DIGESTION STUDIES WITH YOUNG DAIRY CALVES

by

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INTRODUCTION

The special properties of colostrum for the newborn dairy calf have long been appreciated. However, the digestibility of its component nutrients apparently has not been studied.

It seems, also, that neonatal animals have been avoided for use as digestion trial subjects. Even in studies to determine the digestibility of foods for the young, older animals (often of a different species) have been used. The general delicateness of the new-born, together with its rapid developmental changes, are obvious reasons for the choice of older animals for experimental purposes. Yet, the value of a specific food nutrient for the young is not necessarily related to its digestibility as determined with an older animal. For example, the very young calf has little or no ability to digest starch, a highly digestible nutrient for older calves (16, 49).

The development of the digestive tract is directly related to feeding possibilities. Therefore, it would be of interest to determine the coefficient of apparent digestibility of rations fed to young calves, using for the digestion trials calves of the age normally started on each ration. Logically, such a study should begin with a new-born calf when it ingests its first meal of colostrum. The study should be continued, as coarser feeds are introduced into the ration, until the calf's digestive functions reach mature ruminant efficiency for roughage utilization.

The purpose of this experiment was to determine by a series of digestion trials; (1) the coefficient of apparent digestibility of colostrum and early milk for the new-born dairy calf, (2) the influence of age of the calf upon its ability to digest its natural food, the dam's mammary secretion, and (3) the coefficient of apparent digestibility of rations containing oats and/or alfalfa hay added to a milk diet of young calves.

REVIEW OF LITERATURE

No attempt will be made here to review the voluminous amount of literature dealing with the subject of colostrum. With the exception of the work of Frenzel (18) the digestibility of the nutrients of colostrum, or early milk, of interest in this experiment were not found. He used a foal 3 to 7 days of age, receiving its dam's milk, in a digestion experiment and obtained digestion coefficients of 91.0, 90.0, and 90.0 for protein, either extract, and nitrogen free extract, respectively.

The Digestibility of Milk

The digestibility of milk has been determined with several species including dairy calves. Several investigators have attempted to discover the effect of variations in the composition of milk on its digestibility. Natural variations such as fat content and curd tension have been studied, (9, 41, 47) as well as the possible effect of physical and chemical treatments (5, 10, 11, 17, 20, 32, 39, 40).

The physiological development of the animal has been considered in some milk digestion experiments. Hughes and Cave (25) fed two Holstein calves an exclusive milk diet from birth to approximately 8 months of age. By withholding grain and roughage, they prevented normal rumen function and general muscle development of the digestive tract. The calves were about 20 per cent below normal weight at the end of the period, but were of normal skeletal size, as judged by height at the withers. By conducting a digestion trial at the end of the milk feeding period, they concluded that restriction of calves to a milk diet for 8 months does not impair the calf's ability to digest milk and that rumen and digestive tract development caused by roughage feeding is probably not a factor in the secretion of digestive juices. Coefficient of apparent digestibility for protein and fat of partially skimmed milk were 95.2 and 98.3 respectively for these calves at 8 months of age.

Doane and Price (11) were interested in the effect of preservatives on the digestibility of milk. They chose dairy calves for their study because, "The young calf is not what would be termed a hardy animal as they are especially susceptible to anything wrong with the food given them. It takes very little irregularity in feed to disturb digestion and start them to scouring". Because of the possible difference that age of the calf might have on its tolerance for the preservative in the milk, records were kept of the exact age of each calf in each digestion trial period. Three day preliminary feeding periods and 3 day

feces collection periods were used. The coefficients of digestibility for individual calves on a diet of milk containing no preservative are listed below:

Age of calf in days	Per cent digested	
	Protein	Fat
14	93.61	96.80
20	93.66	97.34
22	91.56	96.05
27	94.79	96.82
31	93.16	98.06
49	92.37	98.28
55	93.52	98.37
14	95.24	skimmed milk
15	94.34	skimmed milk

In comparing results obtained with calves of different ages, these authors concluded that age of the calf had no effect on the digestion coefficients obtained. The negligible differences observed were generally in favor of the younger calves.

In an earlier experiment Doane and Price (10) compared the digestibility of raw, pasteurized, and cooked milk. Dairy calves, started on experiment at 14 days of age, were used. Three day preliminary and 3 day collection periods were used. In 6 experiments, the average coefficients of digestibility of the protein and fat in raw whole milk were 94.79 and 96.82, respectively.

Blackwood et al. (5) used dairy calves for nitrogen and mineral balance studies in a 42 day experiment, beginning when the calves were 10 days old. The average digestion coefficient of protein obtained with 16 calves over a 42 day period was 94.

Prytz (47) compared the digestibility of milk of varying curd tension and fat content. For this study dairy calves between the ages of one and three months were used, in 6 day preliminary and one day collection periods. Differences in digestive efficiency due to age (one to three months) were not noted. The average coefficients of digestibility of protein and fat are given below:

Per cent digested			
Fat in milk	Protein	Fat	Type of milk
1.94	89.81	91.50	Soft curd, low fat
5.70	91.79	96.36	Soft curd, high fat
2.04	93.43	92.04	Hard curd, low fat
5.82	92.25	95.90	Hard curd, high fat
9.60	86.77	95.39	Soft curd, very high fat

It was believed that the lower coefficient of fat digestion by the calves on the low fat diet, was due to a greater amount of metabolic fat in the feces in proportion to the residue of food fat rather than a difference of actual digestibility. Two calves were then fed skim-milk and the feces analyzed for fat. On the fat free diet, feces of these two calves contained 2.33 and 2.82 per cent fat.

The time required for milk curds in the stomach of calves to liquify and move into the intestines has been investigated (14, 38). Soft curd milk or milk of high fat content moved out of the abomasum faster than hard curd or low fat milk. Smaller curds were formed from the soft curd than from the hard curd milk. It

was assumed that the larger surface area provided by the smaller curds permits more rapid gastric digestive action as measured by the rate of disappearance of the curd masses.

Dickey et al. (9) found the rate of disappearance of milk curd from the calf's abomasum to have no effect on the coefficient of apparent digestibility of its protein as determined with rats receiving milk from the same samples as the calves were fed. In their experiments the rate of evacuation of milk curd from the stomach was determined by palpation of the abomasum through the rumen wall of rumen fistulaed calves. Carmine was used to determine the rate of movement of food residues through the entire digestive tract of the calf.

Nevens and Shaw (41) used rats to compare the digestibility of milk of five breeds of dairy cattle. Three day preliminary and 10 day collection periods were used. Results obtained in this study are given below:

Milk	Per cent digested				
	Ayrshire	Brown Swiss	Jersey	Holstein	Guernsey
Protein	90.0	92.3	89.7	89.8	89.7
Fat	98.6	99.0	98.4	98.2	98.6
Carbohydrate	100.0	100.0	100.0	100.0	100.0

These workers state that young growing rats were used in the digestion trial with Brown Swiss milk while mature rats were used for the other studies. They concluded that there is no difference in the digestibility of milk of the five breeds of cattle and state: "It would be hard to get digestion coefficients more alike with animals on the same feed".

In other experiments, Nevens and Shaw compared the digestibility of fresh whole milk with that of powdered whole milk (39) and evaporated milk (40). Rats were used for each study. Results of these experiments were as follows:

Food	Per cent digested		
	Protein	Fat	Carbohydrates
Fresh whole milk	90.0	98.7	100
Powdered whole milk	87.4	98.7	100
Fresh whole milk	92.3	99.0	100
Evaporated milk	88.4	99.0	100

Fraps (17) determined the digestibility of many human foods, including milk, using rats in 10 day feeding periods. In 6 digestion trials, the average coefficient of apparent digestibility of the protein and fat in fresh whole milk were 92.0 and 99.2 respectively.

Bryant (6) used a 9 month old boy for a digestion trial in which whole milk was used as the exclusive diet. He obtained digestion coefficients of 93.8, 95.7, 83.3, and 51.6 for protein, fat, carbohydrates, and ash, respectively. One month later he conducted another study with the same boy; milk, oatmeal and sugar constituted the experiment diet. Digestion coefficients for the mixed diet were: Protein 95.6, fat 98.4, carbohydrates 93.9, and ash 60.9. The higher digestion coefficients obtained in the second experiment probably reflect a higher digestibility of the mixed diet rather than a difference in digestive capability of the child due to age. Woods and Merrill (56) found that the digestibility of simple diets for humans were improved by the addition

of milk. Even considering milk nutrients to be 100 per cent digested, the digestibility of bread was improved by the addition of milk.

