein digestibility was significantly greater.

Hatfield et. al. (1955) observed a slightly higher digestibility coefficient of nitrogen when urea was fed. However, when compared to biuret and soybean meal supplemented rations, lower digestibility coefficients for ether extract and crude fiber were reported.

Gallop (1952) observed higher digestibility of urea supplemented rations at all levels of feeding.

In order to test the effect of rumen fermentation, Muhrer et. al. (1953) fed swine rations containing forages and urea that had been fermented in an artificial rumen. The pre-digested rations improved daily gain and feed efficiency. The authors

reported that a ration for non-ruminants can be improved by fermenting some ingredients in an artificial rumen.

In their work with carotene and vitamin A utilization, Gallop et. al. (1950) reported that urea was without effect on vitamin A utilization. Bell et. al. (1955) observed that urea feeding to lambs had no noticeable effect on the retention of calcium, phosphorus or nitrogen.

Conversely, Levy and Donker (1955) working with young dairy steers reported that urea feeding compared to cottonseed meal supplementation considerably reduced daily gain and feed efficiency. In this work urea composed 33% of the total protein of the ration. Embry and co-workers (1957) reported no significant differences in digestibility of nutrients in rations containing soybean meal or linseed meal, with or without urea (0.9% of the total ration). When 5% lard was added to the diets the urea supplemented rations gave significantly greater digestibilities of crude protein and ether extract, but the digestibility of fiber and nitrogen-free extract was decreased.

Gallop et. al. (1952) conducted nitrogen balance

studies in lambs using urea supplemented rations. As the roughage levels decreased, urea nitrogen retention increased. When urea was added above 30 to 40% of the total crude nitrogen, nitrogen retention decreased. A study of the nitrogen balance in steers was made by Hatfield et. al. (1955). Rations containing urea, soybean meal, and biuret were compared. Soybean meal was only slightly higher than urea in terms of nitrogen retained, but was significantly greater than the biuret supplemented ration.

In contrast, studies by Ellis and co-workers (1955) indicated urea supplemented rations resulted in significantly less nitrogen retention as compared to soybean or blood fibrin supplemented rations. This feeding trial illustrated superior utilization of "true" protein as compared to urea by sheep.

In general, the literature illustrates that there is little conclusive evidence which indicates the exact age that it is possible for he young calf to begin to utilize a synthetic nitrogen supply. There are also many ration ingredients that influence the calf's ability to utilize these non-protein nitrogen compounds that need be considered when formulating a

non-protein nitrogen supplemented diet for the young calf.

EXPERIMENTAL PROCEDURE

Selection and Assignment of Animals

Twenty-four male Holstein calves were used in this study. The calves were obtained from the university herd and several local dairymen. The calves were assigned to the different milk replacers randomly as they became available. Towards the end of the experiment, the new calves were assigned according to body weights in an attempt to equalize the initial weights among the groups as much as possible. Since similar feed consumption rates were of considerable importance in the experiment, any calf that refused to eat due to illness or other abnormalities was removed from the experiment and another animal substituted in its place. The only prerequisite for assignment was normal health and appearance.

Feeding and Management

Calves were left with their dams for 48 hours after birth. The calves were then removed from their dams, fasted 12 hours, weighed, and assigned randomly to an experimental ration. The feeding schedule for the calves is presented in Table 1. Milk feeding was terminated at 10 days of age to allow a digestion study

TABLE 1

MILK AND REPLACER FEEDING SCHEDULE

Age	Milk	Water	Replacer	
			Group A	Group B
	----------	lbs.	----------	
0-2 days	Dam			
3-7 days	4.0	4.0	0.6	0.6
8-10 days	2.0	6.0	1.0	1.0
11-19 days	-	12.0	1.4	1.4
20-33 days	-	12.0	1.6	1.0
34-47 days	-	12.0	2.0	0.6
48-56 days	-	12.0	2.0	0.4

to be made, without the influence of milk, before the calves reached 21 days of age. The milk replacers were fed as a gruel in the amounts indicated in Table 1. At 20 days of age, the 8 calves assigned to each milk replacer were divided into 2 sub-groups of 4 calves each. Sub-group A was continued on a milk replacer diet without any dry feed for the duration of the experiment. The calves in sub-group B, at 20 days, were fed reduced amounts of their respective milk replacers as well as a urea supplemented (urea

49.4% of the total protein) calf starter which was fed ad libitim. Both sub-groups were removed from the experiment at 56 days of age. Hay was not fed to either sub-group during the trial.

When the calves were not in digestion stalls, they were housed in small individual stalls bedded daily with wood shavings.

Feed Formulation

The formulae for the 3 milk replacers used in this experiment are presented in Table 2. Milk replacer no. 41 served as the low protein control ration. Milk replacer no. 44 utilized milk proteins for the supplementary nitrogen. In milk replacer no. 45, the supplemental protein was urea (46.9% of the total protein). The protein content of the respective replacers was adjusted by varying the proportions of cerelose, dried whey, and dried skimmilk.

The milk replacers were mixed in quantities sufficiently large enough to last the duration of the trial. They were stored in fiber barrels to prevent contamination and to protect the mixed replacers from moisture.

The formula for the calf starter used by sub-

TABLE 2

COMPOSITION OF EXPERIMENTAL MILK REPLACERS

Ingredient	Replacer 41	44	45
	----------lbs.----------		
Dried skimmilk	5.0	35.0	5.0
Urea (275%)	-	-	2.8
Dried whey	55.0	37.0	54.6
Cerelose	28.9	16.9	26.5
Distillers solubles	5.0	5.0	5.0
Beet pulp	3.0	3.0	3.0
Trace salt	0.5	0.5	0.5
Dicalcium phosphate	2.0	2.0	2.0
Aurofac 10	0.5	0.5	0.5
Vit. & mineral conc.*	0.1	0.1	0.1
TOTAL	100.0	100.0	100.0
Calculated chemical analysis of ingredients (percent)			
Crude protein	10.4	18.0	18.0
Protein from urea	-	-	46.9
Lactose	40.0	43.0	39.7

*Mixture contained:
Vitamin A conc. 20,000 U.S.P. units/g .....20g.
Irradiated yeast, 9,000 I.U. vitamin D/g .....5g.
Cobaltous sulfate ($CoSO_4 \cdot 7H_2O$ .....3g.
Cupric sulfate ($CuSO_4 \cdot 5H_2O$) .....2g.
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$) .....11g.

TABLE 3

COMPOSITION OF EXPERIMENTAL CALF STARTER

Ingredients	Starter
	lb.
Ground yellow corn	1,000.0
Crimped oats	300.0
Urea (275%)	59.0
Corn distillers solubles	100.0
Cane molasses	133.0
Dicalcium phosphate	20.0
Trace salt	20.0
Vit. A & D	1.5
Aurofac 10	3.0
Corn starch	363.5
TOTAL	2,000.0
Calculated chemical analysis of ingredients (percent)	
Crude protein	16.4
Protein from urea	49.4

group B is presented in Table 3.

Representative samples of the replacers and starter were obtained for chemical analysis. The chemical analysis for the respective feeds is presented in Table 4.

TABLE 4

CHEMICAL ANALYSIS OF FEEDS FED

	Replacer			Starter
	41	44	45	
	---------- % ----------			
Ash	7.64	8.40	7.54	4.71
Crude fiber	0.86	0.85	0.97	2.84
Ether extract	0.64	0.70	0.64	3.33
Water	6.40	5.76	6.87	11.01
Protein	10.69	19.25	17.06	15.94
Nit.-free-extract	73.77	65.19	70.35	62.17

Digestion Studies

Each of the 24 calves underwent 3 individual digestion trials. The time schedule for the digestion studies is indicated in Table 5.

