EFFECT OF BENTONITE IN PURIFIED AND COMMERCIAL MILK REPLACERS ON CONTROLLING NUTRITIONAL DIARRHEA IN YOUNG CALVES

by

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TABLE OF CONTENTS

INTRODUCTION

One of the most serious problems for dairymen today is calf diarrhea. This condition, which may be of nutritional or infectional origin, is one of the main causes of calfhood mortality. It is the belief of many dairymen that diarrhea occurs more often when a low quality milk replacer is fed to calves than when milk or a high quality replacer is fed.

To study effectively how the different components of a milk replacer can cause diarrhea, a purified diet is useful. Very few studies have been reported in which a purified diet supported normal growth and did not cause diarrhea.

By adding a bulking agent to slow the passage of feed through the gut, it may be possible to control nutritional diarrhea. One such bulking agent on which no work has been reported is sodium bentonite.

One of the objectives of this study was to develop a satisfactory purified diet that could be used to study the causes of nutritional diarrhea. The second objective was to determine if sodium bentonite would control nutritional diarrhea and, if so, how it affected the utilization of nutrients.

REVIEW OF LITERATURE

The Effect of Various Carbohydrates on Diarrhea in Young Calves

Many different ingredients have been used for the carbohydrate portion of milk replacers. Of these ingredients, lactose has been used in many studies as the main or only carbohydrate source.

Rojas et al. (83) and Owen et al. (72) added lactose to separated milk so that the total lactose content was twice that of the separated milk. They found that calves began to scour within a few hours after the lactose-enriched milk was fed. When Rojas et al. (83) removed the extra lactose, scouring decreased. Huber et al. (44) noted a slight increase in diarrhea when the amount of lactose in whole milk was doubled. They observed considerable diarrhea when the lactose was increased to four times the normal amount.

Using a synthetic ration, Flipse et al. (27) showed that lactose at a 10% (dry matter basis) level caused no diarrhea. Levels of 5 and 30% (dry matter basis) were also favorable but did not give as good results as the 10% level. The levels of lactose used in this work would not be expected to produce diarrhea since they are below the level found in milk. The substitution of lactose for glucose caused a slightly greater incidence of diarrhea (76).

Velu et al. (94) observed no diarrhea when galactose was used as the only carbohydrate source, but fructose produced severe diarrhea. When sucrose was used, severe diarrhea was again produced even when the sucrose was inverted by citric acid or when brewer's yeast was added. However, when sucrose was inverted by invertase, and the pH was elevated to 7.0, no scouring occurred. When the pH was at 4.5 to 5.0, diarrhea did occur in most cases.

With glucose or corn syrup as the main carbohydrate source, Flipse et al. (27) found that calves tended to void loose feces within 2 to 4 days after being on the synthetic ration. Those calves which received corn syrup were more severely afflicted than those which received glucose.

Blaxter and Wood (8) stated that scouring is associated with the presence of easily fermentable material in the lower gut. This was found when glucose or lactose was given to the calves. Their results showed that as the dietary concentration of the sugar was increased, the fecal loss was also increased. This was explained on the basis of an increase in bacterial proliferation in the gut.

In work by Huber (40), amylopectin starch was substituted for lactose at levels of 9, 18, and 27% of the dry milk replacer. There was an increase in diarrhea as higher levels of starch were used. Netke (66) used blackstrap molasses, without acid hydrolysis, and cerelose in a diet made up primarily of dried skimmilk. Both of these produced a severe diarrhea, and calves had to be taken off the trial one week after its start. Using a synthetic milk replacer, Flipse et al. (25) studied the effects of using corn starch, dextrin, and corn sugar as the carbohydrate source. Dextrin and corn starch produced the poorest growth and caused more of a tendency to scour than did corn sugar.

Carbohydrate Utilization in the Young Calf

Dollar and Porter (22), Huber et al. (42), and Okamoto et al. (70) demonstrated that, of the carbohydrates tested, calves were only able to utilize lactose and glucose during the first few weeks of life.

Many researchers have used blood sugar levels to determine the utilization of carbohydrates. Through the response of blood reducing sugar, Okamoto et al. (70), Siddons et al. (89), and Porter et al. (74) observed that starch and sucrose were not utilized by the young calf. However, blood work by Huber et al. (42) showed slight utilization of starch and sucrose. Blood sugar levels indicated that lactose favorably influenced the utilization of corn syrup and starch (26).

Siddons et al. (89), when using lactose, found marked increases in the levels of both the blood reducing sugar and blood glucose. However, little difference was noted between the 10, 30, and 50-day-old groups. Dollar and Porter (22) and Huber et al. (41) showed that lactase activity was very high in the young calf but tended to decrease with age.

Porter et al. (74) and Siddons et al. (89) demonstrated that there was no utilization of maltose at 1 to 2 weeks of age but that utilization increased as the age of the calf increased. Dollar and Porter (22) noted appreciable utilization of maltose at 9 weeks of age. Huber et al. (42) found that maltose was poorly utilized. Blood sugar levels indicated that fructose utilization decreased with age (74). However, Siddons et al. (89) found that fructose caused small increases in the blood sugar level as age increased.

Siddons et al. (89) found that glucose when fed to calves resulted in a greater rate of increase and maximum concentration of blood reducing sugar and blood glucose with 50-day-old calves than with 10-day-old calves. The concentration of blood reducing sugar was similar for calves fed galactose.

When Huber *et al.* (41) added 3% lactose to whole milk, the apparent digestion was 91%. However, carbohydrate digestion was decreased to 76% when 2.5% sucrose and 0.5% starch was added to whole milk. Later, Huber *et al.* (43) found the apparent digestion coefficients of lactose, maltose, sucrose, and tapioca starch to be 94, 97, 57, and 80%, respectively. The apparent digestion of carbohydrates, when glucose, sucrose, or starch was used, was 92.6, 93.4, and 85.8%, respectively (96). Shaw *et al.* (88) demonstrated that starch digestion by calves at 1 week of age was only 21.16% but at 3 to 4 weeks of age the starch digestion had increased to over 90%.

Noller *et al.* (68) found carbohydrate digestibility for whole milk and evaporated milk to average 97.1 and 94.9%, respectively, over four collection periods. However, the carbohydrate digestibility for two vegetable based milk replacers averaged only 57.9, 80.4, 85.9, and 87.2% for the four periods. These four collection periods were made at 10-14, 18-22, 26-30, and 34-38 days of age. Very little variation between periods was noted when milk and evaporated milk were used. Radostits and Bell (78) observed that the carbohydrate digestibility of a milk replacer containing a cereal-origin component increased from 54% at 8 days of age to 77% at 24 days of age. They attributed the low digestibility to the inclusion of oat flour in the milk replacer. Digestibility of the carbohydrate portion of the oat flour was estimated to be 0, 15.0, and 26.0% at 8, 18, and 24 days of age, respectively.

The Effect of Various Fat Sources on Diarrhea in Young Calves

Gullickson *et al.* (36) found that calves fed corn oil, cottonseed oil, or soybean oil mixed with skimmilk suffered more frequent and severe cases of diarrhea than those calves fed coconut oil, peanut oil, lard, beef tallow, or butterfat mixed with skimmilk. Wiese et al. (97) also noted that calves scoured when soybean oil was used in a synthetic ration but not when lard was used. When Marcol B-75, a modified cottonseed oil soapstock, was included in a milk replacer diet causing diarrhea, diarrhea was controlled (60). When using cottonseed oil in a purified diet, Jarvis and Waugh (46) observed that calves developed severe scours after about 1 week of use. Roy (85) reported that beef drippings caused a slightly increased incidence of scouring during the first 2 weeks of life when compared to lard, but results from 3 to 12 weeks of age were better with beef drippings than with lard. In comparing the use of milk fat and lard in a reconstituted milk diet, Foreman et al. (28) found that the incidence of diarrhea was low for both.