Jaffa (28) conducted a milk digestion trial with a one year old child. Coefficients of apparent digestion, for this experiment were: Protein, 88.3; fat, 95.8; carbohydrates, 88.8; and ash, 75.4.

It seems to be a generally accepted idea that children digest milk slightly better than adults. The work of Atwater (3) demonstrates one possible reason for this apparent difference. He conducted 3 successive digestive trials with a 28 year old man. Coefficients of apparent digestibility for protein in the three periods were 88.0, 90.5, and 95.6. Fat was digested to the extent of 97.0, 95.5, and 98.1 per cent in the three successive periods. Increased digestibility of protein through the three periods apparently reflects an adjustment of digestive action to the change from a normal to an all milk diet.

Adults are often changed abruptly to an all milk diet for a digestion experiment whereas children ordinarily receive a high proportion of milk in their normal diet, and might adjust to an exclusive milk diet more quickly than an adult. In the short period of the usual digestion trial, this would be an advantage in favor of the child. In addition, digestion trials with children are usually conducted with a preliminary period of feeding the experimental diet before feces collection is begun. Whereas,

with adults, it is customary to dispense with the preliminary feeding period by incorporating an inert coloring material in the first and last meal of the trial period. The collection is begun when the first marker appears and ended with the appearance of the second. Although this system is an expedient to conducting a digestion trial, incomplete adjustment of digestive processes to a change of diet may be reflected in the digestion coefficients obtained.

It seems strange that some workers reported milk carbohydrate digestibility as high as 100, and values as low as 83.3 were reported by others. These variations may have been due to differences in analytical procedure as well as to possible differences in the digestibility of carbohydrate. In certain experiments lactose in the feces was tested by Benedict's or Fehling's test for sugar. In the studies where these tests were used to test the feces for sugar, results were negative and carbohydrate digestibility was given as 100. (Woods and Merrill,55 , used a digestion coefficient of 98 for carbohydrate, even though no sugar was present in the feces. They assumed that two per cent of the energy expended in secretion of the lactose enzyme.) Frequently, the digestibility of carbohydrate is calculated from the content of carbohydrate in feed and fecal residues that are determined by difference. Such coefficients for carbohydrate digestion include all of the possible errors of analysis for other nutrients and therefore, may not be exact values.

Most of the literature dealing with the food value of milk leads one to the conclusion that milk is completely digested,

and except for metabolic excretions, the digestion coefficients of the organic constituents of milk would be 100 (10, 56). However, the reports of Childrey et al. (7) and Hasoi et al. (20) are exceptions. They surgically removed the large intestine of dogs and joined the ileum to the rectum. This operation permitted fecal residues from the small intestine to pass continuously instead of accumulating in the large intestine for later defecation. These dogs were then used in experiments to find foods that gave low fecal residues and would, in consequence, be desirable ingredients in the diet of humans recovering from intestinal or rectal surgery. Both groups of workers concluded that milk was not as digestible as meat, judged on the basis of fecal weight obtained from the two foods. In fact, the feces of dogs on a meat diet was only two per cent greater than when they were fasting and defecating metabolic products only. To explain the apparent difference in the digestibility of meat and milk. Childrey et al. (7) fed lactose with other foods and found that the fecal residues of foods, other than milk, were increased when lactose was added. He concluded that peristalsis of the intestines caused by the lactose in milk interferred with the digestion and absorption of the other milk nutrients.

Morrison's (37) tables of feed values probably represent the most comprehensive compilation of digestion trial data to be found at the present time. He uses 95, 98, and 98 as the digestion coefficients for protein, fat, and nitrogen free extract of cows' milk. For gravity skim-milk he uses 94, 100, and 100 for protein, fat, and nitrogen free extract, respectively. It is of interest

that no other feed, except soluble blood flour (protein 96 and fat 100, respectively), listed in his tables of feeding stuffs, is given as high coefficients.

Utilization of Grain and Roughage by the Growing Calf

Considerable information on the rate of development of the digestive tract of the growing calf has been obtained from practical feeding experiments designed to determine the minimum requirements of the more expensive feeds necessary to produce normal sized heifers at 6 months or 24 months of age. Yet little information is available as to how completely the young calf digested hay or grain when these feeds are first consumed. The "limited whole milk and dry calf starter" method of calf feeding is widely used. From a description of the method by Turk and Burke (50) the following observations are made: (1) The two week old calf will begin to eat some dry starter mix and hay, but the calf will be 7 to 10 weeks old before a starter mix can be relied upon as a complete replacement for milk; (2) protein synthesis by rumen micro-organisms is sufficiently great at 16 weeks to permit replacement of animal protein in the diet with all vegetable protein; and (3) the digestive capacity is sufficient at about one year of age to permit replacement of all grain with green roughage in the form of excellent pasture.

Shaw et al. (49) added starch to a normal diet fed to two calves at four days of age, and at regular 8 and 10 day intervals, thereafter, to 39 days of age. Each time starch was added,

feces were collected and analyzed for starch. The coefficient of apparent digestibility of the starch was calculated from the total amount of starch fed and recovered during each period. Between 4 and 39 days of age, the coefficient of apparent digestibility of the starch increased from 22 to 99 per cent.

Flipse et al. (16) found that the blood sugar level of 25 to 35 day old calves was not increased within four hours after starch was fed to them. When glucose or lactose was fed to the same calves, the level of blood sugar was increased immediately.

Wallace et al. (51) compared the digestibility of rations containing starter, hay and different milk substitute mixtures. Calves of five and eight weeks of age were used in 10 day preliminary feeding, and 10 day feces collection periods for these trials. All nutrients of the rations were more fully digested by the eight week old calves than by the five week old calves.

Wise et al. (53) studied the postnatal changes of blood vitamin A levels of calves fed whole milk to four weeks of age, and then given skim-milk. Grain and hay had been offered to the calves at two weeks of age, but they were six weeks of age before they utilized sufficient hay to halt the downward trend of vitamin A concentration in their blood.

Conrad et al. (8) investigated the possibility of inoculating the rumen of small calves with micro-organisms from the rumen of mature cattle, as a means of hastening roughage utilization by the growing calf. Rumen inoculation seemed to increase roughage consumption although considerable differences existed within

the groups of inoculated and uninoculated calves. All calves were eating a constant amount of hay daily, by the time they were 7 to 10 weeks of age. Digestion trials were used to determine the effect of rumen inoculation on the digestibility of a milk-alfalfa hay ration. The inoculated calves digested 80.7, 65.76, and 80.99 per cent of the dry matter, cellulose and protein, respectively, as compared with 71.76, 61.34, and 78.70 per cent for the uninoculated group. The age of the calves used on the digestion experiment was not reported. Hay consumption and the type of rumen flora present, not the age of the calf, determined the starting time of the digestion trial.

EXPERIMENTAL

Because different methods were used in determining the digestibility of milk and of a ration containing milk plus grain and/or hay, this report is divided into two parts. Part I deals with the digestion of colostrum or milk by the newborn calf; Part II with the digestion of a ration in which oats and/or alfalfa hay were included with a milk diet.

Part I - Colostrum and Milk Digestion by Newborn Calves

The object of the first trial was to study digestion of food by the newborn calf, receiving its dam's colostrum and milk through the first 8 days of life and whole milk from the 14th to the 18th day. By means of this study it was intended to determine if the calf's efficiency to digest its natural food is the same at birth as it is in later days of early postnatal life.

Although primarily devoted to digestion, this study was, necessarily, also an experiment with neonatal calves as digestion trial subjects and with methods of dividing an uninterrupted feeding schedule, using a diet containing a milk product of varying composition, into a series of consecutive digestion-trial periods.

Animals Used. Twelve purebred male calves, one Ayrshire, 2 Jerseys, and 9 Holsteins, born in the Kansas State College dairy herd were used in this trial. The study extended from October, 1950, to April, 1951. All of the bulls born in the herd during that period were employed except those born when an attendant was not present to remove the calf before it had a chance to nurse.

For convenience the calves used, are designated by letter A, B, C, etc. in this report. Ear tag identification numbers of the calves are given in Appendix, Table 1.