TABLE 5

DIGESTION STUDY SCHEDULE

Age	Handling
2 days	weaned from dam
12 days	in digestion stall
15 days	collection begins
19 days	collection ends
26 days	in digestion stall
29 days	collection begins
33 days	collection ends
40 days	in digestion stall
43 days	collection begins
47 days	collection ends
56 days	calf off trial

A standard 3-day adjustment and a 4-day collection period was utilized in this study.

Frame constructed sheep digestion stalls were used to make the collections. The movable stanchion allowed length adjustment to compensate for variations in respective calf ages and lengths. The stalls were

equipped with a double screen arrangement under much of the area where the calf stood to allow for urine collection. The screens funneled into gallon glass jars which were used for the urine collections. Feces were collected in metal pans attached to the rear of the individual stalls.

Urine and feces were measured and sampled daily. Ten ml. of toulene and 5 ml. of HCL (diluted 1:1 with water) were added to the urine bottles daily to prevent the loss of nitrogen. Five percent aliquot samples of the urine were taken daily for chemical analysis. These samples were kept under refrigeration during the collection period and until the time that the nitrogen content was determined. The feces were weighed daily and transferred to lard cans which were stored under refrigeration. At the end of the collection period, a sample was taken of the 4 day composite which was subjected to dry matter and nitrogen determinations.

Blood Studies

Forty ml. jugular blood samples were taken from each calf at 2, 12, 26, and 40 days of age, the ages that the last 3 samples were taken corresponding to

the dates the calves entered the digestion stalls.

Blood urea nitrogen and blood non-protein nitrogen values were determined on the plasma of each sample.

Analytical Procedures

Milk replacers and calf starter: dry matter, crude fiber, ether extract, water, protein, and nitrogen free extract, (Association of Official Agricultural Chemists, Official Methods of Analysis). 1955.

Feces: dry matter and total nitrogen (kjeldahl), (Association of Official Agricultural Chemists, Official Methods of Analysis). 1955.

Urine: nitrogen (kjeldahl), (Association of Official Agriculture Chemists, Official Methods of Analysis). 1955.

Blood: urea nitrogen and non-protein nitrogen, (Hawk, Oser, and Summerson, Practical Physiological Chemistry). 1954.

Statistical analysis of data: (Snedecor, Statistical Methods). 1956.

RESULTS

PART I -- DIGESTIBILITY STUDIES

The data obtained on individual calves with accompanying graphs and statistical analysis of the digestion studies are summarized in Tables 6 to 11 and Figures 1 to 3.

Nitrogen Balance

During the first digestion period the calves fed milk replacer no. 41 (the low protein basal ration), showed a negative nitrogen balance of -2.29 grams per day (Tables 6 and 7 and Figure 1). In contrast, the mean nitrogen retention values for replacer no. 44 was 3.83 grams and for the urea supplemented replacer, no. 45 was 4.67 grams per day. The nitrogen balance means for replacer nos. 44 and 45 were both significantly higher ($P \leq 0.01$) than the mean for replacer no. 41. There was no significant difference between the means for replacer nos. 44 and 45.

During period 2 the nitrogen retention values for the calves not fed starter, sub-group A, for replacer nos. 41, 44, and 45 were 3.39, 10.46, and 2.73 grams per day, respectively. The mean for replacer no. 44 was significantly greater ($P \leq 0.01$) than either

replacer no. 41 or 45. The nitrogen retention values for the calves that had free access to an urea supplemented calf starter (sub-group B) were 2.07 grams per day for replacer no. 41, 6.81 grams per day for replacer no. 44, and 5.41 grams per day for replacer no. 45. Analysis of these values demonstrated that the means for replacer nos. 44 and 45 were both significantly greater ($P \leq 0.01$) than that for replacer no. 41. In period 2, however, the nitrogen retention mean for replacer no. 44 was not significantly greater than that for replacer no. 45.

Further analysis of the data indicate that the interaction between starters and the various replacers was significant during period 2. These data demonstrate that sub-groups A and B did not give consistant results among the various replacers. This observed difference was probably due to sampling errors caused by small numbers of calves within each of the various groups.

In the third digestion period, sub-group A retention values for replacer no. 44 were significantly greater ($P \leq 0.01$) than for replacer nos. 41 or 45. The respective average nitrogen retention values of

sub-group A for replacer nos. 41, 44, and 45 were 4.26, 12.48, and 0.50 grams per day. The average daily retention values for the individual replacers in sub-group B were 4.78, 12.04, and 8.34 grams per day. The 12.04 grams per day retention for replacer no. 44 was significantly greater ($P \leq 0.05$) than the 4.78 grams per day for replacer no. 41, but was not significantly greater when compared to replacer no. 45's 8.34 grams per day. During the third period, there were much greater differences between the sub-group average retention values than during period 2. During period 2 the values were 5.57 grams per day for sub-group A and 5.89 grams per day for sub-group B. In the third period sub-group A held close to their previous average retention with 4.74 grams per day, while sub-group B increased their retention to an average of 8.38 grams per day.

All sub-groups increased their daily nitrogen retention through all three periods with the exception of sub-group A of replacer no. 45. The daily nitrogen retention for this group decreased from 4.67 grams per day for period 1 to 2.8 grams for period 2, and only 0.50 grams per day during period 3. These values were

influenced by the difficulties encountered from the effects of severe diarrhea in all 4 of the calves assigned to replacer no. 45 during periods 2 and 3.

Apparent Dry Matter Digestibility

Dry matter digestibility data (Tables 8 and 9, and Figure 2) indicated that there were no significant differences between the replacers during period 1. However, the average digestibility coefficient of 65% for replacer no. 45 was considerably greater than 56.2% for replacer no. 44 or 50.6% digestibility for replacer no. 41.

During period 2, however, there was a definite increase in digestibility of dry matter by the animals comprising sub-group B. As compared to sub-group A, average coefficients of sub-group B were 71.7% compared to only 45.7% for sub-group A, (calves which were not fed any dry feed). This difference was found to be significant ($P \leq 0.01$).

Calves in sub-group A had average dry matter digestibility coefficients of 37, 56, and 44.2% for replacer nos. 41, 44, and 45, respectively. The average coefficient of replacer no. 44 was significantly greater ($P \leq 0.05$) than for replacer no. 41, but was

not significantly greater than the average coefficient of replacer no 44. Calves in sub-group B had respective digestibility coefficients of 70.1, 80.9, and 71.2%. There were no differences among the replacers at the 5% level of significance.

In the third period there were even greater differences between the sub-groups' dry matter digestibility. The calves fed the urea supplemented starter (sub-group B) had a dry matter digestibility of 77.7%. In contrast, the digestibility coefficient mean for sub-group A was only 36.7%. This difference was significant ($P=<0.01$). However, in period 3, there was not a significant difference in dry matter digestibility ($P=<0.05$) between the calves fed replacer nos. 41, 44, or 45 in either of the sub-groups.

The composite data for the 3 periods demonstrates that in all cases dry matter digestibility increased with age of the calves allowed free access to liberal amounts of starter and decreased with age for animals that were continued on a gruel diet with no dry feeds available.

Apparent Crude Protein Digestibility

The effect of the various replacers on crude

protein digestibility was similiar to the results of the nitrogen balance study. Namely in all three trials there was a significant difference observed in protein digestibility between the various replacers (Table 10 and 11, and Figure 3).