Barker et al. (5), Jacobson et al. (45), and Murley et al. (64) compared crude, refined, and hydrogenated soybean oil to butter oil. They found that the incidence of scouring was lowest for calves receiving butter oil followed, respectively, by hydrogenated, refined, and crude soybean oil. Cunningham and Loosli (20) reported that feeding of lard resulted in a slightly lower incidence of scouring than did feeding of hydrogenated coconut oil. The incidence of scours was lower when Brown et al. (12) used a 10% level, on a dry matter basis, of refined coconut oil in the milk replacer, as compared to a level of 15% refined coconut oil.

Adams et al. (2) found that when a weekly preparation of corn oil-filled milk was fed, calves were afflicted with severe diarrhea. However, when a daily preparation was used, no diarrhea was observed.

Hydrogenation of the corn oil used in the weekly preparation helped considerably in reducing the incidence of diarrhea. Diarrhea resulted when a lipid-free diet was fed to calves, compared to a lipid-containing diet (15, 55, 71). When lard was replaced by glucose to form a fat-free diet, Cunningham and Loosli (20) observed a much greater tendency for calves to scour. Bush et al. (15) demonstrated that added fat would not prevent severe diarrhea in calves fed a high mineral diet, but the length of time of scouring was reduced. Owen et al. (72) found that the inclusion of butter oil, with or without lecithin, in a high lactose-plus-minerals diet markedly reduced the diarrheic effects.

Scouring was found to be more frequent when calves received a low-fat diet than a normal-fat diet (98). Wing et al. (98) surmised that this was probably caused at least in part by the higher lactose content of the low-fat diet. Grimes and Gardner (35) reported that when milk fed to calves contained 9% fat, as opposed to 6 and 3% fat, the calves had a much higher incidence of scouring.

When using 1.8% butter oil and 0.27% lecithin (dry matter basis) in a semisynthetic diet, Lambert et al. (55) reported a low incidence of diarrhea with no fat deficiency symptoms being exhibited. Kastelic et al. (52) also noted that animals fed a high-fat diet containing lecithin scoured less frequently than those on a regular high-fat diet.

Too high fat concentration or large fat globules in a milk substitute may be detrimental under high "infection" conditions (85). These factors were not so noticeable under low "infection" conditions. Wallace et al. (96) found that a mixture containing 20% (dry matter basis) of a high-fat soya flour caused severe diarrhea in calves.

When Young (100) completely replaced whole milk at 4 days of age with a combination of whey product and fat, an increase in the incidence of diarrhea was observed.

Lipid Utilization in the Young Calf

Raven and Robinson (80) reported that the digestibility of hydrogenated palm oil increased from 76 to 92% during two consecutive 6-day periods. When hydrogenated coconut oil was used in a milk replacer, the average fat digestion increased from 82.6% at 2 weeks of age to 88.6% at 8 weeks of age but dropped to 71.9% at 11 weeks of age (20). Adams _et al._ (2) found that time of preparation and hydrogenation affected the digestibility of corn oil. They reported the following average fat digestibility by calves 35 to 90 days of age: corn oil (prepared weekly), 88.3%; corn oil (prepared daily), 90.2%; and hydrogenated corn oil, 90.3%. Roy (85) reported that margarine was 97% digestible by 4 week-old calves.

The average digestibility of butterfat by calves 5 to 15 days of age and by calves 9 to 21 days of age was 96% (80). Roy (85) reported a fat digestibility of 97% for butterfat, 93% for refined lard, 89% for equal parts of refined lard and beef drippings, and 85% for beef drippings by 4 week-old calves. Using a semisynthetic diet containing lard, Blaxter and Wood (7) found the apparent digestibility of dietary fat to be 91.7% for calves 2 weeks old. Adams _et al._ (2) reported an average fat digestibility of 88.9% for lard by calves 35 to 90 days of age. The fat digestibility of lard increased from 68% at 2 weeks of age to 93.7% at 11 weeks of age (20).

When feeding a milk replacer containing a mixture of animal and vegetable fat, Radostits and Bell (78) found that fat digestibility was initially low (29%), but by the time the calves were 20 days-old, the digestibility was 82%.

Effects of Protein on Diarrhea in Young Calves

Roy (85) reported that whey proteins can be denatured to a marked extent during processing. He stated that milk replacers using this whey will cause the buildup of infection to be increased and the incidence of scouring and mortality to be higher.

Milk replacers containing as much as 60% dried whey resulted in a higher incidence of diarrhea than in rations containing lesser amounts (96). Noller et al. (67) found an improvement in fecal consistency, compared to the basal diet, when a 5% level of whey on a dry matter basis was added to a basal all-vegetable milk replacer.

When Bush and Schuh (14) substituted dried skimmilk and casein for dried whey at levels of 15, 20, and 25% protein of the dry milk replacer, they found no difference in the incidence of diarrhea from one level of protein to another. Bryant et al. (13) replaced dried skimmilk with corn distillers dried solubles and reported that the incidence of scouring was greater for the calves receiving dried skimmilk. When comparing fresh skimmilk to a high-temperature-treated milk, Wood et al. (99) observed an increase in the incidence of diarrhea with the high-temperature-treated milk. Owen et al. (72) reported that none of the semisynthetic diets containing lactalbumin or casein they used were consistently diarrheic.

Using a high soy milk replacer that contained 60% of its protein from a "fully cooked" soybean flour, Gorrill et al. (34) found that a moderate diarrhea was produced. This soybean flour contained 50% crude protein and the trypsin inhibitor, which was not denatured. In a similar milk replacer Gorrill and Thomas (33) used a soybean flour containing 71% crude protein and little trypsin inhibitor. Little or no diarrhea occurred with this milk replacer.

Protein Utilization in the Young Calf

Noller et al. (68) reported that digestibility increased from 81.2 to 93.0% for crude protein in whole milk and from 56.5 to 87.8% for crude protein in evaporated milk over collection periods of 10-14, 18-22, 26-30, and 34-38 days of age. Wood et al. (99) noted that the heat treatment of skimmilk lowered the efficiency of milk protein utilization. They reported average nitrogen balance values of 3.1, 3.9, and 10.3 grams per day for period I and -9.2, -3.2, and 8.3 grams per day for period II for low-temperature-treated skimmilk, high-temperature-treated skimmilk, and fresh skimmilk, respectively. These two collection periods were made at 4-13 and 14-23 days of age, respectively. The nitrogen balance values in the second period were lower than in the first period because a great portion of the milk protein was utilized for energy.

Wallace et al. (96) reported that when a milk replacer contained 50% skimmilk, the apparent protein digestibilities were 66.7% at 5 weeks and 72.9% at 8 weeks of age. This is in comparison to a milk replacer containing 30% skimmilk and 25% dried whey which had apparent protein digestibilities of 67.8 and 83.5% at 5 and 8 weeks of age, respectively. Bryant et al. (13) used corn distillers dried solubles to replace 0 to 50% of the crude protein provided by dried skimmilk. As the level of crude protein provided by the corn distillers dried solubles increased, the apparent protein digestibility decreased from 86.3 to 66.6% at 3 weeks of age and from 90.1 to 73.4% at 7 weeks of age.

Gorrill and Nicholson (32) compared a milk replacer containing all-milk protein with replacers in which 70% of the total protein was from a soybean protein concentrate, with or without methionine supplementation. They found that the different protein sources had no effect on nitrogen retention but that nitrogen digestion was 5.7% units better for the all-milk protein replacer. Schmutz et al. (87) found that for best growth Promosoy (soy protein concentrate) could be used to replace milk protein at levels of 8 and 10% but not 16% in a milk replacer. Morrill et al. (63) reported that for optimum growth milk protein in a milk replacer could be replaced by a 6% level of Promosoy but not a 12.2% level.

Porter and Hill (75) found that soya flour had a low protein digestibility and that poor nitrogen retention resulted. The nutritive value of fully cooked soy flour for the very young calf can be improved by acid treatment (16). Later Colvin and Ramsey (17) showed that alkali-treated soy flour produced similar responses to acid-treated soy flour and was markedly superior to untreated flour.

Stein and Knodt (92) reported that when soybean flour and whey solubles were fed in a 7:1 ratio in a dried processed form, they were more effective in replacing oat flour, dextrose, and dried brewer's yeast in the basic formula studied than when soybean flour and whey solubles were used separately.