Limited facilities and difficulties described elsewhere prevented the fullest use of all 12 animals. Only one metabolism cage was available and when calves were born at intervals of less than 18 days (the time each calf was to be kept for the colostrum and milk digestion trial) the older calf was either discontinued from the experiment or was placed in a temporary pen for the remainder of the 18 day period. Digestion trials with 7 Holstein calves were completed and are included in this report. When it became necessary to use temporary pens, they were constructed in the same room with the metabolism cage (one exception reported elsewhere). One half inch mesh hardware cloth, stretched over a frame of 2 x 4's, was used for the floor of one pen, and 2 x 2

inch slats were used for the floor of the other pen. These pens were poor substitutes for the metabolism cage. Recovery of feces that escaped from the feces collection bag on the calf, involved raising the pen floor. Whenever feces lodged between the slats of the wood floor, or on the cross braces of the wire floor, complete recovery was often impossible, and involved the initiation of a new trial.

Feeding and Care of Animals. Calves were removed from their dams and placed in the metabolism cage shown in Fig. 1. The cage was kept in an artificially heated room of the Kansas State College dairy barn. Prior to the time of placement in the cage the following things were done: (1) The calf was dried off, (2) weighed, (3) its naval cord removed and the naval disinfected with tincture of iodine, (4) the hair was clipped from the area around the anus to prevent matting with feces, and (5) the feces collection bag and harness (Fig. 2) were placed on the calf.

The calf's dam was milked out completely, usually within the hour after parturition, and the calf was fed a representative sample of colostrum from the complete milking. In the first day or two after birth, when the calf was fed more often than the cow was milked, milk from the most recent milking was fed. For instance, when the calves were fed three times the first day of life, the first milking from the dam was used for the first 2 feedings and the second milking was used for the third feeding. When the calf was fed twice daily, milk from the morning and night milkings of the dam was used. On the 9th day after birth, whole

milk from the Kansas State College dairy herd was substituted for dam's milk.

Throughout the experiment all calves were fed from a nipple bottle to minimize the chance of milk entering the rumen instead of proceeding directly to the abomasum (54). Colostrum or milk was heated to 98° F. in a water bath before each feeding.

The amount of milk fed per day was one pound of milk per 8 pounds of body weight for Jerseys and one pound of milk per 10 pounds of body weight for Holsteins, not to exceed a total of 9 pounds of milk per calf. The milk was weighed to within one gram. The amount of milk fed was determined by accepted feeding standards except that the total quantity of milk was held somewhat low in proportion to the calf's gain in weight. It was hoped this would eliminate the possibility of scours due to overfeeding. When scours did appear, feed allowance was reduced to 1/2 the scheduled amount and gradually increased as the condition improved.

Medicinal therapy was not used in cases of scours because of the possible effect on digestion. Each calf received 400 I. U.'s of vitamin D daily in the form of irradiated yeast in a gelatin capsule.

Methods of Correlating Food and Feces in Digestion Experiments. With the exceptions discussed later, 4 digestion experiments were conducted with each calf. Three of the experiments were done in succession from birth to the 8th day. They were

Fig. 1. Metabolism cage used for the colostrum and milk digestion trials.

divided into the following periods: (1) 1st and 2nd day, (2) 3rd and 4th day, and (3) 5th through the 8th day. The 4th experiment covered the 14th through the 17th day of the calf's life.

Carmine at the rate of approximately 1/4 teaspoonful per quart of milk was incorporated in the first feeding of each experimental period (except the first period, as noted below) and in the first feeding after the end of the period. Feces collected from the first appearance of carmine to its next appearance were combined as the total fecal residues for that digestion period. In the consecutive digestion experiments carmine was added to the milk fed in the first meal of each period and in the meal following the completion of the last period. Except with the first two calves, carmine was not added to the first neonatal feeding. Meconium differs enough in appearance from the first food residues that a marker was not necessary.

The method of marking feces discussed above proved the most satisfactory of various methods tried. It was used throughout most of the experiments. With the first calf, carmine was added to all of the milk fed in alternate digestion periods. Later, carmine was added to the milk fed the first and last feeding of alternate periods. It was found by these experiments that it is much easier to determine the first appearance of feces from a meal marked with carmine, than to ascertain the exact point where the feces from that meal ends. Apparently, some carmine

adheres to the intestinal wall and mixes with or coats the residue of the next feeding, causing a gradation of color instead of a complete break.

Feces Collection. Feces were collected by means of plastic liners inside of the canvas feces collection bag shown in Fig. 2. At each feeding time the bags were inspected. Whenever feces were present, the plastic liner containing the feces was removed, labeled with calf number and time of collection, and then stored in a refrigerator in a friction top can. At the end of each digestion experiment the bags with feces were arranged in date order. The feces for the exact experimental period were then separated from the "before" and "after" excretions by observing the presence of the carmine marker. Feces representing the division point between two periods were usually contained in the same liner. A spatula was used to make the separation at the junction of "colored" and normal feces.

Chemical Analysis. The following analytical procedures were used:

Solids. A sample of approximately 10 grams of feces or milk was weighed into a porcelain dish and heated in an air oven at 103° C. for approximately 12 hours. Total solids were calculated from the weight of the residue.

Ash. The residue from the determination of solids was heated in a muffle oven at 500° C. for approximately 12 hours. Ash was calculated from the weight of the residues.

Protein (N). Nitrogen was determined by the A. O. A. C. Kjeldahl method (1). Samples of the following quantity were found to be satisfactory: Feces 3 g, milk 10 g, and colostrum 5 g.

Ether Extract (fat) 1. Feces. A 10 g sample of feces was ground with 90 g of anhydrous sodium sulfate. A 1/4 aliquot of the mixture (corresponding to 2 g of feces) was placed in a corumdum thimble and extracted over night with anhydrous ether in a Goldfinch extractor. The residue was heated in a vacuum over and then weighed.

2. Milk and Colostrum. A 1.5 g sample was ground with 19 g of anhydrous sodium sulfate and transferred to a corundum thimble. Otherwise, the same procedure was followed as for ether extract of feces. This method of determining the fat content of colostrum and milk were compared with the Babcock method and results obtained were quite similar with either method.

Carbohydrates (lactose). The carbohydrate content of milk and feces was obtained by subtracting the sum of other nutrients in each sample from the total solids.

Several samples of feces were tested for reducing sugar with Fehling's solution. Negative results were obtained in every case.

Vitamin A and Carotenoids. Ten grams of feces were saponified for 30 minutes with a 20 per cent potassium hydroxide-alcohol mixture. The mixture was extracted with ether and the ether layer washed with water (cold, acidified, alcoholic water); then washed again with water after adding Skellysolve B to

Fig. 2. Feces collection bag and harness.

decrease the solubility of the water in the upper layer containing the vitamin A and carotenoids. The solution was then evaporated to dryness under vacuum, and the residue taken up by Skellysolve F. An aliquot of the solution was read in an Evelyn photometer using a 440 mu filter. The absorbance was used in calculating the amount of carotenoids present.

Ten milliliters of solution used for the carotenoid reading was evaporated under vacuum and heat at 60° C. and the residue was taken up in 1 ml of chloroform. Nine ml of Carr-Price reagent was added and the reading taken 5 seconds later using a 620 mu filter. The absorbance (corrected for carotenoids) was used in calculating the amount of vitamin A in the sample. The method is a modification of that used for vitamin A in milk and colostrum by Parrish et al. (44).

Apparent digestibility. The coefficient of apparent digestibility of each nutrient was calculated by the following formula:

$$\text{Apparent digestibility} = \frac{\text{Weight of nutrient absorbed} \times 100}{\text{Weight of nutrient consumed}}$$

Weight of nutrient absorbed = the weight of the nutrient consumed minus the weight of the nutrient recovered in the feces.

Experimental Results and Discussion. Results of the colostrum and milk digestion trials with 7 calves are presented in Table 1. Several deviations from the planned pattern of 1-2, 3-4, 5-8 day experimental periods were necessary. The deviations occurred in experiments where the division point between the

fecal residues of milk marked with carmine and previous or subsequent meals could not be distinguished. In such cases it was necessary to combine 2 experiments in the series, or start another experiment after the calf's digestive tract cleared of carmine.

The Digestibility of Milk and Colostrum. For purposes of discussing the digestibility of colostrum and milk, it seems desirable to distinguish between the two products. Although most of the change from colostrum to milk, in successive milkings after calving, occurs before the 4th milking (43), "milk" produced prior to the 9th milking ordinarily is considered not fit for human consumption. The calf receiving its dam's mammary secretion is consuming a gradient colostrum-milk combination, after the first meal. The division line used in this study, between the two products, is purely an arbitrary one.