In the first period the average protein digestibility coefficients were 63.1, 80.4, and 83.0% digestibility for milk replacer nos. 41, 44, and 45 respectively. At the 5% level of significance protein digestibility values for replacer nos. 44 and 45 were significantly greater than the value for replacer no. 41.

During the second period there were no significant increases in digestibility due to starter feeding. However, in sub-group A the average digestibility coefficients were 67.6, 84.3, and 78.6% for replacer nos. 41, 44, and 45, respectively. The values for replacer nos. 44 and 45 were significantly greater ($P=<0.01$) than the value for replacer no. 41. Average crude protein digestibility coefficients for sub-group B in the second period were 72.9% for replacer no. 41, 86.8% for no. 44, and 79.3% for replacer no. 45. The apparent protein digestibility of replacer no. 44 was significantly greater ($P=<0.01$) than the value for re-

placer no. 41 and was greater than replacer no. 45 at the 5% level of significance. The average coefficient of protein digestibility for replacer no. 45 was significantly greater ($P=<0.05$) than was the average coefficient for replacer no. 41.

In period three the average protein digestibility coefficient of 83.1% obtained for replacer no. 44, sub-group A, was significantly greater ($P=<0.05$) than the mean values for replacer nos. 41 or 45 which were 73.1 and 74.4%, respectively. Considering sub-group B, the 87.1% digestibility coefficient for replacer no. 44 and 80.3% digestibility value for replacer no. 45 were both larger than the value of 71.8% for replacer no. 41 at the 5% level of significance.

The protein digestibility coefficients for each replacer were relatively constant during all 3 collection periods.

PART II --- BLOOD STUDIES

Tables summarizing the blood studies for the individual calves with accompanying graphs and the statistical analysis of the data are presented in Tables 12 to 15, and Figures 4 and 5.

Blood Urea Nitrogen

While there were some differences among calves and replacer groups in blood urea nitrogen values when the calves were assigned to the experiment, the differences among replacer groups were not significant (Tables 12 and 13, and Figure 4).

At 12 days of age calves fed replacer no. 41 averaged 9.05 mg.% blood urea nitrogen, as compared to 9.91 mg.% for replacer no. 44, and 11.31 mg.% for replacer no. 45. These differences were not significant.

The data from sample three (26 days of age) also indicate no significant differences in the mean values. The averages for the eight calves in each replacer group were 7.76, 9.68, and 10.39 mg.% for replacer nos. 41, 44, and 45, respectively. However, the mean value for the urea supplemented replacer no. 45 approached significance ($P \leq 0.05$) in relation to the value obtained for replacer no. 41. There were no significant differences among replacers due to starter feeding. However, the starter fed calves averaged 8.5 mg.%, as compared to 10.05 mg.% blood urea nitrogen for the calves on the gruel diet.

At 40 days of age the blood urea nitrogen averages for replacer nos. 41, 44, and 45 were 7.54, 8.86, and 8.71 mg.%, respectively. The differences among groups were not significant. The mean blood urea level for calves in sub-group A was 9.08 mg.% as compared to 7.06 mg.% for sub-group B, again a non-significant difference.

Blood Non-Protein Nitrogen

In general the data for blood NPN showed similiar trends to that for blood urea nitrogen (Tables 14 and 15, and Figure 5). The values for the calves assigned to replacer nos. 41, 44, and 45 were 25.9, 24.5 and 28.1 mg.%, respectively. These differences among groups were not significant.

At 12 days of age, the values for both replacer nos. 44 and 45 were not significantly larger ($P \leq 0.05$) than that for replacer no. 41. The actual values were 22.1, 24.1, and 24.2 mg.% for replacer nos. 41, 44, and 45, respectively.

At 26 days of age, blood NPN values averaged 20.0, 21.1, and 25.96 mg.% for calves fed replacer nos. 41, 44, and 45. The NPN level of calves fed replacer no. 45 was significantly higher ($P \leq 0.05$) than

values for the other two replacers. Calves in sub-group A were found to have averages higher than the calves of sub-group B, the averages being 23.5 mg.% for A and 21.2 mg.% for sub-group B. Similarly to the urea nitrogen studies, however, these differences were not significant at the 5% level.

The calves on replacer no. 45 had the highest mean NPN value at 40 days of age. Their mean NPN value was 22.2 mg.%, as compared to 19.5 mg.%, and 20.2 mg.% for replacer nos. 41, and 44, respectively. This difference was not significant. ($P=<0.05$). The mean NPN value for sub-group A was greater than for sub-group B. However, this difference was very small, averaging 20.74 mg.% for A, as compared to 20.53 mg.% for sub-group B.

TABLE 6.
NITROGEN BALANCE
INDIVIDUAL CALF VALUES

Grams nitrogen retained during 4-day collection period

REPLACER #41-A

calf no.	period 1	period 2	period 3
443	-15.74	-2.28	7.62
465	17.04	41.37	-6.88
456	-3.28	7.85	33.30
466	12.03	7.26	34.02
Av.	2.51	13.55	17.02

REPLACER #41-B

calf no.	period 1	period 2	period 3
427	-55.79	-3.20	29.77
433	1.31	20.31	-3.14
453	- 2.69	13.67	32.13
463	-26.07	1.88	17.62
Av.	-20.81	8.29	19.10

REPLACER #44-A

calf no.	period 1	period 2	period 3
434	15.45	28.16	48.62
449	- .33	50.27	43.93
455	40.05	48.20	58.95
470	17.35	40.67	48.23
Av.	18.13	41.83	49.93

REPLACER #44-B

calf no.	period 1	period 2	period 3
421	20.12	23.74	54.02
425	6.83	3.74	54.32
452	1.83	48.45	51.82
460	37.13	32.94	32.46
Av.	16.48	27.22	43.16

TABLE 6 Continued
NITROGEN BALANCE
INDIVIDUAL CALF VALUES

Grams nitrogen retained during 4-day collection period

REPLACER #45-A

calf no.	period 1	period 2	period 3
444	11.71	6.22	-14.06
440	26.60	3.11	-39.70
476	22.88	22.94	41.37
478	30.08	12.20	20.02
Av.	22.34	11.12	2.01

REPLACER #45-B

calf no.	period 1	period 2	period 3
422	31.13	15.48	39.86
432	3.29	15.58	14.14
458	9.43	26.86	37.00
469	14.04	28.57	42.36
Av.	14.47	21.62	33.34

TABLE 7.

NITROGEN BALANCE

STATISTICAL ANALYSIS

PERIOD I

source	d.f.	Σx^2	m.sq.	F ratio
total	23	10,098.45		
replacers	2	3,932.29	1,966.16	6.696
within	21	6,166.16	293.63	

PERIOD II

source	d.f.	Σx^2	m.sq.	F. ratio
total	23	3,971.39		
replacers	2	1,638.25	819.12	9.524
starters	1	11.69	11.69	.136
rep. x starters	2	773.23	386.61	4.495
within	18	1,548.22	86.01	

PERIOD III

source	d.f.	Σx^2	m.sq.	F ratio
total	23	14,0 12.55		
replacers	2	5,190.22	2,595.11	6.838
starters	1	669.50	669.50	1.764
rep. x starters	2	1,321. 10	660.55	1.740
within	18	6,831.73	379.54	

TABLE 8
DRY MATTER DIGESTIBILITY
INDIVIDUAL CALF VALUES

Digestibility coefficients (percent)

REPLACER #41-A

calf no.	period 1	period 2	period 3
443	47.9	8.7	42.4
465	57.0	68.8	35.7
456	37.2	41.9	37.2
466	69.2	28.5	25.2
Av.	52.3	37.0	35.1