Harshbarger and Gelwicks (37) reported that larger live weight gains were obtained from feeding a milk replacer containing 20% fish flour than from a milk replacer containing 10% fish flour or 50% dried skimmilk. When using fish flour to replace 0, 33, and 66% of the total protein for a milk replacer, Slade and Huber (90) noted no consistent trends in protein digestibility or nitrogen retention. In the second part of the experiment they used fish flour to replace 0, 20, 40, and 60% of the total protein and found that the 40% group gained better than the other groups but only significantly greater ($P<.01$) than the 60% group.

Using a synthetic milk replacer, Porter and Hill (75) demonstrated that ADM assay protein had mean nitrogen retention values of 30 and 38% and apparent protein digestibilities of 75 and 87% at 1-2 and 4-5 weeks of age, respectively.

When Lassiter et al. (56) decreased the level of protein in the milk replacer from 30.9 to 15.2%, the average protein digestibility and nitrogen retention for the collection periods of 14-28 and 36-42 days of age decreased from 90.6 to 78.6% and 22.8 to 11.6 grams per day, respectively.

When using a milk replacer in which part of its protein was derived from oat flour, Radostits and Bell (78) showed an increase in the apparent digestibility of protein from 63% at 8 days of age to 84% at 24 days of age. They suggested that the protein of the oat flour portion of the milk replacer was relatively indigestible during the early life of the calf.

The Effect of Curd Formation on Diarrhea in Young Calves

Mylrea (65) demonstrated that clotting of milk occurred in the abomasum rapidly after feeding. Gorrill and Thomas (33) found that milk coagulated in the abomasum 1 to 1.5 hours after feeding. They observed no coagulation in this amount of time in calves fed a milk replacer.

Blaxter and Wood (8) noted that the formation of curd was necessary to prevent diarrhea. Reduction of the casein content in liquid diets will prevent formation of the clot. When the casein content was reduced, severe scours resulted (8). Scours were also produced when gelatin replaced casein in the diet. When the calcium was lowered enough to increase clotting time, diarrhea resulted.

At 1 week of age, colostrum-deprived calves were fed a semisynthetic diet in which the calcium-sodium ratio had been altered enough to prevent coagulation by rennet (52). All of these calves developed severe diarrhea. However, the same diet gave satisfactory results when fed to calves that were fourteen days old.

To prevent curd formation in whole or skimmilk, Owen _et al._ (71) added sodium citrate. When the treated milk was fed the incidence of diarrhea was not increased in comparison to that when normal milk was fed. The experimental diet was fed only to calves that were 11 days of age or older. Farhan (24) also reported that addition of sodium citrate to inhibit curd formation did not influence the incidence of diarrhea. However, these calves performed satisfactorily on this diet starting at the age of 4 days.

Wing et al. (98) suggested that an increase in diarrhea when dried whey was included in the reconstituted diets was probably due at least in part to the type of curd formed after ingestion. When feeding calves milk with different curd tensions, Owen et al. (72) observed no significant effect on the consistency of the feces of young calves.

The Effect of Vitamins on Diarrhea in Young Calves

Norton et al. (69) reported from a study involving 60 heifer calves that supplementing a normal diet with capsules or tablets containing vitamins A, D, and E, several of the B-vitamins, and ascorbic acid did not reduce the incidence or severity of scours. Hibbs and Krauss (38) found similar results. When they supplemented the diet of calves with 10,000 USP units of vitamin A, 300 USP units of vitamin D, 50 mg of niacin, and 250 mg of ascorbic acid, no reduction in the incidence of scours was found. Gilmore et al. (29) also noted no reduction in the incidence of scours when they supplemented the diet of calves with 17,000 USP units of vitamin A, 7 mg of thiamine chloride, 7 mg of riboflavin, 30 mg of pantothenic acid, 35 mg of choline, and 70 mg of niacin in capsule form.

Working with filled milks containing 3% (reconstituted basis) crude expeller soybean oil, Jacobson et al. (45) tried to reduce scouring by supplementing thiamine, riboflavin, nicotinic acid, calcium pantothenate, pyridoxine, ascorbic acid, and mixed tocopherols. Results showed no lowering of the incidence of diarrhea. Adams et al. (2) added tocopherol to a corn oil-filled milk, but the severity of diarrhea was not reduced.

Calves fed a high-carbohydrate milk replacer were maintained in good condition with a daily oral supplementation of (mg/lb of feed): thiamine HCl, 3.0; biotin, 0.05; pyridoxine HCl, 0.3; Ca pantothenate, 0.6; riboflavin, 0.3; and choline Cl 130.0 (84). These same workers (6) were able to control diarrhea in calves fed a low-fat, high-carbohydrate milk replacer by oral supplementation of a mixture of relatively high levels of thiamine and biotin in combination with certain other B-vitamins.

When pantothenic acid, nicotinic acid, and vitamin A were added to a diet which produced diarrhea, the feces returned to normal within 12 to 24 hours (73). Later work by Lundquist and Phillips (61) showed that when vitamin A levels were adequate and scouring was evident, 50 to 100 mg per day of nicotinic acid was effective in helping to control scours. However, if pantothenic acid was used instead of nicotinic acid, there was no favorable effect on controlling diarrhea.

Using a synthetic diet, Johnson et al. (50) observed that calves on a nicotinic acid-free diet scoured less than calves receiving nicotinic acid. However, Hopper and Johnson (39) reported that two out of three calves placed on a nicotinic acid-deficient synthetic milk replacer had diarrhea. Severe diarrhea was produced by a thiamine-deficient milk replacer in some calves (47). When calves were fed a pyridoxine-deficient synthetic milk replacer, Johnson et al. (49) found that calves scoured while those receiving pyridoxine did not. Johnson et al. (48) reported that calves on a choline-deficient synthetic milk replacer had diarrhea, but that those receiving choline did not.

The Effect of Minerals on Diarrhea in Young Calves

Owen et al. (72) reported that when the mineral content of milk was increased to four times the normal amount by addition of simulated milk ash, diarrhea was increased moderately. Later, he found that there apparently were other factors involved with the response to minerals. With a slightly different feeding and management regime in which the mineral content was increased to ten times the normal amount found in milk, there was no noticeable increase in diarrhea.

When minerals were added to a basal diet, Bush et al. (15) observed a higher incidence of diarrhea than when no minerals were added to the basal diet. Minerals added to the diet also increased the rate of removal of ingesta from the abomasum. This was the apparent cause for the higher incidence of diarrhea when minerals were added.

Owen et al. (72) found that when feeding a 14% whey product suspension the incidence of diarrhea was higher than when a 10% (reconstituted) dried skimmilk suspension was fed. Wing et al. (98) reported that when dried whey was included in a reconstituted diet, scouring was increased in all instances. They surmised that this increase in diarrhea resulted at least in part from the higher mineral content of the whey product.

Using rats, Daniel and Harvey (21) showed that the mineral content of whey caused diarrhea. The rats were fed diets containing undialyzed whey, dialyzed whey, and dialyzed whey with restored minerals. Those receiving the diets containing undialyzed whey or dialyzed whey with restored minerals had diarrhea throughout the 6 week experimental period. However, rats getting dialyzed whey had diarrhea only during the first week. It was suggested that the mineral constituents of the whey were responsible for its low nutritional value. The mineral constituents are associated with a tendency for diarrhea and also an impaired ability to absorb carbohydrates as was shown by the high galactose excretions.

The Use of Purified Diets with Young Calves

Purified diets have been used considerably in nutritional research. Because purified diets are made up of pure nutrient sources the effect of different levels of, or the absence of, a certain nutrient can be more effectively studied. Synthetic diets have been utilized in an effort to find a suitable milk replacer.

Johnson *et al.* (51) noted poor growth rates and periodic digestive upsets when using a synthetic milk replacer consisting of casein, lactalbumin, sugar, butter or lard, minerals, and water. Using a purified diet containing casein, cerelose, lactose, lard, minerals, and vitamins, Thomas and Okamoto (93) found that calves grew at only 85% of the normal rate.