If the division were placed between the 4th and 5th milking, colostrum is better digested than milk by very young calves (Table 1). The difference in digestibility is slight, but is noticeable in the regard to protein. Excluding the digestion experiments in which severe scours occurred (calf C in the 1-2 and 3-4 day period, calf D in the 3-4 day period and calf L in the 5-8 day period) on the average, protein was digested to the extent of 93.1 per cent in the first 2 days of life as compared to 89.0 per cent in the 3rd and 4th day and 90.4 per cent in the 5th through 8th day period. In the 14th to 18th day experiment protein of milk was 93.1 per cent digested, the same coefficient as for the protein of colostrum in the 1-2 day period.

Table 1. Coefficients of apparent digestibility of colostrum and milk by newborn dairy calves.

Period, days of age	Calf number C	D	G	H	I	K	L	Av.
Protein								
1 - 2	*79	92	90	93	96[5]	96	92[9]	91.1
3 - 4	*70[1]	*78	87	-	85[6]	95		84.5
5 - 8	99[2]	90[3]	92[4]	88	83[7]	-	*74	87.6
14 -17	94	96	93	95	89[8]	90[10]	95	93.1
Ether extract								
1 - 2	*92	96	97	97	99[5]	98	96[9]	96.4
3 - 4	*96	*90	98	-	98[6]	99		96.1
5 - 8	100[2]	98[3]	98[4]	96	98[7]	-	*85	96.1
14 -17	90	99	99	99	99[8]	99[10]	99	97.7
Carbohydrate								
1 - 2	*-	94	99	100	100[5]	98	81[9]	95.3
3 - 4	*90[1]	*100	99	-	98[6]	99		94.5
5 - 8	100[2]	99[3]	100[4]	100	96[7]	-	*100	99.1
14 -17	99	99	100	100	98[8]	99[10]	100	99.3
Ash								
1 - 2	*86	91	91	96	99[5]	98	86[9]	92.4
3 - 4	*86[1]	*88	93	-	94[6]	98		90.8
5 - 8	100[2]	95[3]	95[4]	93	92[7]	-	*80	92.6
14 -17	76[11]	97	94	97	90[8]	95[10]	97	95.0
Carotenoids								
1 - 2	-	-	70	52	96[5]	80	51[9]	74.5
3 - 4	-	-	45	-	-	65		53.6
5 - 8	-	34[3]	82[4]	31	47	-	*19	34.0
14 -17	-	59	49	74	48[8]	53[10]	59	57.0
Vitamin A								
1 - 2	-	-	98	88	94[5]	97	85[9]	92.4
3 - 4	-	*45	91	-	91[6]	93		81.0
5 - 8	-	97[3]	96[4]	93	90[7]	-	*84	92.0
14 -17	-	94	95	98	94[8]	97[10]	98	96.0

[1]3rd day only.
[2]4 - 7 days.
[3]5 - 9 days.
[4]4 - 10 days.
[5]1 - 3 days.
[6]4 - 6 days.
[7]7 - 9 days.
[8]13 - 15 days.
[9]1 - 4 days.
[10]15 - 18 days.
[11]Dirt through muzzle (value not included in average).
*Severe scours, undigested milk recognizable in feces.

In all experiments completed protein digestion was lower in the 3-4 day period than any other period of the experiment. In explanation of this the following hypotheses are advanced: (1) Perhaps the protein of colostrum is more digestible than the protein of milk, for the very young calf and the proportion of colostrum in the transitional milk diet decreases more rapidly than the calf's digestive tract can adjust to the changing diet. (2) Howe has suggested from his metabolism studies with humans after fasting (24), and from feces analysis with newborn calves (23), that it requires about 3 days after the food first enters the digestive tract for the metabolic processes of the body to adjust themselves. With men, urinary excretion of ammonia is very high on the 3rd day after breaking a fast. Whether the newborn calf has a high fecal excretion of metabolic nitrogen on the 3rd or 4th day after birth, is not known. (3) Perhaps the experimental technique used in the trial in some unknown way affected results.

Kaeser and Sutton (30, 31) have shown that calves make more rapid weight gains if the colostrum feeding period is extended and that extra colostrum is more valuable in the ration of very young calves than for older ones. The higher nutrient content of colostrum (43) as compared to milk, would partially account for increased growth if the two products were equally well digested. Nutrient factors of colostrum, not present in milk, (23) might account for the difference in response of young and older calves to extra colostrum.

Carbohydrates and fats were highly digested in all trials. Differences in digestibility for different ages were negligible.

Ash was highly absorbed in all periods. Coefficients of absorption were 92.4, 90.8, 92.6, and 95.0 for the 1-2, 3-4, 5-8, and 14-17 day old calves, respectively.

Vitamin A and carotenoids were more completely absorbed in the first 2 days of life than in either of the 2 succeeding periods. Vitamin A was absorbed to the extent of 92.4, 81.0, 92.0, and 96.0 per cent in the 1-2, 3-4, 5-8, and 14-17 day periods, respectively. Carotenoid absorption was highly variable (4 to 96 per cent) with different calves and in different periods for the same calf.

With one exception, all data completed are included in Table 1. Calf A, the first animal used, digested 99 per cent of the fat and 95 per cent of the ash, of whole milk, in the 7 to 12 day period. The digestibility of other nutrients was not determined.

As was previously mentioned, it was necessary to place experimental calves in temporary pens when more than one digestion trial was being conducted. Calf C was put into a dirt floored pen, bedded with shavings, for the 14-17 day period. Even though muzzled, he rooted dirt through his muzzle and swallowed enough that clay and sand were easily recognized in the feces ash.

Newborn Calves as Digestion Trial Subjects. There are several factors, worthy of mention, that might have an effect on the results obtained with this type of digestion experiment. Some of them are discussed in the following paragraphs.

The feces of all calves used contained some hair throughout the experiments. No estimation could be made as to the amount or its effect on lowering the apparent digestibility of protein. Muzzles made of 1/4 inch mesh hardware cloth, were used with the first calves, but the wire wore skin off of the calf's nose and did not seem to reduce the amount of hair in the feces in early life. Hair is present in the calf's digestive tract at birth (42), and possibly all of it is not removed with the meconium.

According to the findings of Wise et al. (54) milk fed to young calves from nipple pails usually does not enter the rumen but the possibility that some milk might enter the rumen must not be overlooked. Pounden and Hibbs (45) removed milk curds from the rumen of one day old calf by means of a stomach tube. Retention of milk in the rumen would increase apparent digestibility for the period in which it was fed. If the retained milk moved on through the digestive tract during the course of a later digestion trial digestion coefficients would be lowered.

The accuracy of marking the feces of a particular meal by the incorporation of an inert material in the food is not completely satisfactory. Several investigators (4, 27, 52, 55, 56) have demonstrated this fact. Irwin and Crampton (27) changed the diet of humans at the same time a marker material was given. Some of the marker was found in the fecal residue of food eaten before and/or after the meal in which the marker was given. This was apparent by the difference in the character of the feces of

the separate diets. Two possible reasons why feces marker might become mixed with the residues of previous and subsequent meals are illustrated by the work of Washburn and Jones (52). They found that some of the colored dye given to pigs after milk feeding moved on into the intestines immediately and that colored milk curd in the stomach could be surrounded by the curd of milk fed later.

One factor in milk digestion trials that tends to minimize errors in procedure is the high digestibility of milk. Rather large errors in feces collection would have had little influence on the coefficients obtained in this experiment.

Carmine as a Feces Marker with Young Calves. Carmine is listed by Maynard (35) as one of the most frequently used feces marker substances. It was chosen for this experiment because of the high color it gives to feces.

With several of the calves used in the early part of the study, feces containing carmine seemed much more moist than feces excreted at other times. Frequently small quantities of blood were excreted with carmine. In several instances after the excretion of carmine, feces would be of almost whey consistency for 2 or 3 days.

Only one report of physiological effect of carmine was found in the literature. Macy (33) used carmine as a feces marker in balance studies with children 7 to 11 years of age. She noticed a difference in the consistency of feces when it contained carmine (0.2 or 0.3 g of carmine was given in one

meal at the beginning and again at the end of 6 day experimental periods). Using the Rontgen ray, she then studied the effect of carmine on the rate of passage of barium milk through the digestive tract (34). When carmine was given with barium milk, the time for total passage was not affected, but the evacuation of milk from the stomach was increased 30 to 50 per cent over periods in which carmine was not given with the milk. Movement of food through the lower digestive tract was retarded by carmine to approximately the same extent that stomach emptying time had been increased by its presence. However, Johnson et al. (29), and Pounden and Hibbs (45) report that the moisture content of the feces of young calves is highly variable and feces of near water consistency are frequently voided after the first 3 or 4 days of life.