REPLACER #41-B

calf no.	period 1	period 2	period 3
427	16.1	73.4	78.6
433	78.6	75.8	67.8
453	63.7	60.2	76.7
463	34.3	71.1	64.2
Av.	48.3	70.1	71.8

REPLACER #44-A

calf no.	period 1	period 2	period 3
434	83.7	57.9	43.7
449	27.1	54.4	22.4
455	42.2	60.8	43.0
470	32.3	51.0	27.3
Av.	46.3	56.0	34.1

REPLACER #44-B

calf no.	period 1	period 2	period 3
421	42.5	78.2	91.4
425	80.6	82.8	86.4
452	78.5	87.3	80.5
460	62.5	75.3	78.6
Av.	66.0	80.9	84.2

TABLE 8 Continued
DRY MATTER DIGESTIBILITY
INDIVIDUAL CALF VALUES

Digestibility coefficients (percent)

REPLACER #45-A

calf no.	period 1	period 2	period 3
444	57.4	54.8	44.8
440	73.1	53.2	25.2
476	69.8	51.4	52.6
478	65.5	17.3	-35.7*
Av.	66.5	44.2	40.9

REPLACER #45-B

calf no.	period 1	period 2	period 3
422	82.4	80.7	87.4
432	70.1	70.6	70.1
458	50.8	72.3	71.6
469	44.5	61.1	78.9
Av.	63.5	71.2	77.0

* value discarded

TABLE 9 .
DRY MATTER DIGESTIBILITY
STATISTICAL ANALYSIS
PERIOD I

source	d.f.	Σx^2	M. sq.	F ratio
total	23	8,463.79	420.72	1.159
replacers	2	841.44	362.97	
within	21	7,622.35		

PERIOD II

source	d.f.	Σx^2	M. sq.	F ratio
total	23	9,192.93		
replacers	2	948.72	474.36	2.53
starters	1	4,819.50	4,819.50	25.99
rep. x starters	2	73.87	36.94	.20
within	18	3,350.84	186.16	

PERIOD III

source	d.f.	Σx^2	M. sq.	F ratio
total	23	11,841.51		
replacers	2	165.62	82.810	1.109
starters	1	10,081.90	10,081.900	135.070
rep. x starters	2	250.56	125.280	1.673
within	18	1,343.43	74.640	

TABLE 10
PROTEIN DIGESTIBILITY
INDIVIDUAL CALF VALUES

Digestibility coefficients (percent)

REPLACER #41-A

calf no.	period 1	period 2	period 3
443	59.2	49.9	77.9
465	71.9	81.9	72.2
456	62.5	72.0	71.3
466	80.3	66.4	71.1
Av.	68.6	67.6	73.1

REPLACER #41-B

calf no.	period 1	period 2	period 3
427	41.1	72.9	74.0
433	84.3	73.5	62.8
453	66.0	69.4	76.1
463	38.6	75.9	74.3
Av.	57.6	72.9	71.8

REPLACER #44-A

calf no.	period 1	period 2	period 3
434	92.1	80.6	83.1
449	65.8	82.3	79.7
455	76.3	89.0	85.8
470	75.0	85.4	83.7
Av.	77.3	84.3	83.1

REPLACER #44-B

calf no.-	period 1	period 2	period 3
421	69.3	81.6	92.2
425	88.8	87.3	87.2
452	88.5	90.1	84.4
460	87.0	88.2	84.5
Av.	83.4	86.8	87.1

TABLE 10 Continued
PROTEIN DIGESTIBILITY
INDIVIDUAL CALF VALUES

Digestibility coefficients (percent)

REPLACER #45-A

calf no.	period 1	period 2	period 3
444	75.3	80.4	81.5
440	85.0	80.1	71.8
476	88.6	84.2	86.4
473	87.2	69.5	57.7
Av.	84.0	78.6	74.4

REPLACER #45-B

calf no.	period 1	period 2	period 3
422	89.8	85.8	86.4
432	83.7	69.0	69.0
458	79.8	82.0	82.1
469	74.3	80.3	83.7
Av.	82.0	79.3	80.3

TABLE 11.

PROTEIN DIGESTIBILITY

STATISTICAL ANALYSIS

PERIOD I

source	d.f.	Σx^2	M. sq.	F ratio
total	23	4,774.07		
replacers	2	1,863.79	934.40	6.754
within	21	2,905.28	138.35	

PERIOD II

source	d.f.	Σx^2	M. sq.	F ratio
total	23	1,933.56		
replacer	2	1,144.89	572.44	14.361
starter	1	49.02	49.02	1.230
rep. x starter	2	22.07	11.03	.277
within	18	717.58	39.86	

PERIOD III

source	d.f.	Σx^2	M. sq.	F ratio
total	23	1,614.43		
replacer	2	647.42	323.71	6.769
starter	1	49.60	49.60	1.037
rep. x starter	2	56.72	28.36	.593
within	18	860.69	47.82	

TABLE 12
BLOOD UREA
INDIVIDUAL CALF VALUES
Mg. %

REPLACER #41-A

calf no.	sample 1	sample 2	sample 3	sample 4
443	10.45	5.20	8.15	5.50
465	15.75	13.25	10.20	6.60
456	12.85	3.85	10.20	10.75
466	18.35	15.20	7.45	6.60
Av.	14.83	9.38	9.00	7.36

REPLACER #41-B

calf no.	sample 1	sample 2	sample 3	sample 4
427	6.15	7.75	3.50	11.10
433	9.35	12.20	5.80	1.60
453	11.35	7.20	8.00	6.60
463	17.95	7.75	9.40	11.60
Av.	11.20	8.73	6.53	7.73

REPLACER #44-A

calf no.	sample 1	sample 2	sample 3	sample 4
434	9.25	10.70	8.45	6.40
449	4.55	7.90	8.00	10.75
455	11.90	8.85	12.70	8.55
470	7.75	17.10	8.85	16.00
Av.	8.36	11.14	9.50	10.43

REPLACER #44-B

calf no.	sample 1	sample 2	sample 3	sample 4
421	19.80	7.50	8.70	5.50
425	6.70	6.00	11.10	5.75
452	6.15	12.15	8.30	11.35
460	9.50	9.10	11.30	6.05
Av.	10.54	8.69	9.85	7.29

TABLE 12 Continued
BLOOD UREA
INDIVIDUAL CALF VALUES
Mg. %

REPLACER #45-A

calf no.	sample 1	sample 2	sample 3	sample 4
444	8.35	8.95	14.30	15.20
440	6.30	6.30	13.00	8.70
476	13.20	13.50	11.45	9.10
478	17.10	10.25	7.90	6.80
Av.	12.24	11.13	11.66	9.45

REPLACER #45-B

calf no.	sample 1	sample 2	sample 3	sample 4
422	3.35	11.65	5.10	6.40
432	10.45	8.05	9.35	5.35
458	11.85	15.20	13.50	9.65
469	15.20	11.05	8.55	10.45
Av.	10.21	11.49	9.13	7.96

TABLE 13.