Wiese *et al.* (97), Jarvis and Waugh (46), Cunningham and Loosli (20), Flipse *et al.* (25, 26), and Porter and Hill (75) have used synthetic milk replacers to study the effect of different fats, carbohydrates, and proteins on growth and tendency to cause diarrhea.

Johnson *et al.* (47, 48, 49, and 50) and Hopper and Johnson (39) have used a purified milk replacer to study various vitamin B complex deficiencies in young calves. Safford *et al.* (86) and Culik *et al.* (19) when working with young calves and lambs, respectively, used a purified diet to study vitamin E deficiencies.

The Effects of Bulkage when Added to Diets

The bulking agent sodium bentonite has been added to many different types of diets. It is composed mainly of inert clay particles called montmorillonite (aluminum silicate). The sodium bentonite swells in water until it increases 10 to 15 times of original size.

Vetter and Gay (95) reported that steers receiving approximately 9% bentonite in their ration supplement had a higher rate of gain than those receiving the control diet but that there was no difference in feed efficiency between the groups. When using 3% sodium bentonite in a concentrate ration fed to steers, Erwin _et al._ (23) noted that the rate of gain, feed efficiency, and digestibility of dry matter and crude fiber were not significantly effected. Martin _et al._ (62) added 2% bentonite to a high-concentrate diet for lambs and found it had no significant effect on nitrogen digestibility or retention, growth, and feed consumption. However, when bentonite was added to a high-roughage diet, there was an apparent, although not significant, improvement in nitrogen digestibility or retention, growth, and feed consumption.

Kurnick and Reid (53) reported that the addition of 2.5% bentonite to a poultry diet produced a highly significant improvement in the growth rate of chicks, a slightly delayed feed passage time, and an increased feed intake. They fed levels as high as 12.5% to chicks for a 4 week period without any detrimental effects on growth rate or feed conversion. Chickens receiving bentonite had better feed efficiency than those birds receiving the basal diet (77). Almquist _et al._ (3) showed that addition of bentonite to turkey diets consistently improved nutrient retention and that more than

1% was needed for full effect, with 2% possibly being optimal.

Bringe and Schultz (10) improved the milk fat test of cows on a fat-depressing ration by adding 5% bentonite. They thought the beneficial effect of bentonite resulted from a slower rate of passage of the feed through the digestive tract. The addition of 10% bentonite to a fat-depressing diet provided beneficial results for fat test similar to the 5% addition (82).

Laughland and Phillips (58) reported that sodium bentonite impaired the ability of vitamin A-deficient rats to store vitamin A in the liver by limiting absorption. Normal rats were not affected. Later they (59) found that bentonite decreased the availability of vitamin A and carotene in all the research diets they used for poultry. When 3% or more bentonite was added to a complete synthetic diet, New Hampshire chicks developed symptoms of vitamin A deficiency (9). However, when they added 5% bentonite to a commercial ration, the chicks showed no detrimental effects. Erwin et al. (23) reported that a 3% addition of bentonite did not significantly affect the hepatic vitamin A and carotene retention in steers.

When Brown et al. (11) fed slacked lime to scouring calves, scouring stopped. They observed no recurrence of diarrhea after discontinued feeding of the lime.

By adding bulk in the form of sawdust, purified wood cellulose, or oat hulls to a milk replacer, Gorrill and Nicholson (31) reduced the incidence of diarrhea. There were no significant differences in nutrient digestibility during the third and sixth weeks of age although dry matter and energy digestibilities were reduced. Further work was done by Gorrill (30) with the following bulking agents: oat hulls, sawdust, and wood shavings. He concluded that if bulk is added to milk replacers, it must either by-pass the rumen (eg. sawdust) or pass through the rumen at a sufficient rate to prevent compaction of this organ (eg. oat hulls). Wood shavings were found to do neither.

EXPERIMENTAL PROCEDURE

Experiment I

This experiment was designed to find a purified milk replacer that would produce acceptable results when fed to young dairy calves. This diet would be useful for studying the cause and prevention of nutritional calf diarrhea and the effect of diarrhea control on the utilization of nutrients.

Trial 1. Four Holstein bull calves were used (Table 1). After 3 days with their dams they were moved to metabolism crates to allow complete observation. They were fed milk until 7 days of age at which time the diet was gradually changed, over a 3 day period, to Purified Diet 1 (Table 2). The reconstituted diet was fed at a level of 8% of the body weight per day in two equal feedings. At 2 weeks the level of feeding was increased to 10% of the body weight. The purified diet was reconstituted with water to 15.5% total solids.

Fecal observations were made twice daily. When severe diarrhea occurred, the amount of diet fed was reduced by one-half. If diarrhea persisted, the diet was changed to milk until normal fecal consistency was maintained for several days. Fecal consistency evaluations were made on a scale of zero to three, where zero denoted normal feces and three denoted fluid feces.

Calves were weighed at birth and at 7-day intervals thereafter for the duration of the trial. After each weighing the level of the diet was adjusted accordingly.

TABLE 1. Experimental animals and diets used in Experiment I.

Trial	Calf	Diet	Time on trial
1	B12 and B14	Purified Diet 1	3 weeks
	B15	Purified Diet 1	7 weeks
	B16	Purified Diet 1	6 weeks
2	B17 and B19	Purified Diet 2	5 weeks
3	B22[a]	Purified Diet 2	5 weeks
	B23	Purified Diet 2	3 weeks
	B25 and B26[a]	Purified Diet 1	2 weeks

[a]These calves' diets were supplemented with sodium bentonite at a level of 2% of the reconstituted diet.

TABLE 2. Composition of the purified diets, Experiment I.

Ingredient	Diet 1	Diet 2
	(%)	(%)
Casein[a] (edible, 90 mesh)	23	27
Lactalbumin[b] (edible)	1	1
Lard[c] (with emulsifier)	10	18
Lactose[d] (crude)	61.68	49.68
Mineral mix[e]	4.20	4.20
Vitamin mix[f]	0.12	0.12

[a]Erie Casein Company, Erie, Illinois.

[b]General Biochemicals, Chagrin Falls, Ohio.

[c]Milk Specialties, Inc., Dundee, Illinois.

[d]Foremost Food Company, San Francisco, California.

[e]See Table 3 for composition.

[f]See Table 4 for composition.

TABLE 3. Composition of mineral mix for purified diets 1 and 2, Experiment I.

Ingredient	(g)
$CaCl_2 \cdot 2H_2O$	750
KH_2PO_4	300
Na_2HPO_4	300
$MgSO_4$	300
$CaHPO_4$	200
$FeSO_4 \cdot 7H_2O$	50.0
$MnSO_4 \cdot H_2O$	2.8
$ZnSO_4 \cdot 7H_2O$[a]	1.8
$CuSO_4 \cdot 5H_2O$[a]	1.5
CrO_3[a]	0.17
MoO_3[a]	0.13
KI[a]	0.06
$CoSO_4 \cdot 7H_2O$[a]	0.05
Na_2SeO_3[a]	0.01
KF[a]	0.01

[a]These ingredients were mixed with a few grams of glucose and ground together before being added to the other ingredients.

TABLE 4. Composition of vitamin mix for purified diets 1 and 2, Experiment I.

Ingredient	
	(g)
Choline	40.0
Vitamin E[a]	11.35
Niacin[b]	.840
Ca Pantothenate[b]	.650
Vitamin A and D[b, c]	.545
Thiamine HCl[b]	.210
Pyridoxine HCl[b]	.210
Riboflavin[b]	.130
Menadione[b]	.030
Biotin[b]	.006 (.002 actual)[d]
B12[b]	2.000

[a]220 IU/g.

[b]These ingredients were added to a few grams of glucose and mixed before being added to the other ingredients.

[c]250,000 IU/g of A, 50,000 IU/g of D.

[d]0.1% trituration.

Trial 2. Because of the diarrhea caused by Purified Diet 1, the diet needed to be improved. Purified Diet 2 (Table 2) was a modification of Purified Diet 1, and its effect on diarrhea was studied in Trial 2.