Part II -- The Digestion of Rations Containing Milk Plus Oats and/or Alfalfa Hay by Young Calves

Preliminary Experiment -- Digestion Experiment with a Milk Plus Alfalfa Hay Ration. When the experiments reported in this section were planned, facilities with which they could be conducted were not available. Two calves were used in a preliminary study to establish condition for a satisfactory method to use in later digestion trials.

Calves C and D used in the milk digestion experiments reported in Part I were placed in individual calf pens bedded with shavings. Alfalfa hay was offered twice daily after milk feeding. Except at feeding time the calves were kept muzzled. Both calves

soon learned to dip bedding into their muzzles. To prevent this and to give them a better opportunity to learn to eat hay, the muzzles were removed and the calves were placed in regular calf stanchions. A 3 ply fir board, the width of the stall, was fitted to the front of the stall and the pattern of the opened stanchion cut out. To permit the calf to lie down without choking himself, the bottom of the stanchion opening, and the top of the manger had to be within about 4 inches of the floor. At this height bedding was pushed through the opening into the manger by the calf's movement. To prevent this a heavy cloth was attached to the bottom of the opening. A strong elastic was put through the top of the cloth and fastened across the opening, above knee height of the calf. The elastic permitted the calf to lie down but held the cloth at knee height when he stood up. This method seemed to be a satisfactory solution to the problem of conducting a digestion experiment with calves in bedded stalls, for the cloth barrier kept all bedding out of the manger, and still did not restrict the calf's movements.

Beginning at 35 days of age, Calf C was fed 12 pounds of whole milk and 100 g of chopped dehydrated alfalfa daily through a 10 day preliminary and a 10 day feces collection period. The amount of alfalfa fed was determined by the ad libitum intake over the 33 and 34 day period. Water was offered once each day but consumption was negligible. This was to be expected with calves of this age (2). Four hundred I. U.'s of vitamin D in

the form of irradiated yeast in gelatin capsule was administered daily. (Calf D injured his hock and was removed from the experiment.)

This Holstein bull calf weighed 152 pounds at 45 days of age, when feces collection was begun. It weighed 168 pounds at 55 days of age when the digestion experiment ended, therefore indicating a normal rate of gain (48).

Exercise was provided daily throughout the experimental period. In the early part of the preliminary period the calf was removed from the stanchion, muzzled, and turned loose in a dry lot for about an hour each day. The muzzle did not prevent the calf from eating dirt and bits of trash found in the lot. Therefore, beginning 2 days before the feces collection period, Calf C was exercised about 15 minutes each day by leading it up and down the alley of the calf barn. This exercise was provided for the comfort of the calf rather than for the possible effect on digestion. Ellenberger and Schneider (12) found that exercise has little effect on digestion trial results.

The same procedure of feces collection and storage was used as in the milk digestion experiment described in Part I. Standard A. O. A. C. methods (1) were used for analysis of the hay and feces. Feces were sampled, dried, and ground for analysis of nutrients. Protein (N) was also determined from a wet sample of feces. The same methods were used for analysis of the milk as described in Part I. In this trial milk samples were composited in two 5 day periods for analysis. Results of this digestion trial appear in Table 2. Analytical data are given in Appendix, Table 2 and 3.

Table 2. Digestibility of a milk-alfalfa hay ration determined by a 10-day trial using a Holstein calf (Calf C) from 45 to 55 days of age.

Daily feed, g	Coefficients of apparent digestibility					
	Protein	Ether extract	Nitrogen free extract	Crude fiber	Total carbohydrates	Ash
Whole milk, 5448 Dehydrated alfalfa 100	90.5	97.7	74.9	19.2	61.5	70.9

Protein and ether extract digestion coefficients obtained in this experiment are comparable to the coefficients obtained when milk was fed alone (Part I). Coefficients for carbohydrates and ash were 61.5 and 70.9, respectively, with the milk plus alfalfa ration, as compared to 95.2 to 99.4 and 91.4 to 94.7 for carbohydrates and ash of milk diet alone (Part I).

Digestion coefficients for alfalfa cannot be determined by difference in this study, because an exclusive milk diet was not fed to control animals under the same experimental conditions. Such a small proportion of the total nutrients in the ration were from alfalfa that it would be meaningless to use average coefficients for milk and calculate alfalfa digestion by difference. For example, 92 per cent of the protein in the ration was from the milk. If the protein of milk was 90.5 per cent digested, then the protein of alfalfa was also 90.5 digested. However, if a digestion coefficient of 94.0 is assumed for milk protein, then the coefficient of digestion for the alfalfa protein, then the coefficient of digestion for the alfalfa protein would be 36.0.

Coefficients of digestibility for carbohydrates and ash were low, considering the high proportion of milk in the ration and the coefficients obtained in other experiments with an exclusive milk diet.

Crude fiber was digested to the extent of 19.2 per cent. From the result of this one trial it would appear that the fiber of alfalfa is poorly digested by a 7 week old calf in comparison to what would be expected with a mature animal. (Morrison(37) gives a digestion coefficient of 44 for crude fiber of alfalfa hay, all analysis.) However, later calves kept in the same digestion stall were observed eating wood shavings (discussed later) and possibly that Calf C might have eaten shavings, too. If shavings were consumed the digestion coefficient of crude fiber would be affected.

Digestion Experiments with Milk Plus Oats and/or Alfalfa Hay - Experimental. Six calves were divided into 3 pairs for digestion trials at 30 days and again at 60 days of age. Two calves were to receive a milk plus oats ration. A second pair were to be given a milk plus alfalfa ration and the third pair were to have a milk plus oats and alfalfa hay ration throughout the period. Due to inadequate facilities one calf from the milk plus oats ration had to be discontinued.

Animals Used. The four calves G, H, E, and F used in the milk digestion experiments (Part I) and one Jersey bull calf M were used in this study. Calves E and F, a Holstein and an Ayrshire, were used for the milk-oats-alfalfa ration. Calves G and

H, Holsteins, were placed on the milk-alfalfa ration and the Jersey, M, was fed the milk-oats ration.

Care of Animals. The same procedure followed in the milk-hay digestion trial was used. For this experiment, the calves, at 20 days of age, were stanchioned in stalls bedded with wood shavings. Five and 6 days later 2 calves were observed eating shavings. They had learned to arch their necks enough to get their noses behind the elastic-cloth stanchion cover. They would then lower their heads to the bottom of the stanchion and eat shavings that were against the stanchion. Other methods of arranging the barrier between the manger and stall were tried with somewhat better success. However, it was finally decided that bedding would have to be dispensed with.

Mattresses were made by filling burlap sacks with wood shavings. The mattresses were placed in the pens for the calves to lay on. However, this was unsatisfactory because the mattresses became wet. Without bedding or when kept on wet mattresses the calves developed colds and scours. (At certain times during this period the outside temperature dropped below -10° F.)

As a solution to the difficulties outlined above, the expanded metal floored pens illustrated in Fig. 3 were built in the heated room where the colostrum milk experiments were conducted. Three 4 x 8 foot sheets of 5/8 inch mesh, 16 gauge expanded metal were used for the floor. This floor space was divided into 6 pens 4 x 4 feet square. Discarded steel calf stanchions were used for the sides, and 1" x 4" boards were used for

partitions between the pens. These pens were satisfactory for conducting digestion trials, but they could have been improved by metal construction throughout thus excluding the possibility of calves eating wood. It would be desirable to use heavier metal for the floor of the pen to reduce the number of braces needed to support it. Fewer braces would facilitate cleaning under the pens and simplify the fitting of urine collection pans if the pens were to be used for balance studies.

Calves E and F were 54 days of age and were the oldest of the 5 experiment calves when they were moved into the battery of pens. Plans for digestion experiments, other than those at 60 days of age, had been abandoned earlier because of the inadequate facilities that were present when the calves were 30 days old.

Feeding. As each calf reached 20 days of age he was offered hay, oats, or oats and hay, depending upon the experimental group to which he had been assigned. The amount of feed offered was in excess of what the calf would consume. Between 30 and 33 days of age the average amount of hay and/or oats actually consumed was adjusted to a per day basis and this amount was fed daily thereafter to the end of the trial; i.e., to 67 days of age.

Whole milk, standardized to 3 per cent butterfat content (Babcock test), was fed from open pails. The daily rate of milk feeding was based on the calves weight at 30 days of age. They were fed one pound of milk per 10 pounds of body weight.