BLOOD UREA

STATISTICAL ANALYSIS

SAMPLE I

source	d.f.	Σx^2	M. sq.	F ratio
total	23	543.42		
sampling	2	49.74	24.37	1.058
within	21	493.68	23.51	

SAMPLE II

source	d.f.	Σx^2	M. sq.	F ratio
total	23	393.72		
replacers	2	20.74	10.37	.584
within	21	372.98	17.76	

SAMPLE III

source	d.f.	Σx^2	M. sq.	F ratio
total	23	162.40		
replacers	2	29.60	14.80	2.479
starters	1	14.50	14.50	2.429
rep. x starters	2	10.87	5.43	.910
within	18	107.43	5.97	

SAMPLE IV

source	d.f.	Σx^2	M. sq.	F ratio
total	23	258.81		
replacers	2	8.26	4.13	.329
starters	1	12.12	12.12	.964
rep. x starters	2	12.26	6.13	.488
within	18	226.17	12.57	

TABLE 14
BLOOD NPN
INDIVIDUAL CALF VALUES
Mg. %

REPLACER #41-A

calf no.	sample 1	sample 2	sample 3	sample 4
443	22.7	18.7	20.6	13.2
465	30.4	20.5	24.3	17.17
456	21.9	13.2	22.6	21.0
466	---	29.8	14.9	19.9
Av.	25.0	22.05	20.6	17.9

REPLACER #41-B

calf no.	sample 1	sample 2	sample 3	sample 4
427	33.7	21.9	21.1	27.3
433	25.7	25.2	15.3	11.2
453	24.6	18.3	21.5	21.0
463	23.2	22.6	19.9	24.8
Av.	20.3	22.12	19.45	21.075

REPLACER #44-A

calf no.	sample 1	sample 2	sample 3	sample 4
434	41.5	21.1	20.6	15.8
449	17.7	21.1	17.7	25.4
455	21.4	17.7	26.5	21.0
470	25.4	25.3	22.0	21.5
Av.	26.5	23.3	21.7	20.025

REPLACER #44-B

calf no.	sample 1	sample 2	sample 3	sample 4
421	20.3	20.9	---	18.7
425	19.3	30.5	23.3	17.9
452	24.6	24.8	22.1	21.0
460	23.5	21.5	16.C	20.4
Av.	22.5	24.425	20.47	19.5

TABLE 14 Continued
BLOOD NPN
INDIVIDUAL CALF VALUES
Mg. %

REPLACER #45-A

calf no.	sample 1	sample 2	sample 3	sample 4
444	23.8	21.4	24.9	23.2
440	20.9	18.7	20.3	19.1
476	37.0	27.0	38.2	29.4
478	27.0	29.4	29.4	24.7
Av.	27.175	24.125	28.2	23.75

REPLACER #45-B

calf no.	sample 1	sample 2	sample 3	sample 4
422	21.7	24.1	---	18.7
432	42.3	20.9	26.0	18.5
453	24.8	27.0	22.6	26.5
469	26.5	25.9	22.6	20.4
Av.	28.95	24.475	23.73	21.025

TABLE 15.

BLOOD NPN

STATISTICAL ANALYSIS

SAMPLE I

source	d.f.	Σx^2	M. sq.	F ratio
total	23	982.16		
sampling	2	57.77	28.89	.656
within	21	924.39	44.02	

SAMPLE II

source	d.f.	Σx^2	M. sq.	F ratio
total	23	551.66		
replacers	2	24.08	12.04	.479
within	21	527.58	25.12	

SAMPLE III

source	d.f.	Σx^2	M. sq.	F ratio
total	23	534.06		
replacers	2	160.40	80.20	4.402
starters	1	31.28	31.28	1.717
rep. x starters	2	14.42	7.21	.396
within	18	327.96	18.22	

SAMPLE IV

source	d.f.	Σx^2	M. sq.	F ratio
total	23	437.12		
replacers	2	30.79	15.39	.745
starters	1	.26	.26	.0013
rep. x starters	2	34.15	17.08	.827
within	18	371.92	20.66	