Two Holstein bull calves were used (Table 1). The feeding and management were the same as described in Trial 1 except that Purified Diet 2 was fed.

Trial 3. The purpose of this trial was to determine if diarrhea was controlled when sodium bentonite[1] was added to Purified Diets 1 and 2.

Four Holstein bull calves were used (Table 1). The feeding and management were the same as described in Trial 1 with two exceptions: 1) diets of B22 and B26 were supplemented with bentonite at a level of 2% on a reconstituted basis, and 2) all calves were kept in pens, bedded with wood shavings, instead of the metabolism crates.

Bentonite was added to the diet of B23 at 3 weeks of age in an attempt to control severe diarrhea; however, the calf died at 4 weeks of age. Calves B25 and B26 were removed from the trial at 3 weeks of age and used in Experiment II.

Experiment II

Feeding and management of experimental animals. Ten bull calves were paired by age, and each pair was randomly assigned to the treatments as shown in Table 5 to determine nutrient digestibility, nitrogen retention, and incidence and severity of diarrhea.

Calves B17, B19, B25, and B26 had been used in Experiment I. After these calves were put on Experiment II, feeding and management proceeded as described in Trial I of Experiment I except that: 1) the amount of reconstituted diet fed was 8% of the body weight and 2) a commercial milk

[1]Number 200 Volclay, provided by American Colloid Company, Skokie, Illinois.

TABLE 5. Animals and diets used in Experiment II.

Group	Calf	Breed	Age at start of trial	Time on trial
Bentonite[a]	B17	Holstein	6 weeks	2 weeks
	B25	Holstein	3 weeks	5 weeks
	B29	Holstein	1 week	6 weeks
	B31	Holstein	1 week	6 weeks
	B32	Holstein	1 week	6 weeks
Control[b]	B19	Holstein	6 weeks	2 weeks
	B26	Holstein	3 weeks	4 weeks
	B27	Holstein	1 week	6 weeks
	B30[c]	Ayrshire	1 week	4 weeks
	B33	Holstein	1 week	6 weeks

[a]Bentonite was added to the commercial milk replacer at the level of 1% of the reconstituted diet.

[b]Each calf in the Control Group received only the commercial milk replacer.

[c]Calf B30 was removed from the experiment because diarrhea prevented fecal collections.

TABLE 6. Proximate analysis and ingredients of the commercial milk replacer used in Experiment II.

	(%)
Protein (N x 6.25)	25.76
Nitrogen-free extract	56.42
Ether extract	10.00
Crude fiber	0.25
Ash	7.57

Ingredients: Dried skimmed milk, dried whey, dried buttermilk, dried whey product, casein, animal fat (preserved with BHA), soy lecithin, soy flour, oat flour, vitamin B12, niacin, calcium pantothenate, riboflavin, vitamin A palmitate, D-activated animal sterol (source of vitamin D_3), vitamin E supplement, 0.50% dicalium phosphate, 0.25% salt, iron carbonate, manganous oxide, potassium iodide, cobalt carbonate, zinc oxide, and copper oxide.

replacer was fed (Table 6). Calves B27, B29, B30, B31, B32, and B33 were fed and managed the same as in Trial I of Experiment I with the following exceptions: 1) the calves were kept in individual pens in the calf barn until 7 days of age, 2) the level of reconstituted diet fed was 8% of the body weight, and 3) a commercial milk replacer was used (Table 6).

Because of the occurrence of diarrhea when the purified diets were used, it would not have been possible to make complete fecal collections from the Control Group. Therefore, in order to make complete fecal collections, a commercial milk replacer was used in Experiment II.

Diarrhea was assumed to be of infectional origin if the rectal temperature of the calf was 39° C or higher and of nutritional origin if the rectal temperature was under 39° C.

Calf B30 was removed from the experiment at 5 weeks of age because diarrhea prevented collections during Periods 1 and 2.

Collection and analysis of samples. Fecal and urine collections were made at 2, 4, and 6 weeks of age. The collection periods lasted 4 days.

The feces were collected in plastic bags as described by Noller et al. (68) with the following alterations: 1) the straps used on the rumps of the calves were double straps, sewed together at each end, and 2) small staples were used to attach the bag to the straps. The straps, on the rump and on the underside of the calf, were attached with branding cement. To attach the plastic bag, the tail was first passed through the tail opening. The upper flap was then passed between the double straps and attached to the upper strap. The lower flap was passed between the body and the loop formed by the belly strap. The lower flap was then attached to the strap.

The fecal bags were removed at each feeding time and at any other time of visit to the calf barn. The bags were labeled and placed in a freezer. After the collection period the fecal samples were thawed and mixed together. At this time duplicate samples were taken for determination of nitrogen content by the A.O.A.C. (4) method. Triplicate samples were dried to determine dry matter content. The dried samples were then ground and mixed together for proximate analysis by the A.O.A.C. (4) method.

Urine was collected in plastic buckets containing thymol for prevention of nitrogen loss. At the morning and evening feedings, the amount of urine collected was recorded. A 10% aliquot was taken and refrigerated until the end of each collection period, at which time a sample was taken for determination of nitrogen content by the A.O.A.C. (4) method.

Feed samples were analyzed by the A.O.A.C. (4) method for proximate composition.

All data were subjected to one-way analysis of variance as outlined by Snedecor (91).

RESULTS AND DISCUSSION

Experiment I

Trial 1. When calves were fed Purified Diet 1, diarrhea occurred very frequently (Table 7). Calves B14 and B16 developed diarrhea within 1 day after being completely transferred to the purified diet. After being on the purified diet for 5 days, calves B12 and B15 developed diarrhea. When B12 was given milk at 3 weeks of age, the fecal consistency was improved over that of the previous week. Since the fecal consistency of calves B12 and B14 did not improve when on the purified diet, these calves were removed from the trial at 4 weeks of age. When the diets of B16 and B15 were changed to milk for 1 and 2 weeks, respectively, diarrhea ceased. However, when these calves were again fed the purified diet, diarrhea recurred.

No obvious relationship between the incidence of diarrhea and daily body weight changes (Appendix Table 16) was observed. The mean weight gains were below Ragsdale's standards (79).

Rojas et al. (83) and Owen et al. (72) found that when twice the normal amount of lactose was fed, calves began to scour within a few hours after feeding. Since the lactose content of Purified Diet 1 was almost twice that of milk, it was thought that this could be the cause of the scours. Purified Diet 2 was reformulated with the amount of lactose reduced to 1.5 times that of milk. The fat and protein contents were raised from the levels of the first purified diet.

TABLE 7. Weekly average fecal score, Experiment I.

Trial	Diet	Animal	Weeks of age 1[a]	2	3	4	5	6	7
1	1[b]	B12	0[c]	1.22	0.38[d]				
		B14	0.38	0.43	0.85				
		B15	0	0.73	1.20	0[d]	0[d]	0.82	1.67
		B16	0.86	1.44	0[d]	0.20	1.00	1.56	
2	2[e]	B17	0.30	1.00	1.12	0.10			
		B19	0	1.36	0[d]	0.78			
3	2[e]	B22[f]	0	0	0	0	0		
		B23	0	0.73	1.18[f] (died)				
	1[b]	B25	0.80	1.60					
		B26[f]	0	0					

[a]The diet of each calf was gradually changed from milk to the purified diet during this week.

[b]Purified Diet 1.

[c]Average fecal score = fecal consistency evaluations made on the scale of zero to three, where zero denoted normal feces and three denoted fluid feces.

[d]Received milk during that week.

[e]Purified Diet 2.

[f]Bentonite was added to diet.

Trial 2. A limited evaluation of Purified Diet 2 was made in this trial. When compared to the results from Purified Diet 1, the results from Purified Diet 2 (Table 7) show that the fecal consistencies of calves B17 and B19 were not greatly improved. At 4 weeks of age the fecal consistency was improved over that of B15 at 6 and 7 weeks of age and B16 at 5 and 6 weeks of age. The reduction of the lactose content of Purified Diet 2 seemed to improve the fecal consistency somewhat as the age of the calf increased.