Fig. 3. Close up of one of the battery of six digestion pens.

It was not a part of the original experimental plan to maintain the calves on a constant level of feed from 33 to 67 days of age. But due to the many difficulties encountered in finding satisfactory stall arrangements and in overcoming colds and scours the start of the experimental period had to be frequently postponed. The feed intake during this interim had been kept constant so that feces collection could commence immediately without the usual 10 day preliminary feeding period delay when the physical obstacles were surmounted.

When the calves were moved into the battery of digestion pens they were not kept stanchioned between feedings. It therefore, became necessary to muzzle them to keep them from chewing on their feces collection harness, or on the wooden partitions between the pens.

Water was offered to each calf once per day. Little was consumed at first, but all of the calves, except Calf E were drinking considerable amounts of water at the end of the experiment. Since the milk allowance was not increased through the 33-67 day period their water consumption was undoubtedly influenced (2).

Each calf was given 400 I. U. of vitamin D, in the form of irradiated yeast, daily throughout the experiment.

Feces Collection. The feces collection harnesses and bags (described in Part I) were used for these trials. The 7 day feces collection period was begun with each calf when it reached 60 days of age.

Chemical Analysis. Feed samples were taken for 7 days, beginning and ending one-half day ahead of feces collection. Milk and feces were refrigerated until prepared for analysis. The methods of chemical analysis used in the preliminary experiment (Part II) were used in these trials.

RESULTS AND DISCUSSION

Failure to complete a digestion experiment with these calves except at 60 days of age, eliminated the intended comparison of digestive efficiency of calves at different ages.

A comparison of the digestibility of different rations using calves of the same age was obtained. Results of this digestion study, with 5 calves at 60 to 67 days of age, appear in Table 3. Analyses of the feed and feces are given in Appendix, Table 4, 5, 6, and 7.

Comparison of digestion coefficients obtained with the different rations, was complicated by the fact that the proportion of milk to grain and/or alfalfa of the ration was not the same with any 2 calves. However, the coefficients obtained with calves in the same ration group were quite similar, despite the difference in proportion of the grain and/or hay to milk.

The coefficients of digestibility for all nutrients of the rations except crude fiber, were lowest with calves E and F on the milk-oats-alfalfa ration. Calf M receiving milk-oats had the lowest digestibility of crude fiber. Carbohydrates and nitrogen free extract coefficients for the 3 rations were as follows:

Milk-alfalfa-80.6, 89.5; Milk-oats-79.1, 85.8; and milk-oats-alfalfa-67.3, 76.2.

Protein and fat digestion coefficients were highest with the milk-oats rations. However, the differences between the ration groups or between individual calves in the same group, were comparatively small. The highest individual protein digestion coefficient was 87.5 (Milk-oats ration), and the lowest was 84.1 (Milk-oats-alfalfa). The highest coefficient of fat digestion was 97.1 (Milk-oats ration), the lowest was 95.2 (Milk-oats-alfalfa ration.)

Ash absorption was 64.2 for the calves on the Milk-oats-alfalfa ration, 76.0 for those receiving Milk-oats, and 77.3 for calves on the Milk-alfalfa ration.

The outstanding differences in digestibility of rations containing milk plus oats and/or alfalfa hay were the difference in the coefficient of apparent digestibility of crude fiber. The calves receiving milk and alfalfa digested 43.6 and 44.6 per cent of the crude fiber, those being fed milk plus oats and alfalfa, digested 17.1 and 20.4 per cent, and a coefficient of a -17.4 was obtained with Calf M on the milk-oats ration.

Two possible reasons for this difference in the digestibility of crude fiber are: (1) the crude fiber of oats is less digestible than the crude fiber of alfalfa hay (37), and (2) the proportion of grain to roughage in the diet of calves affects the rumen microbiological population. Pounden et al. (46) found

that the rumen micro-organisms characteristically present in the rumen of hay consuming calves, could be reduced or replaced by other types of organisms by increasing the proportion of grain in the ration. In later studies Conrad et al. (8) changed one calf from hay to grain long enough to replace all micro-organisms commonly found in the rumen of hay eating calves. This calf was then changed to a hay ration and a digestion trial conducted immediately. Cellulose digestion was 11.26 per cent lower in this case than with a similar calf in which the rumen micro-organisms reappeared during the course of the experiment. Therefore, it is quite possible that the low crude fiber digestibility of oats or oats and hay rations is caused by the lack of the correct type of rumen micro-flora resulting from the absence of sufficient amounts of roughage in the ration.

The crude fiber digestion coefficient for Calf M is possibly due to an experimental error, since feces fiber must come from food fiber. If more oats had been fed than were accounted for, it seems that coefficients for the other nutrients than fiber, would have been low, also. There is a possibility that some of the fiber of oats eaten during the preliminary period had accumulated in the rumen, and moved on through the digestive tract during the feces collection period. Since the total amount of food fiber was small and the fiber was poorly digested or non-digested small errors of feces collection could have resulted in large errors of digestion coefficient.

Table 3. Coefficients of apparent digestibility of rations composed of milk plus oats and/or alfalfa hay by dairy calves 60 to 67 days of age.

Calf	Calf weights		Daily feed intake			Coefficient of apparent digestibility					
	60 days	67 days	Milk lb.	Oats g	Alfalfa g	Crude protein	Ether extract	Crude fiber	Ash	Nitrogen free extract	Carbohydrates
G	149	155	11	0	240	87.4	95.4	43.6	78.1	91.5	82.8
H	150	153	11	0	300	86.5	95.9	44.6	76.6	87.6	78.4
M	54	54	5	100	0	87.5	97.1	-17.4	76.0	85.8	79.1
E	111	113	7	280	140	84.8	95.5	17.1	63.1	70.4	61.7
F	154	158	11	320	160	84.0	95.2	20.4	65.3	82.1	73.0

Hughes (26) states that non-digestible materials might remain in the rumen of calves for several months. He kept calves on a milk diet for 8 months. When these calves were slaughtered at the end of the period, their rumens contained odd bits of straw, sticks, and trash, believed to have been ingested during an extended period of time. Other workers have reported that the fiber fraction of feed tends to lodge in the rumen until partially digested (13, 19).

Twelve grams of fiber in the feces of Calf M was a sufficient amount to lower crude fiber digestion from zero to -17. It is possible that the calf could have chewed a small piece off the end of one of the canvas straps of his feces collection harness. Muzzles were kept on the calves except at feeding time, but the calves were not stanchioned nor watched while eating.

Calves G and H were the only ones observed chewing on the wooden partition before muzzles were resorted to. Feces collection did not begin until 4 days after calves were muzzled. (Normal rate of passage of food through the digestive tract is 60 to 80 hours after ingestion (15, 36).

Samples of feces from all calves were washed through a screen to separate the fiber fraction. No wood fiber or canvas threads were located. Very little fiber remained on the screen from the feces of calves G and H. Most of the fiber fraction of the calves E, F, and M was recognizable as oat hulls. Six or 7 whole oat grains were found in the feces of calf M, none was found in the feces of calves E and F.

Calf M was never a vigorous animal. At 2 months of age he weighed only 4 pounds more than he had weighed at 3 weeks. Perhaps his health influenced mastication of grain. According to the findings of Hilton et al. (22) whole kernels do not pass in the feces of calves, fed whole grain, until the calves are past 4 months of age.

SUMMARY AND CONCLUSIONS

Part I

A series of digestion trials were conducted to determine the coefficients of apparent digestibility of the nutrients in colostrum and milk by newborn calves. Bull calves, used in this study, were removed from their dams and placed in a metabolism cage at birth. The mammary secretion of the dam was fed during the first 8 days and whole milk (herd mixture) was fed after the 8th day. Feces were collected in plastic bags placed inside canvas bags constructed to fit over the calf's rump. The canvas bags were held into place by harnesses, made of cotton webbing straps. Carmine was used as a food-feces marker to permit the division of an uninterrupted feeding schedule with a milk diet of variable composition into separate digestion trial periods.

Coefficients of apparent digestibility of colostrum and milk were determined with 7 calves for the following periods of the calf's life: (1) First 2 days of life, (2) 3rd and 4th day, (3) 5th through 8th day, and (4) the 14th through 17th day period.