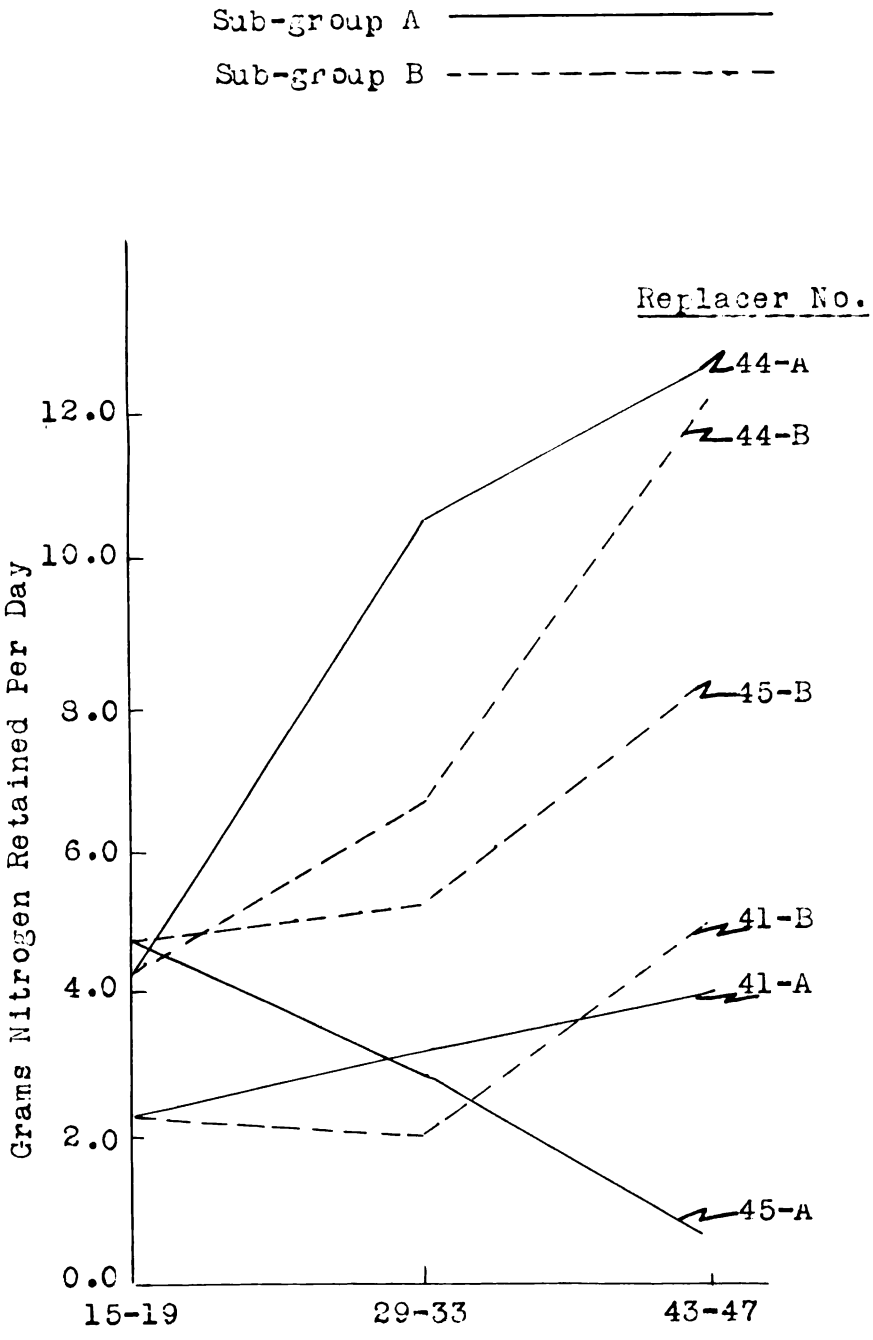

Figure 1

AVERAGE NITROGEN BALANCE VALUES

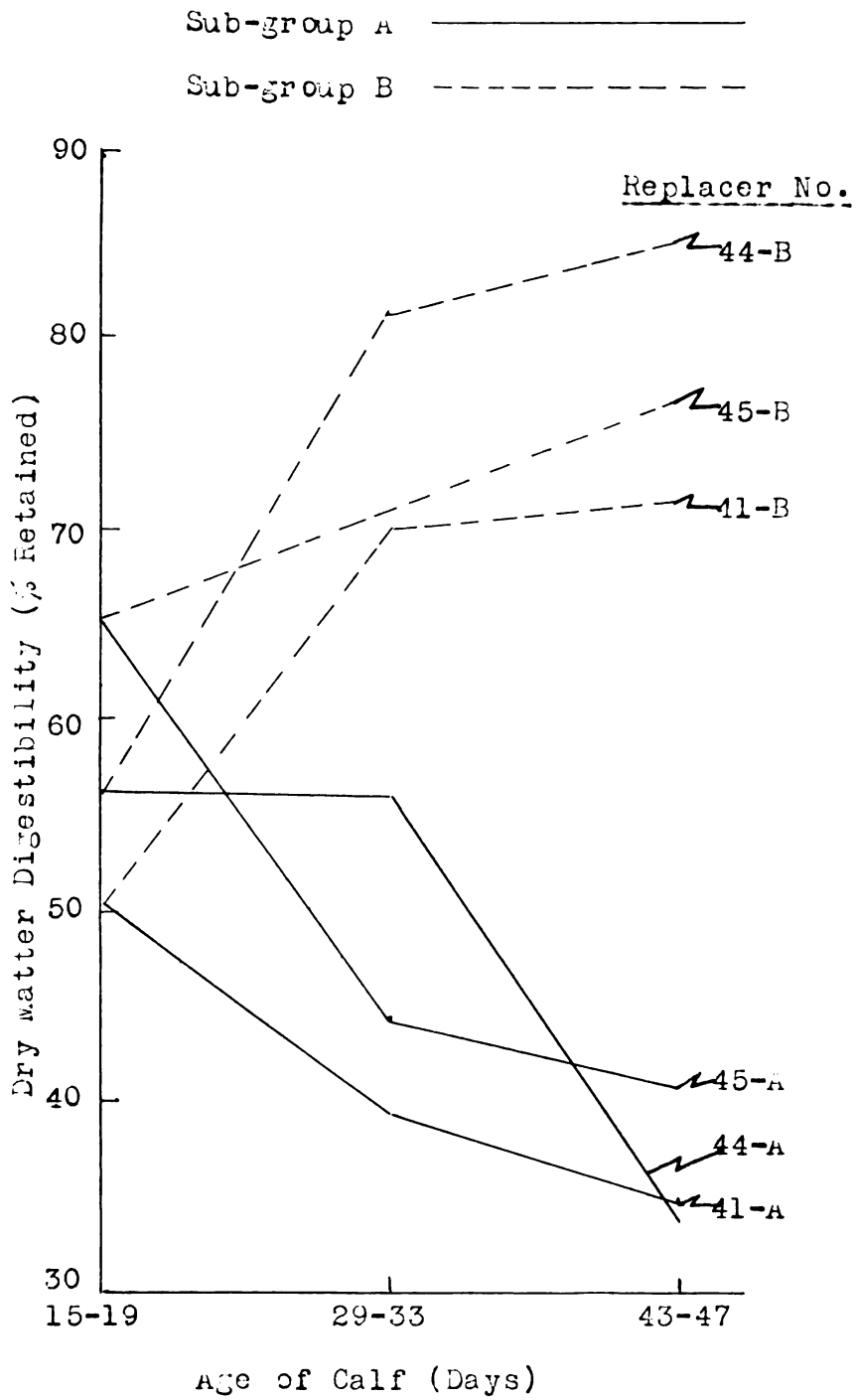

Figure 2

AVERAGE APPARENT DRY MATTER DIGESTIBILITY VALUES

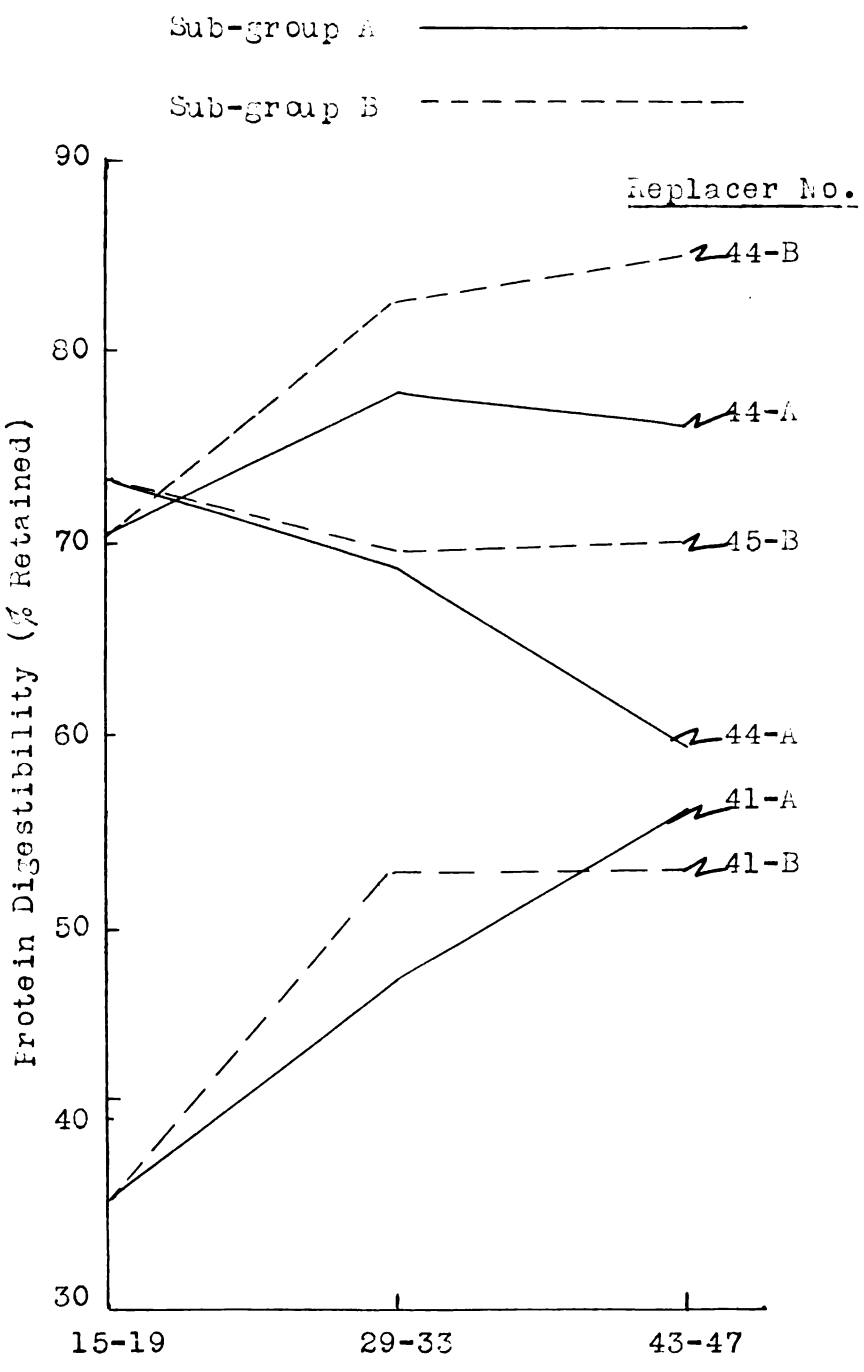

Figure 2

AVERAGE APPARENT PROTEIN DIGESTIBILITY VALUES

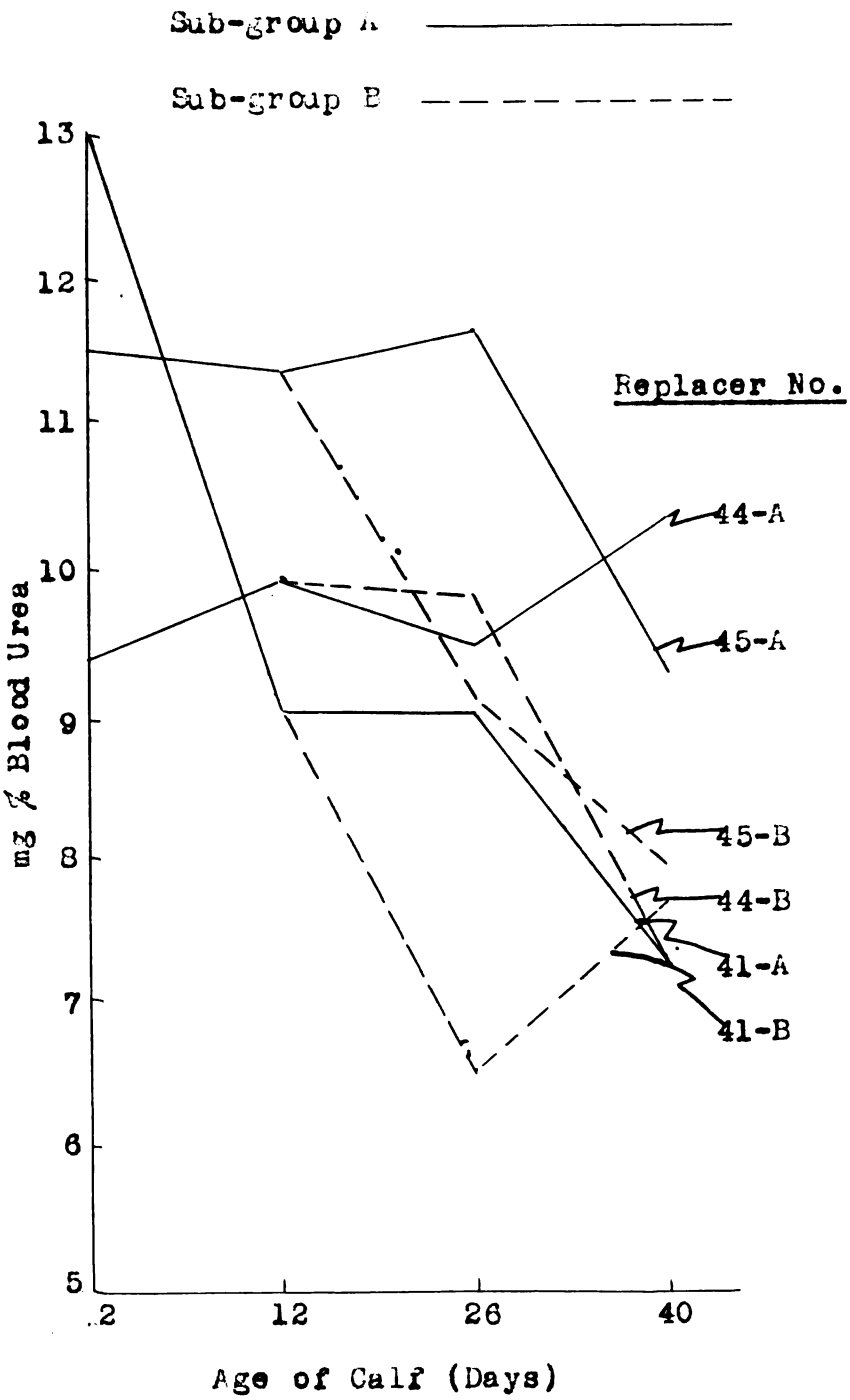

Figure 4

AVERAGE BLOOD UREA VALUES

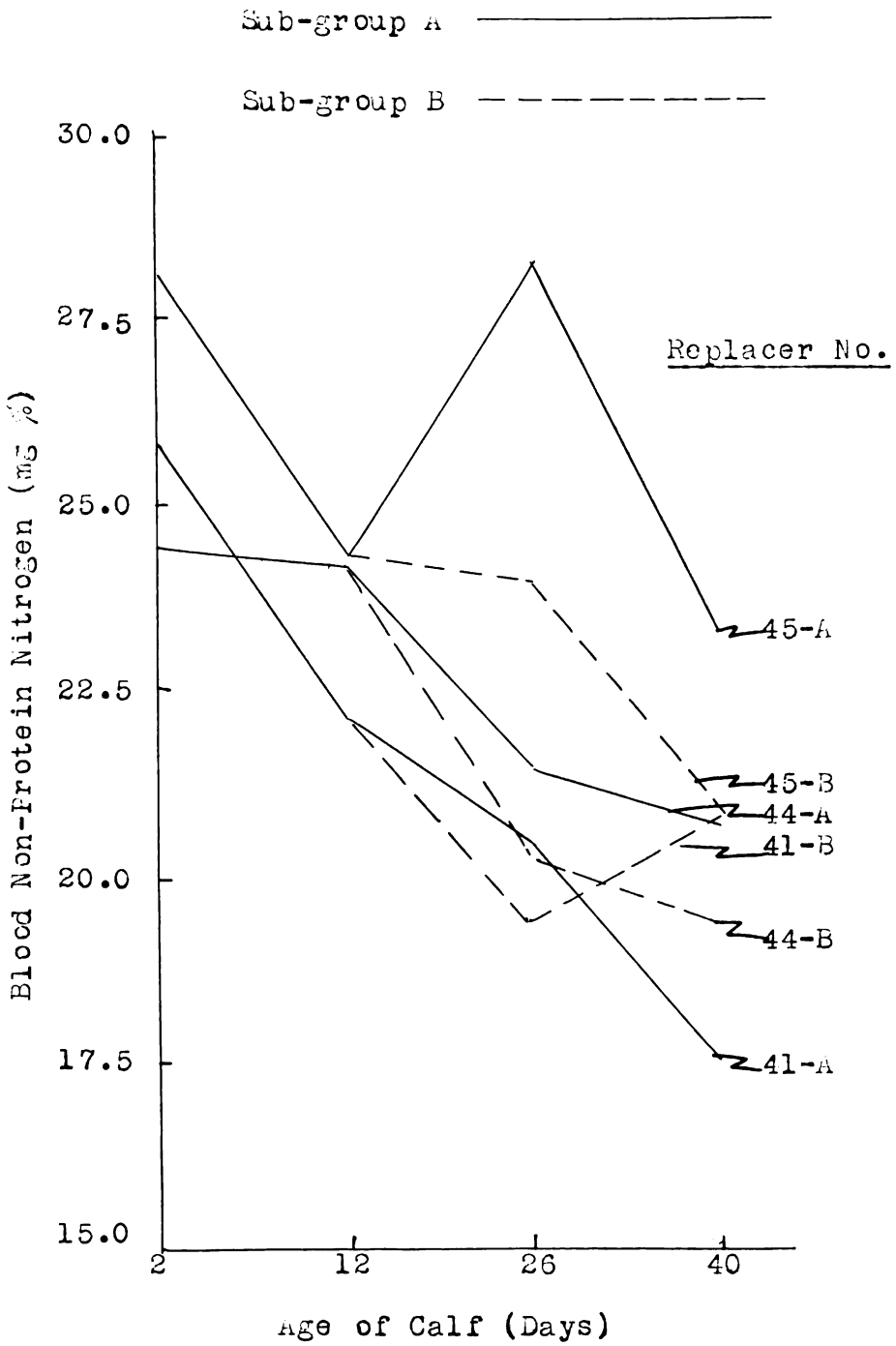

Figure 5

AVERAGE BLOOD NON-PROTEIN NITROGEN VALUES

DISCUSSION

Data for the urea supplemented milk replacer no. 45, during the first digestion period, indicated that the 15 to 19 day old calf utilized the non-protein nitrogen source, urea. The nitrogen balance, apparent protein digestibility, and apparent dry matter digestibility average values indicated that the young calf can utilize urea equally as well as the conventional milk protein diets as studied in this trial.