No obvious relationship between the incidence of diarrhea and daily body weight changes (Appendix Table 16) was observed. The mean weight gains were below Ragsdale's standards (79).

The difficulty in formulating a purified diet can be seen from the results obtained in Trials 1 and 2. Some studies indicated that optimum growth for calves was obtained when feeding milk replacers containing 23 to 25% protein (14, 18, 56, 57). On this basis it would not be of any value to raise the level of protein over the 27% level used in Purified Diet 2. With this amount of protein and the level of minerals and vitamins used, the remainder of the diet, approximately 68%, must consist of carbohydrates and fat. Under the conditions in which this diet was prepared, a higher level of fat than that used in Purified Diet 2 would be very difficult to incorporate into the rest of the diet. Therefore, almost 50% of the diet must be supplied by carbohydrates.

Lactose is utilized very well by the young calf (22, 41, 42, 70,89). Glucose is also well utilized (22,42, 70), but Abe (1) observed ethanol production which caused intoxication in young calves when milk replacers containing glucose were fed. Siddons et al. (89) found that glucose and galactose were better utilized by older calves than by younger calves. During the first few weeks of life the calf can utilize little or no maltose, fructose, sucrose, or starch (22, 41, 42, 70, 74, 89).

Although the lactose can cause diarrhea when used in levels higher than normal (44, 72, 83), it is the best carbohydrate to use in the purified diet. When using Purified Diet 2 which contained less lactose than in Purified Diet 1, an improvement in the fecal consistency was noted as age increased.

Trial 3. Kurnick and Reid (53) reported that the addition of sodium bentonite to a poultry ration slowed the rate of feed passage through the gut. Bringe and Schultz (10) theorized that the beneficial effect of bentonite when added to a high-grain ration resulted from the slower rate of feed passage. By adding a bulking agent to slow the rate of feed passage in Trial 3, it was thought that nutritional diarrhea could be controlled.

Purified Diets 1 and 2 were reformulated to contain bentonite. When fed to calves B22 and B26, diarrhea did not occur (Table 7). When calves B23 and B25 were fed the same diets without bentonite, diarrhea occurred. These limited results indicated that the addition of bentonite to Purified Diets 1 and 2 controlled diarrhea. Therefore, if bentonite does not suppress nutrient digestibility these purified diets can be used to determine the nutritional effect of various ingredients used in milk replacers. However, in studying the nutritional causes of diarrhea, the use of these purified diets may not be possible since bentonite has an anti-diarrheic effect.

Although the body weight changes (Appendix Table 16) were somewhat improved for the bentonite fed calves over that for the non-bentonite fed calves, the gains were below normal (79).

The necropsy performed by the Kansas State University Veterinary Clinic indicated that calf B23 died of enteritis--malabsorption syndrome.

Experiment II

The purpose of this experiment was to determine if bentonite would affect the nutrient digestibility and nitrogen balance of calves fed a commercial milk replacer and to study further its effect on the control of diarrhea.

Incidence of diarrhea. The weekly average fecal scores are presented in Table 8. Although the differences were not significant ($P < 0.05$, Appendix Table 1), the calves fed bentonite had a lower mean fecal score every week except for the first week. Assuming diarrhea to be of a nutritional origin if the rectal temperature was under 39°C, the Bentonite Group had less nutritional diarrhea than the Control Group although the difference was not significant ($P < 0.05$). The results also showed that infectional diarrhea was not controlled by the addition of bentonite. The mean fecal scores did not change significantly ($P < 0.05$) as the age of the calves increased (Appendix Table 2).

The analysis of variance (Appendix Table 3) revealed that the fecal dry matter content (Table 9) in Periods 2 and 3 was significantly ($P < 0.05$) higher for the Bentonite Group than for the Control Group. If there had been more animals contributing to the means in Period 1, a significantly higher content might have also been noted for the Bentonite Group. There

TABLE 8. Weekly average fecal score, Experiment II.

Group	Animal	Weeks of age 1	2	3	4	5	6
Bentonite	B17					0[a]	0
	B25			0	0	0.38[b]	0.10[b]
	B29	0	0	0	0	0	0
	B31	0	0	0	0	0	0
	B32	0.10[c]	0	0	0	0	0
	Mean	0.03[d]	0[d]	0[d]	0[d]	0.08[d]	0.02[d]
Control	B19					0.80[b]	0
	B26			0.80[c]	0	0	0.18[c]
	B27	0	0	0	0.46[b]	0	0
	B33	0	0.20[b]	0	0	0	0
	Mean	0[d]	0.10[d]	0.29[d]	0.15[d]	0.20[d]	0.05[d]

[a]Fecal score average = fecal consistency evaluations made on the scale of zero to three, where zero denoted normal feces and three denoted fluid feces.

[b]Diarrhea was assumed to be of nutritional origin.

[c]Diarrhea was assumed to be of infectional origin.

[d]The means were not significantly ($P < 0.05$) different between groups within weeks and between weeks within groups.

TABLE 9. Percent fecal dry matter, Experiment II.

Group	Animal	Collection periods 1	2	3
Bentonite	B17			28.9
	B25		29.1	28.1
	B29	25.2	28.9	28.5
	B31	27.6	30.1	26.0
	B32	29.6	27.7	30.5
	Mean	27.5[a]	29.0[a,b]	28.4[a,b]
Control	B19			22.4
	B26		22.7	25.4
	B27	24.2	25.8	26.9
	B33	23.5	23.7	22.6
	Mean	23.9[a]	24.1[a,c]	24.3[a,c]

[a]The means were not significantly ($P < 0.05$) different between periods within groups.

[b,c]Means in the same column having different superscripts are significantly ($P < 0.05$) different from each other.

were no significant differences ($P < 0.05$, Appendix Table 4) in the fecal dry matter content between periods within the same group. The added bulk seemed to improve the fecal consistency by increasing the dry matter content through the addition of bentonite.

The fecal dry matter values for both groups were much higher than that of 17.9% reported by Gorrill and Nicholson (32). Wood et al. (100) stated that normal feces contained 20% or more dry matter. According to the previous statement, the results obtained for both the Bentonite and Control Groups were normal.

<u>Apparent nutrient digestibility and nitrogen balance</u>. An analysis of variance (Appendix Tables 5 and 6) of protein digestibility (Table 10) indicated no significant ($P < 0.05$) differences between groups within collection periods and between collection periods within groups. The protein digestibility by calf B27 during Period 2 was possibly reduced from that of the other calves in the same period because of diarrhea during the week prior to the collection period. However, when calves

TABLE 10. Percent protein digestibility, Experiment II.

		Collection periods		
Group	Animal	1	2	3
Bentonite	B17			81.2
	B25		68.7	77.8
	B29	49.2	71.1	74.6
	B31	78.3	81.6	69.3
	B32	78.5	74.4	80.0
	Mean	68.7[a]	74.0[a]	76.6[a]
Control	B19			84.9
	B26		78.9	74.9
	B27	80.1	60.9	80.0
	B33	82.6	75.3	73.6
	Mean	81.4[a]	71.7[a]	78.4[a]

[a]The means were not significantly ($P < 0.05$) different between groups within periods and between periods within groups.

B32, B25, and B26 had diarrhea just before a collection period, as shown by the fecal scores in Table 8, the protein digestibility was not greatly reduced when compared to the other values in the same periods.

Urinary nitrogen (Table 11) was lower in every period for the Bentonite Group. Although not significant ($P < 0.05$, Appendix Table 9), the efficiency of nitrogen retention (Table 12) was much greater for the Bentonite Group than for the Control Group during Periods 2 and 3. Rindsig and Schultz (81) found similar results for urinary nitrogen and efficiency of nitrogen retention when adding bentonite to a high-grain ration fed to cows. They theorized that bentonite may maintain a more constant rumen NH_4^+ level by holding it in a readily exchangeable form thus increasing the efficiency of nitrogen retention. However, this is not possible in the non-ruminating calf. No explanation can be given for the increase in efficiency of nitrogen retention in this experiment.