Average digestion coefficients at the four respective periods were: Protein -- 91.1, 84.5, 87.6, 93.1; ether extract -- 96.4, 96.1, 96.1, 97.7; carbohydrates -- 95.3, 94.5, 99.1, 99.3; ash -- 92.4, 90.8, 92.6, 95.0. These values include the results of all digestion trials completed. If results for calves that had severe scours are excluded from the averages, some of these values would be increased slightly. Protein digestion was affected more by scours than was the digestion of other nutrients. Excluding the periods in which severe scours occurred, protein digestion coefficients were 93.1, 89.7, 90.4, and 93.1 for the 1-2, 3-4, 5-8, and 14-17 day periods respectively.

Results of this experiment indicate that the nutrients in milk are highly digested by the newborn calf from birth to 18 days of age. The lowest digestion coefficients were obtained when the calves were from 3 to 4 days of age, and the highest when the calves were 14 to 18 days of age. However, differences due to age were small, and it may be concluded that there is little improvement in the digestibility of milk by the growing calf during its early life.

The repeatability of results with different calves in this experiment indicate that a reasonably accurate picture of the manner in which a newborn calf digests the nutrients in milk has been obtained. However, due to improvements in technique throughout the course of the digestion experiments, it would appear advisable that digestion experiments be completed with a few more calves to increase the reliability of this information.

Part II

Dairy calves, 2 months of age, were used in digestion experiments to compare the digestibility of rations containing milk plus oats, milk plus alfalfa hay, and milk plus oats and alfalfa hay. In this study, the calves were given a constant amount of feed daily during a 10 day preliminary and a 7 day feces collection period.

Average coefficients of apparent digestibility of protein, ether extract, crude fiber, nitrogen free extract and ash for the different rations were as follows: Milk plus alfalfa hay -- 86.9, 95.6, 44.1, 89.5, 77.3; milk plus oats -- 87.5, 97.1, -17.4, 85.8, 76.0; milk plus oats and alfalfa hay -- 84.4, 95.3, 19.2, 76.2, 64.2.

Results obtained in a digestion experiment with one calf 45 to 55 days of age, on a milk plus dehydrated alfalfa ration were as follows: Protein -- 90.5, ether extract -- 97.7, nitrogen free extract -- 74.9, crude fiber -- 19.2, and ash -- 70.9.

Several factors prevent the formulation of definite conclusions from the results of these digestion trials. Such a large

proportion of the nutrients, other than crude fiber, of the ration were from the milk that it would be impossible to estimate the digestibility of the nutrients other than fiber in the oats or alfalfa.

The crude fiber of oats was poorly digested or non-digested when oats were fed with milk. The crude fiber of alfalfa was better digested when alfalfa was fed as the sole supplement to a milk diet than when oats were also added. For instance a coefficient of 44 was obtained for crude fiber digestibility when alfalfa was fed with milk. If a coefficient of zero is assumed for the crude fiber of oats and 44 for alfalfa the calculated fiber digestion coefficient for the milk plus oats and alfalfa ration would be 29; the coefficient actually obtained with the milk plus oats and alfalfa ration was 18.7.

In a single trial with a 45 day old calf receiving a milk alfalfa ration, crude fiber was 19.2 per cent digested. The difference in fiber digestion with different rations may be due to the effect of feed on the type of flora present in the calf's rumen. Lower fiber digestion by the 45 day old calf than by the 2 month old calves on the same type of ration might have occurred because of differences in the time at which rumen flora became established.

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APPENDIX

Table 1. Identification, date of birth, and birth weight of experimental calves.

Breed	Letter designation used in thesis narrative	Name and ear tag number of dam	Ear tag number of calf	Birth date of calf	Birth weight of calf in lbs.
Jersey	A	Animation 326B	0340B	10-26-50	44
Jersey	B	Opera 316B	0341B	11-12-50	52
Holstein	C	Helen 115A	0143B	11-15-50	89
Holstein	D	Estella 11A	0144B	11-19-50	104
Ayrshire	E	Affable 284A	0225B	1-12-51	65
Holstein	F	Elation 151A	0145B	1-12-51	99
Holstein	G	Optimum 161A	0146B	1-15-51	107
Holstein	H	Impudence 137A	0147B	1-24-51	113
Holstein	I	Cognette	0148B	2-11-51	72 Born twin with heifer.
Holstein	J	Endowment 133A	0149B	2-15-51	83
Holstein	K	Actress 167A	0150B	2-25-51	110
Holstein	L	Jewel 156A	0152B	3-22-51	103
Jersey	M	-	29	1-16-51	46*
Jersey	N	-	43	2- 3-51	59*

*Calves were purchased from private herds.

F Weighed at 4 days of age, G weighed at 7 days of age.

Table 2. Composition of feed fed to calves on colostrum milk digestion trials.

Period, days of age	Weight g	Per cent Solids	Protein	Ether extract	Ash	Carbohydrate	Vitamin A/100 ml	Carotenoids mu/100 ml
Calf C								
1 - 2	6505		16.5	6.36	1.05		31.	
3	1906	16.4	4.83	6.77	0.841	3.96		
4 - 7	12672	15.2	4.28	5.81	0.787	4.32		
14-18	17600	14.7	3.91	5.73	0.775	5.28		
Calf D								
1 - 2	6592	23.1	11.5	7.27	0.936	3.39		
3 - 4	7026	14.3	4.30	5.14	0.778	4.07	31.2	
5 - 9	19166	14.1	3.91	5.10	0.779	4.31	17.82	27.8
14-18	17600	14.7	3.96	5.51	0.767	4.46	19.00	29.4
Calf H								
1 - 2	8180	19.2	10.2	4.87	0.920	4.21	195.8	113.7
5 - 8	19128	13.6	3.94	4.90	0.771	3.99	24.8	16.30
14-18	18571	13.1	3.72	4.28	0.758	4.34	16.70	17.54
Calf G								
1 - 2	5707	20.6	7.20	9.01	0.931	3.46	146.4	97.2
3 - 4	6812	15.6	4.18	6.46	0.843	4.12	36.4	27.1
5 -10	22922	14.0	4.12	4.57	0.731	4.58	17.88	14.98
14-18	18801	13.0	3.85	4.36	0.752	4.04	19.91	14.93
Calf I								
1 - 3	8177	16.3	7.24	3.83	0.928	4.30	124.1	47.9
4 - 6	7651	11.8	3.86	3.41	0.877	3.65	26.1	
7 - 9	8650	12.4	3.65	4.16	0.767	3.82	21.9	11.51
13-15	9109	11.2	3.16	2.92	0.681	4.44	20.6	9.04
Calf K								
1 - 2	6216	18.4	10.0	4.26	1.13	3.01	156.6	69.8
3 - 4	7077	14.4	4.03	5.47	0.830	4.07	60.0	28.1
15-19	14259	11.0	3.17	2.69	0.701	4.44	8.02	13.40
Calf L								
1 - 4	13230	14.7	5.97	5.50	0.897	3.33	83.5	68.1
5 - 8	11070	12.6	3.35	3.97	0.729	4.59	21.4	11.56
14-18	13492	10.6	3.05	2.96	0.668	3.92	11.60	8.46

Table 3. Composition of feces of calves on colostrum/milk digestion trials.

Period, days of age	Weight: gm.	Per cent Solids:	Protein:	Ether extract:	Ash:	Carbohydrate:	Vitamin A:	Carotenoids
Calf C								
1 - 2	901	31.6	24.6	3.74	1.16	2.10		
3	134	33.0	22.2	3.73	1.70	5.37		
4 - 7	36	25.7	18.8	2.86	1.37	2.63		
14-18	348	27.4	11.4	2.86	9.30*	3.84		
Calf D								
1 - 2	321	31.4	20.0	6.56	1.64	3.20		
3 - 4	455	23.6	14.5	7.96	1.39	9.75	2.64	
5 - 9	506	21.4	15.1	3.68	1.53	1.09	0.221	6.68
14-18	193	22.4	14.6	3.62	1.81	2.37	1.024	10.74
Calf G								
1 - 2	190	34.4	22.4	8.30	2.40	1.30	1.071	8.44
3 - 4	236	23.1	15.5	4.86	1.74	1.00	0.956	4.14
5 -10	587	17.4	12.2	3.75	1.02	0.43	0.253	1.038
14-18	574	13.6	8.94	1.93	1.52	1.21	0.299	2.41
Calf H								
1 - 2	247	32.0	25.1	4.82	1.38	0.70	7.82	17.48
5 - 8	640	22.2	14.0	6.34	1.71	0.15	0.529	3.24
14-18	275	17.6	13.2	1.91	1.36	1.13	0.257	2.93
Calf I								
1 - 2	79	37.8	31.0	3.73	1.14	1.93	8.27	1.691
4 - 6	292	20.4	15.2	2.10	1.28	1.82	0.602	4.12
7 - 9	393	20.6	13.5	1.88	1.40	3.82	0.438	2.36
13-15	602	8.55	5.39	0.57	1.03	1.56	0.173	0.693
Calf K								
1 - 2	123	27.8	19.7	3.54	1.28	3.28	2.31	6.61
3 - 4	117	20.6	13.0	3.05	1.30	3.25	2.47	5.80
15-19	261	23.9	16.6	2.10	2.00	3.20	0.210	2.00
Calf L								
1 - 4	1256	14.8	4.94	2.08	1.34	6.44	1.260	3.42
5 - 8	969	17.6	10.1	6.74	1.62		0.400	1.032
14-18	123	24.2	16.8	3.98	2.14	1.28	0.196	3.66

*Feces contained fine stones and clay.