However, the results for the two succeeding digestion studies were not as conclusive. In digestion periods 2 and 3, the calves that were fed the urea replacer, no. 45, in sub-group B, (calves allowed free access to calf starter) significantly exceeded the mean nitrogen balance for the control group. During the second digestion study (calves 29 to 33 days of age), the relative increase of replacer no. 45 over no. 41, was 70.5% as large as the increase of no. 44 over no. 41. The actual values for the 3 replacer groups during period 2 were for no. 41, 2.07 grams/day, no. 44, 6.81 grams/day, and for no. 45, 5.41 grams/day nitrogen retention. In the third

digestion period in sub-group B, the calves allowed urea starter as a dry feed (the urea supplemented calves, replacer no. 45) account for 49% of the increase in nitrogen retention of replacer no. 44 over no. 41. The actual retention values for the replacer groups were for no. 41, 4.78 grams per day, no. 44, 12.04 grams per day, and for no. 45, 8.34 grams per day.

Many workers have pointed out that ration characteristics greatly influence urea utilization. Lengemann and Allen (1955) reported that amounts of dry feeds and amounts and kinds of bacteria ingested effected the development of a functioning rumen. Flatt et. al. (1956) reported that the rumen mucosa of calves fed dry feeds developed faster than those kept on milk diets. Brownlee (1956) reported that nutritive values of the dry feeds also influenced development of a functionally mature rumen.

The results of this study also indicated increased utilization when dry feeds were included in the young calf's diet. More favorable results were obtained when the combination of gruel and the urea supplemented calf starter was offered ad libitum

compared to gruel feeding alone. The relative differences in nitrogen retention between the calves fed the starter and those fed only gruel increased with age, indicating that under the conditions of this study, including dry feed in the diet increased the relative nitrogen balance and urea utilization by the calves. The calves receiving only milk replacer no. 45, (the urea supplemented replacer), as a gruel with no dry feed offered, were afflicted with severe diarrhea which may have influenced their respective nitrogen balance values.

It is apparent that the very young calf is able to utilize urea nitrogen at all ages studied. The results of the first digestion period indicate that when the calf is weaned from milk at an early age it becomes able to utilize non-protein nitrogen by 15 days of age.

Critical analysis of the apparent protein digestibility coefficient values also indicated early utilization of urea. The relative results were very similar to those obtained in the nitrogen balance study.

During the first digestion period the calves on replacer no. 45 digested a higher percentage of their

nitrogen intake than those on the conventional protein supplemented replacer no. 44 or the low protein basal group fed replacer no. 41.

In the second period the apparent protein digestibility values for these calves were 67.6% and 72.9% for 41 A and B, 84.3% and 86.8% for 44 A and B, and 78.6% and 79.3% for 45 A and B, respectively. Comparing the relative increase in protein digestibility of the calves fed replacer no. 44 over no. 41 to those fed replacer no. 45 over no. 41, the increase for replacer no. 45 in sub-group A was 65.2% as great as that for those fed replacer no. 44. The relative increase of replacer no. 45 over no. 41 for sub-group B was 43.0%. These values for calves fed replacer no. 45 were significantly greater ($P \leq 0.05$) than the apparent protein digestibility of the calves fed the basal diet, replacer no. 41. The mean value for sub-group B, (replacer no. 45) during the third period was 55.5% as great as for no. 44. The actual values for sub-group B were 71.8%, 87.1%, and 80.3%, respectively, for replacer nos. 41, 44, and 45. However, in sub-group A, during period three, the increase over the basal group was slight, due in part to errors from

unnatural responses by the animals.

The similarity of the results from the nitrogen balance and nitrogen digestibility portions of the study supports the conclusions derived from the early nitrogen utilization.

The mean coefficients for apparent dry matter digestibility were much more stable between the replacers and among the sub-groups than were the coefficients for either nitrogen balance or apparent protein digestibility. The largest and most significant differences were between the sub-groups, that is, calves receiving the starter gave significantly greater retention values than the gruel fed animals. This condition is at least partially explained by the difference in fecal characteristics of the sub-groups. The calves assigned to sub-group A produced considerably more fluid excreta than the calves in sub-group B which had the dry feed.

Higher levels of protein in the supplemented replacer nos. 44, and 45, as shown in the second and third periods, both gave significantly greater ($P=<0.05$) dry matter digestibility values than that for replacer no. 41.

In all cases there is a positive correlation between apparent dry matter digestibility and age.

The blood data produced few statistical conclusions. In general, the values for blood urea and non-protein nitrogen reduced with increasing age of the calves. The most notable exception to this generalization was for sub-group A fed replacer no. 45 whose values for urea nitrogen and NPN held quite steady during the second and third periods.

The mean values for both blood urea and non-protein nitrogen were within the averages quoted by Handbook of Biological Data (1956). In the last three samples taken after replacer feeding was commenced, the calves fed the urea supplemented replacer, no. 45, produced higher blood urea and non-protein nitrogen values than did either the calves fed replacer no. 41, the basal group, or those fed replacer no. 44, the conventionally supplemented group. In all samples studied, the mean for sub-group A of replacer no. 45 calves was higher than sub-group B. In sample three the non-protein nitrogen value for replacer no. 45, sub-group A was significantly higher ($P \leq 0.05$) than the averages for replacer nos. 41 or 45.

It can be concluded that the feeding of urea to the young calf tends to raise the blood levels of urea nitrogen and non-protein nitrogen. However, since with only the one exception, these values were not significantly higher, it can be concluded that the calf has the ability to utilize at least a portion of its nitrogen from a urea source.

SUMMARY

A study was carried out to determine the ability of young calves to utilize milk replacers supplemented with urea. Twenty-four male Holstein calves were assigned to three experimental milk replacer diets. The basal diet was a 10% crude protein replacer designated as no. 41. Milk replacer no. 44 was a 18% protein replacer supplemented with conventional milk proteins. Milk replacer no. 45 was an 18% protein urea supplemented ration (urea 46.9% of the total protein). The calves were weaned from milk at ten days of age. At twenty days, the eight calves assigned to each replacer group were divided into two sub-groups, A and B, of four calves each. Sub-group A were fed an increasing amount of milk replacer as a gruel with no dry feed offered. In contrast sub-group B calves were fed a decreasing amount of replacer but had free access to an urea supplemented calf starter (urea 49.4% of the total protein). Neither group were allowed hay during any period in the study. Digestion studies were conducted on all calves at 15, 29, and 43 days of age.

The data assembled from the digestion studies indicated that the young calf could utilize urea as a dietary source of protein at 15 to 19 days of age. Blood levels of urea nitrogen and non-protein nitrogen were found to consistantly decrease with age. The calves receiving the urea supplemented milk replacer had higher blood values for urea nitrogen and non-protein nitrogen than did calves in either of the other two experimental rations.

The results of the present study are in agreement with earlier studies reported. It appears that when the young calf is weaned at a very early age, it develops the ability to utilize a non-protein nitrogen source by the time it reaches three weeks of age. However, it appears that several dietary and managerial factors must be considered in determining the future use of urea as a protein substitute in the diets of the very young calf.

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