The analysis of variance (Appendix Tables 7 and 8) indicated there were no significant ($P < 0.05$) differences in the mean nitrogen balances (Table 11) between groups within periods and between periods within groups. Although the differences were not significant ($P < 0.05$), Rindsig and Schultz (81) reported a markedly higher nitrogen balance for cows receiving bentonite compared to those not receiving bentonite. Gorrill and Nicholson (31) observed no effect on nitrogen balance when bulk was added to a milk replacer.

Blaxter and Wood (7) reported an average nitrogen retention of 4.7 g per day when using a semisynthetic diet. Wood _et al._ (100) found average nitrogen balance values of 10.3 g per day for calves 4 to 13 days

TABLE 11. Nitrogen intake, excretion, and balance in Experiment II.

		Collection periods											
		1				2				3			
		N	N excretion		N	N	N excretion		N	N	N excretion		N
Group	Animal	intake	Feces	Urine	balance	intake	Feces	Urine	balance	intake	Feces	Urine	balance
		(g/day)											
Bentonite	B17									32.0	5.9	12.5	13.6
	B25					29.2	9.0	9.7	10.5	32.9	7.2	14.9	10.8
	B29	20.7	11.4	5.8	3.5	21.1	6.0	5.1	10.0	22.6	5.7	5.6	11.3
	B31	26.8	5.8	13.7	7.3	28.3	5.1	16.4	6.8	29.7	10.1	14.0	5.6
	B32	23.5	5.0	9.3	9.2	24.9	6.3	9.5	9.1	26.8	5.3	9.2	12.3
	Mean	23.7	7.4	9.6	6.7[a]	25.9	6.6	10.2	9.1[a]	28.8	6.8	11.2	10.8[a]
Control	B19									33.4	5.0	18.4	10.0
	B26					25.9	5.4	10.3	10.2	28.7	7.1	12.7	8.9
	B27	24.0	4.7	9.4	9.9	26.8	10.8	10.4	5.6	26.8	5.3	13.2	8.3
	B33	25.4	4.4	12.8	8.2	26.3	6.4	13.5	6.4	27.7	7.2	12.1	8.4
	Mean	24.6	4.6	11.1	8.9[a]	26.3	7.5	11.4	7.4[a]	29.2	6.2	14.1	8.9[a]

[a]The nitrogen balance means were not significantly ($P < 0.05$) different between groups within periods and between periods within groups.

of age and 8.3 g per day for calves 14 to 23 days of age when using fresh skimmilk. These values compare favorably to those in Table 11.

Although the differences were not significant ($P < 0.05$, Appendix Table 10), it appeared that during Periods 2 and 3 the addition of bentonite improved the digestion of the ether extract (Table 13) in the milk replacer, when compared to the Control Group. If variation within groups had not been so great, significant differences might have been more

TABLE 12. Efficiency of nitrogen retention in Experiment II.

Group	Animal	Collection periods 1	2	3
		(%)		
Bentonite	B17			42.5
	B25		36.0	32.8
	B29	16.9[a]	47.4	50.0
	B31	27.2	24.0	18.9
	B32	39.1	35.1	45.9
	Mean	27.7[b]	35.6[b]	38.0[b]
Control	B19			29.9
	B26		39.4	31.0
	B27	41.3	20.9	31.0
	B33	32.3	24.3	30.3
	Mean	36.8[b]	28.2[b]	30.6[b]

[a]Efficiency of N retention = $\frac{\text{N retention}}{\text{N intake}} \times 100$.

[b]The means were not significantly ($P < 0.05$) different between groups within periods.

readily detectable. By slowing the rate of feed passage, bentonite may have allowed greater utilization of the ether extract. The analysis of variance (Appendix Table 11) revealed no significant ($P < 0.05$) increases in the ether extract digestibility between periods within groups.

From the ingredient list of the milk replacer (Table 6) it would appear that the main source of fat was provided by animal fat. Adams *et al.* (2), Blaxter and Wood (7), and Roy (85) reported the apparent digestibility of lard by calves to be 88.9 to 93%. Cunningham and Loosli (20) observed that the apparent digestibility of lard by calves increased

TABLE 13. Percent ether extract digestibility, Experiment II.

		Collection periods		
Group	Animal	1	2	3
Bentonite	B17			79.8
	B25		63.8	77.8
	B29	75.0	81.7	77.1
	B31	48.8	73.7	57.1
	B32	45.4	77.3	76.4
	Mean	56.4[a]	74.1[a]	73.7[a]
Control	B19			71.6
	B26		66.7	--
	B27	76.5	69.3	63.3
	B33	78.0	70.6	42.9
	Mean	77.3[a]	68.9[a]	59.3[a]

[a]The means were not significantly ($P < 0.05$) different between groups within periods and between periods within groups.

from 68% at 2 weeks of age to 94% at 11 weeks of age. These values are much higher than those reported in Table 13. The low values observed in this experiment could be the result of larger-than-normal endogenous fecal fat values. However, no explanation can be given for the cause of these larger-than-normal values.

The nitrogen-free extract digestibility (Table 14) was not significantly ($P < 0.05$) different between groups within periods (Appendix Table 12) and between periods within groups (Appendix Table 13). Huber et al. (41,43) and Noller et al. (68) reported the digestibility of lactose to range from 91 to 97.1%. The mean values reported in Table 14 fit in

TABLE 14. Percent nitrogen-free extract digestibility, Experiment II.

Group	Animal	Collection periods 1	2	3
Bentonite	B17			96.0
	B25		96.1	95.3
	B29	91.3	95.5	97.6
	B31	96.8	95.6	97.2
	B32	95.1	96.9	94.6
	Mean	94.4[a]	96.1[a]	96.1[a]
Control	B19			97.8
	B26		93.1	96.6
	B27	96.0	97.6	99.5
	B33	96.3	98.3	98.0
	Mean	96.2[a]	96.3[a]	98.0[a]

[a]The means were not significantly ($P < 0.05$) different between groups within periods and between periods within groups.

this range.

The dry matter digestibility (Table 15) did not differ significantly ($P < 0.05$, Appendix Tables 14 and 15) between groups within periods and between periods within groups. The results obtained for dry matter digestibility for both groups were similar to those reported in previous work. Blaxter and Wood (7) reported values of over 90% dry matter digestibility when 5-day-old calves were fed a milk replacer. When feeding a milk replacer, Radostits and Bell (78) found that the digestibility of dry matter did not reach 80% until the calves were 14 days old. Values

TABLE 15. Percent dry matter digestibility, Experiment II.

Group	Animal	Collection periods 1	2	3
Bentonite	B17			91.7
	B25		86.9	88.7
	B29	76.9	87.4	89.7
	B31	91.3	90.9	87.3
	B32	89.7	89.8	90.4
	Mean	86.0[a]	88.8[a]	89.6[a]
Control	B19			91.8
	B26		87.6	83.1
	B27	90.5	82.8	90.2
	B33	91.0	88.7	88.3
	Mean	90.8[a]	86.4[a]	88.4[a]

[a]The means were not significantly ($P < 0.05$) different between groups within periods and between periods within groups.

up to 97% dry matter digestibility were observed by Raven and Robinson (80) when calves were fed a reconstituted spray-dried whole milk powder. Gorrill and Nicholson (32) reported 90.6 and 88.8% dry matter digestibility for milk and soy-milk, respectively.

No obvious relationship was observed between nutrient digestibility or incidence of diarrhea and daily body weight changes (Appendix Table 17). The mean weight gains were below Ragsdale's standards (79).

Some difficulty in making fecal collections was encountered. The main problem was keeping the strap across the rump of the calf securely in place. Fecal samples were usually lost at the start of a collection period due to this problem. This always required starting the collection period over. A more reliable fecal collection procedure should be developed for future work. Something involving a harness apparatus might be more suitable.

A problem was also encountered in removing all the feces from the collection bag after they had been thawed out. Some variation in the results reported could be due to incomplete removal of the feces. It was noted that the most complete removal occurred when the feces were allowed to thaw for a very short time.

The results from Experiment II indicate that bentonite does not suppress nutrient digestibility or nitrogen balance and that nutritional diarrhea is almost completely controlled. Therefore, it would appear that bentonite could be added to either purified diet used in Experiment I and that these diets could be used in determining the nutritional effects of various ingredients used in milk replacers.