Table 4. Composition of milk used in the rations containing milk plus oats and/or alfalfa.

Calf	Weight g	Per cent				
		Solids	Protein	Ether extract	Ash	Carbohydrate
C	54480	14.0	3.94	4.92	0.757	4.38
E	22090	11.0	3.17	2.62	0.710	4.40
F	35116	11.0	3.18	2.62	0.707	4.39
M	16828	10.8	3.12	2.76	0.694	4.23
G	34768	10.8	3.13	2.72	0.696	4.25
H	33662	10.6	2.92	3.13	0.668	3.84

Table 5. Composition of alfalfa and oats used in digestion trials reported in PartII.

Calf	Feed	Per cent						
		Protein	Ether extract	Crude fiber	Moisture	Ash	Nitrogen free extract	Carbohydrate
C	Hay	18.81	2.33	20.80	7.69	7.66	42.71	63.51
E, F, G, & H	Hay	17.13	1.46	27.14	9.57	7.78	36.92	64.06
E, F, & M	Oats	13.19	4.65	11.10	10.34	3.44	57.28	68.38

Table 6. Composition of feces dry from trials reported in Part II.

Calf	Per cent						
	Protein	Ether extract	Crude fiber	Moisture	Ash	Nitrogen free extract	Carbohydrate
C		7.60	21.08	4.28	17.87		
E	12.00	2.47	31.52	3.32	8.71	41.98	73.50
F	14.88	3.26	29.34	3.79	9.52	39.21	68.55
M	17.31	3.75	23.62	5.63	8.77	40.92	64.54
G	20.50	5.66	32.32	8.87	10.25	22.44	54.56
H	16.56	4.84	34.35	6.26	9.83	28.6	62.51

Table 7. Weight and protein content of feces (wet) of calves used in the milk plus oats and alfalfa trial.

Calf	Weight g	Per cent protein
C	3288	6.73
E	3929	4.38
F	5495	4.62
M	1456	5.30
G	3624	4.84
H	3649	5.00

DIGESTION STUDIES WITH YOUNG DAIRY CALVES

by

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The special properties of colostrum for the neonatal dairy calf have long been appreciated. Yet, the digestibility of its component nutrients seems to have been neglected. Likewise the nutritional and economic importance of supplementing a milk diet, for the growing calf, with other feeds has received much attention. However, little information is available as to how completely the young calf digests hay or grain, when these feeds are first consumed.

This study was undertaken to determine how well the newborn calf digests its natural food, the mammary secretion of its dam in early life, and to determine the digestibility of rations containing milk plus oats and/or hay by calves one and two months of age. (Because of necessary changes in methods, digestion trials were not completed at one month of age.)

Part I

A series of digestion trials were conducted to determine the coefficients of apparent digestibility of the nutrients in colostrum and milk by newborn calves. Bull calves, used in this study, were removed from their dams and placed in a metabolism cage at birth. The mammary secretion of the dam was fed during the first 8 days and whole milk (herd mixture) was fed after the 8th day. Feces were collected in plastic bags placed inside canvas bags constructed to fit over the calf's rump. The canvas bags were held into place by harnesses, made of cotton webbing straps. Carmine was used as a food-feces marker to permit the division of

an uninterrupted feeding schedule with a milk diet of variable composition into separate digestion trial periods.

Coefficients of apparent digestibility of colostrum and milk were determined with 7 calves for the following periods of the calf's life: (1) First 2 days of life, (2) 3rd and 4th day, (3) 5th through 8th day, and (4) the 14th through 17th day period. Average digestion coefficients at the four respective periods were: Protein 91.1, 84.5, 87.6, 93.1; ether extract 96.4, 96.1, 96.1, 97.7; carbohydrates 95.3, 94.5, 99.1, 99.3; ash 92.4, 90.8, 92.6, 95.0 These values include the results of all digestion trials completed. If results for the calves that had severe scours are excluded from the averages, some of these values would be increased slightly. Protein digestion was affected more by severe scours (white or gray feces in which milk or milk curds were recognizable) than was the digestibility of other nutrients. Excluding the periods in which severe scours occurred, average protein digestion coefficients were 93.1, 89.7, 90.4, and 93.1 for the 1-2, 3-4, 5-8 and 14-17 day periods respectively.

Results of this experiment indicate that the nutrients in milk are highly digested by the newborn calf from birth to 18 days of age. The lowest digestion coefficients were obtained when the calves were 3 to 4 days of age, and the highest when the calves were 14 to 18 days of age. However, differences due to age were small, and it may be concluded that there is little improvement in the digestibility of milk by the growing calf during its early life.

The repeatability of results with different calves in this experiment indicate that a reasonably accurate picture of the manner in which a newborn calf digests the nutrients in milk has been obtained. However, due to improvements in technique throughout the course of the digestion experiments, it would appear advisable that digestion experiments be completed with a few more calves to increase the reliability of this information.

Part II

Dairy calves, 2 months of age, were used in digestion experiments to compare the digestibility of rations containing milk plus oats, milk plus alfalfa hay, and milk plus oats and alfalfa hay. In this study, the calves were given a constant amount of feed daily during a 10 day preliminary and a 7 day feces collection period.

Average coefficients of apparent digestibility of protein, ether extract, crude fiber, nitrogen free extract and ash for the different rations were as follows: Milk plus alfalfa hay 86.9, 95.6, 44.1, 89.5, 77.3; milk plus oats 87.5, 97.1, -17.4, 85.8, 76.0; milk plus oats and alfalfa hay 84.4, 95.3, 19.2, 76.2, 64.2.

Results obtained in a digestion experiment with one calf 45 to 55 days of age, on a milk plus dehydrated alfalfa ration were as follows: Protein 90.5, ether extract 97.7, nitrogen free extract 74.9, crude fiber 19.2, and ash 70.9.

Several factors prevent the formulation of definite conclusions from the results of these digestion trials: (1) A negative fiber digestion coefficient was obtained with one calf, the only animal on the milk plus oats ration; (2) in as much as the animals used in these trials were on another experiment from birth to 18 days of age, they had not received normal care prior to this study; (3) although of value in the development of procedure for use in later digestion trials, repeated changes in technique possibly affected the digestion coefficients obtained.

Such a large proportion of the nutrients, other than crude fiber, of the ration were from the milk that it would be impossible to estimate the digestibility of the nutrients other than fiber in the oats or alfalfa. For instance, with the 45 to 55 day old calf protein of the milk plus alfalfa ration was 90.5 per cent digested. If a coefficient of 90.5 is assumed for the protein of milk the protein of alfalfa was also 90.5 per cent digested. If a coefficient of 94.0 is assumed for the protein of milk, the coefficient for the protein of alfalfa would be 36.0

The crude fiber of oats was poorly digested or non-digested when oats were fed with milk. The crude fiber of alfalfa was better digested when alfalfa was fed as the sole supplement to a milk diet than when oats were also added. For instance a coefficient of 44 was obtained for crude fiber digestibility when alfalfa was fed with milk. If a coefficient of zero is assumed for the crude fiber of oats and 44 for alfalfa the calculated fiber digestion coefficient for the milk plus oats and alfalfa

ration would be 29; the coefficient actually obtained with the milk plus oats and alfalfa ration was 18.7.

In a single trial with a 45 day old calf receiving a milk alfalfa ration, crude fiber was 19.2 per cent digested. The difference in fiber digestion with different rations may be due to the effect of feed on the type of flora present in the calf's rumen. Lower fiber digestion by the 45 day old calf than by the 2 month old calves on the same type of ration might have occurred because of differences in the time at which rumen flora became established.