The possibility of using sodium bentonite in a commercial milk replacer to help control nutritional diarrhea should be considered. It appears that bentonite added to a commercial milk replacer might increase the efficiency of nitrogen retention. There is also a possibility that bentonite could improve the ether extract digestibility.

Further studies on the effect of bentonite on the control of nutritional diarrhea and improvement of nitrogen utilization and ether extract digestibility are needed. Future research should be conducted to study the effect of bentonite on the absorption of minerals and vitamins. Also, to increase the sensitivity of future work, more animals should be used than were used in this experiment.

SUMMARY

This study was designed to develop a purified milk replacer that could be used to study the causes of nutritional diarrhea and to determine if sodium bentonite would control nutritional diarrhea.

In Experiment I, Purified Diet 1 caused diarrhea and unsatisfactory growth when fed to young dairy calves. As the calves increased in age no improvement in fecal consistency was noted. Diarrhea and unsatisfactory growth were again observed when Purified Diet 2, which contained a lower level of lactose than Purified Diet 1, was fed. However, some improvement in fecal consistency was noted as calves increased in age. No diarrhea occurred when sodium bentonite was added to either of the previously used diets.

In Experiment II sodium bentonite was added to a commercial milk replacer and its effect on nutrient digestibility, nitrogen balance, and control of diarrhea was studied. Bentonite had no significant ($P < 0.05$) effect on digestibility of protein, ether extract, nitrogen-free extract, or dry matter. Also, nitrogen balance was not significantly ($P < 0.05$) affected by the addition of bentonite. Although the differences were not statistically significant ($P < 0.05$), bentonite appeared to increase the efficiency of nitrogen retention in the second and third periods. Fecal dry matter was significantly ($P < 0.05$) increased in Periods 2 and 3 by the addition of bentonite. Although nutritional diarrhea was not a serious problem in either group, it was almost completely controlled in the Bentonite Group.

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APPENDIX

APPENDIX TABLE 1. Analysis of variance of the weekly average fecal scores between groups, Experiment II.

	Weeks of age											
	1		2		3		4		5		6	
Source of variation	df	Mean square	df	Mean square	df	Mean square	df	Mean square	df	Mean square	df	Mean square
Groups	1	.001	1	.012	1	.122	1	.041	1	.034	1	.001
Error	3	.002	3	.007	5	.085	5	.028	7	.085	7	.005

APPENDIX TABLE 2. Analysis of variance of the weekly average fecal scores between weeks, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Weeks	5	.004	5	.028
Error	18	.007	12	.091

APPENDIX TABLE 3. Analysis of variance of the fecal dry matter content between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	15.9	1	40.7*	1	41.2*
Error	3	3.3	5	1.5	7	3.8

*Indicates significance at $P < 0.05$.

APPENDIX TABLE 4. Analysis of variance of fecal dry matter between periods, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Periods	2	1.9	2	.15
Error	9	2.6	6	3.3

APPENDIX TABLE 5. Analysis of variance of protein digestibility between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	192.9	1	9.4	1	7.0
Error	3	190.8	5	60.6	7	24.5

APPENDIX TABLE 6. Analysis of variance of protein digestibility between periods, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Periods	2	58.9	2	64.6
Error	9	83.8	6	44.1

APPENDIX TABLE 7. Analysis of variance of nitrogen balance between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	6.8	1	5.0	1	7.4
Error	3	6.1	5	4.0	7	5.6

APPENDIX TABLE 8. Analysis of variance of nitrogen balance between periods, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Periods	2	18.2	2	2.2
Error	9	6.9	6	2.6

APPENDIX TABLE 9. Analysis of variance of the efficiency of nitrogen retention between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	98.7	1	94.5	1	124.0
Error	3	95.8	5	93.6	7	88.4

APPENDIX TABLE 10. Analysis of variance of ether extract digestibility between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	513.6	1	47.0	1	392.1
Error	3	178.4	5	36.7	6	129.5

APPENDIX TABLE 11. Analysis of variance of ether extract digestibility between periods, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Periods	2	344.4	2	199.5
Error	9	115.3	5	89.1

APPENDIX TABLE 12. Analysis of variance of nitrogen-free extract digestibility between groups, Experiment II.

	Period 1		Period 2		Period 3	
Source of variation	df	Mean square	df	Mean square	df	Mean square
Groups	1	3.8	1	0.1	1	7.1
Error	3	5.4	5	3.4	7	1.6

APPENDIX TABLE 13. Analysis of variance of nitrogen-free extract digestibility between periods, Experiment II.

	Bentonite Group		Control Group	
Source of variation	df	Mean square	df	Mean square
Periods	2	3.3	2	3.3
Error	9	2.6	6	3.4

APPENDIX TABLE 14. Analysis of variance of dry matter digestibility between groups, Experiment II.

Source of variation	Period 1		Period 2		Period 3	
	df	Mean square	df	Mean square	df	Mean square
Groups	1	27.4	1	9.6	1	3.3
Error	3	41.2	5	6.1	7	7.7

APPENDIX TABLE 15. Analysis of variance of dry matter digestibility between periods, Experiment II.

Source of variation	Bentonite Group		Control Group	
	df	Mean square	df	Mean square
Periods	2	12.6	2	11.7
Error	9	16.3	6	10.4

APPENDIX TABLE 16. Body weight changes in Experiment I.

Trial	Animal	Weeks of age						
		1	2	3	4	5	6	7
		(g/day)						
1	B12	-64	-327	327				
	B14	-327	259	-195				
	B15	132	64	-518	518	781	518	195
	B16	0	195	327	636	132	195	
	Mean	-65	48	-15	577	457	357	195
2	B17	-132	518	390	-64			
	B19	390	-195	327	390			
	Mean	129	162	359	163			
3	B22	327	390	132	327	-195		
	B23	327	0					
	B25	327	390					
	B26	327	259					

APPENDIX TABLE 17. Body weight changes in Experiment II.

Group	Animal	Weeks of age 1	2	3	4	5	6
		(g/day)					
Bentonite	B17					390	132
	B25			0	908	132	195
	B29	132	132	64	64	259	195
	B31	132	259	132	132	327	195
	B32	-64	132	195	259	259	195
	Mean	67	174	98	341	273	182
Control	B19					713	-132
	B26			-195	518	327	195
	B27	132	195	518	0	0	327
	B33	132	132	195	195	195	64
	Mean	132	164	173	238	309	114

EFFECT OF BENTONITE IN PURIFIED AND COMMERCIAL MILK REPLACERS ON CONTROLLING NUTRITIONAL DIARRHEA IN YOUNG CALVES

by

NORMAN LEMLEY WONDERLICH

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AN ABSTRACT OF A MASTER'S THESIS

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Manhattan, Kansas

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This study was designed to develop a purified milk replacer that could be used to study the causes of nutritional diarrhea and to determine if sodium bentonite would control nutritional diarrhea.

In Experiment I, Purified Diet 1 caused diarrhea and unsatisfactory growth when fed to young dairy calves. As the calves increased in age no improvement in fecal consistency was noted. Diarrhea and unsatisfactory growth were again observed when Purified Diet 2, which contained a lower level of lactose than Purified Diet 1, was fed. However, some improvement in fecal consistency was noted as calves increased in age. No diarrhea occurred when sodium bentonite was added to either of the previously used diets.

In Experiment II sodium bentonite was added to a commercial milk replacer and its effect on nutrient digestibility, nitrogen balance, and control of diarrhea was studied. Bentonite had no significant ($P < 0.05$) effect on digestibility of protein, ether extract, nitrogen-free extract, or dry matter. Also, nitrogen balance was not significantly ($P < 0.05$) affected by the addition of bentonite. Although the differences were not statistically significant ($P < 0.05$), bentonite appeared to increase the efficiency of nitrogen retention in the second and third periods. Fecal dry matter was significantly ($P < 0.05$) increased in Periods 2 and 3 by the addition of bentonite. Although nutritional diarrhea was not a problem in either group, it was almost completely controlled in the Bentonite Group.