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Response of Lactating Dairy Cows to Small and Large Amounts of Dried Whey in the Concentrate Mixture

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RESPONSE OF LACTATING DAIRY COWS TO SMALL AND LARGE AMOUNTS OF DRIED WHEY IN THE CONCENTRATE MIXTURE

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Dairy Science Department Date

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Finally, I wish to dedicate this work to God the Giver of all things in this life.

ABSTRACT

Short-term (6 to 13 wk) experiments indicated that adding small amounts of dried whey to the concentrate mix fed to lactating dairy cows increased milk fat percentage, but decreased milk production. In order to determine if the increased fat percentage was a positive response to dried whey in the ration, or an artifact of drying off the cows early, 5% dried whey product (DWP) was included in the concentrate mix fed to 10 Holstein cows. All cows started on the experiment in their 4th wk postpartum and continued for the duration of their lactation. The DWP replaced a portion of the ground shelled corn, soybean meal, and dicalcium phosphate which was included in the control group's concentrate mix. Corn silage was fed ad libitum, with alfalfa hay fed at 5 kg/hd daily, while concentrates were fed at 1 kg/3 kg milk produced. There was no difference in actual milk production between the control and DWP-fed cows (21.3 kg/day for both groups), but 4% fat-corrected milk and percent milk fat were higher for the DWP-fed cows (19.6 and 20.0 kg/day; 3.58 and 3.68%, respectively). Persistencies of actual production during the experiment (changes from 3rd wk postpartum) were slightly less for the DWP-fed cows, but persistency of 4% fat-corrected milk and milk fat yields were greater for the DWP-fed cows. Milk protein and solids-not-fat production and percentages of each were not affected by ration treatment.

A subsequent 16 wk lactation trial was conducted to evaluate the effects of feeding large amounts of dried whey (65%) in the

concentrate mix. Two groups of 10 Holstein cows which had been paired according to stage of lactation and lactation number were used. The dried whey replaced all of the ground shelled corn, dicalcium phosphate, trace mineralized salt, and portions of the rolled oats and soybean meal which were included in the control group's concentrate mix. The cows were fed corn silage ad libitum, 3.5 kg alfalfa hay/hd and grain (1 kg/3 kg milk produced) daily. Control cows produced more milk (25.3 and 22.1 kg/day, respectively) and more 4% fat-corrected milk (23.1 and 21.2 kg/day, respectively). However, cows fed dried whey had higher percent milk fat (3.77 and 3.46%, respectively). Persistencies of actual production during the experiment (changes from pretreatment) were less for the whey-fed cows, but persistency of 4% fat-corrected milk was about the same due to an increase in milk fat percent from pretreatment for cows fed dried whey. Nitrogen components of milk were essentially the same for both groups with slightly less non-protein nitrogen in the milk of whey-fed cows. Rumen samples taken via stomach tube indicated higher molar percentages of butyrate and valerate, and lower values for acetate, propionate, and isobutyrate for whey-fed cows. Dry matter content of feces samples indicated that feeding this large amount of dried whey caused some diarrhea.

INTRODUCTION

The amount of cheese sold in the United States increased 57% in the past 10 yr (27). In order to meet this increased demand, cheese plants are producing more cheese and thereby increasing the amount of whey produced. In 1974, the annual production in the United States was 13.9 billion kg of cheese whey or .9 billion kg of whey solids (47). Despite efforts to increase the usage of whey, from 1970 to 1975, utilization in human and animal foods only increased from 53 to 58% of the total whey production in the United States (31). The remainder was disposed of mainly by dumping the whey into rivers and streams. This not only causes pollution, but also wastes a very highly nutritious by-product. Consequently, there is a challenge to find new methods of utilizing whey.

One method of utilizing whey is to feed it to dairy cows. Previous research indicated that including small amounts of dried whey in grain mixes fed to lactating dairy cows caused increased fat test, but also resulted in a slight reduction in milk yield (8, 44). Those responses occurred despite the fact that ad libitum amounts of roughage were fed to maintain sufficient quantities of fiber so that these rations were not considered fat-depressing. However, all of those were short term trials with 6 to 13 wk experimental periods. One objective of this research was to utilize a lactation length trial to determine if the increased fat test was a positive response to dried whey or an artifact of drying off.

Depending on current prices, there may be times when it would be profitable to feed ruminants large amounts of dried whey or dried whey products. Large amounts of lactose, a major component of dried whey, have been fed in the concentrate mix of lactating dairy cows with results similar to those in previously mentioned trials (9). A second aspect of this research was to evaluate the response of lactating dairy cows to large amounts of dried whole whey in the concentrate mix.

LITERATURE REVIEW

Feeding Liquid Whey to Ruminants

Because many dairy farmers also raised swine, liquid whey was usually fed to hogs for the sake of convenience (19). Today, more specialized farming and greater distance between dairy and swine operations has brought on a decrease in feeding liquid whey to swine due to increased transportation costs (41). Since dairy farms are often relatively close to milk processing plants, there has been increased interest in recycling whey through cows.

Liquid whey has been fed in drinking bowls (32, 53) or by group feeding methods (2). Gravity flow can be used to supply whey to water cups (32); however, an excessive number of watercups would require additional air pressure to maintain flow rates. Watercup systems should also be washed twice a wk (32), thus, increasing needed labor time over group feeding methods.

Utah (2, 3, 21), Vermont (35, 53), and USDA (19) researchers have successfully fed liquid whey to lactating cows. Cows consumed an average of 90 liters of liquid whey per day with no effect on milk production (2). Rogers, et al. (35) found that dairy cows and steers can consume as much as 3.36 kg of whey dry matter without adversely affecting fiber digestion.

Welch and Nilson (53) fed as much as 136 kg/day/cow and noted above average milk production; however, high levels of intake caused excessive urination (35, 53). Another problem was that whey kept more than 36 h at ambient temperatures was not consumed readily due to increased acid content.

Feeding liquid whey decreased hay or grain intake (2, 35, 53). Welch et al. (53) had 17 Jersey cows consuming 44 kg/cow/day liquid whey which replaced 4 kg concentrate with no decline in milk production. Anderson et al. (2) noted that liquid whey replaced an average of 5.9 kg of hay/day for lactating cows receiving whey only. Both groups (2, 53) noted that for each kilogram of whey solids consumed there was approximately a one kilogram decrease in either concentrate or hay intake. Anderson also noted that whey-fed cows were not as eager for their grain.

Most of the whey fed to cattle has been sweet (cheddar cheese) whey, but acid (cottage cheese) whey can also be fed to cattle. The feeding of liquid acid whey produced favorable results when fed to growing steers and calves (25, 53). Lynch et al. (25) increased dry matter intake (DMI) as liquid acid whey from 28 to 48% of total DMI of Holstein steers by restricting grain intake versus feeding grain ad libitum without any extremely adverse effects. Steers fed liquid acid whey plus restricted grain consumed 57% of their DMI from whey, however, several instances of bloat were observed in whey-fed calves. Steers were slaughtered after the experiment and those receiving acid whey had lower carcass dressing percentages, which may have been due to a different stage of finish. Welch and Nilson (53) fed steers and heifers liquid acid whey. Steers on pasture consumed 48 kg liquid whey/day/steer. Five heifers fed liquid acid whey gained 80 kg while five control heifers gained only 46 kg.

Anderson (1) noted higher overall ration dry matter (DM) digestibility for sheep receiving liquid whey. Sheep fed whey received 28.9% of their DM from whey by consuming 7.38 kg of liquid whey daily. Digestibilities of whey solids were 86.9% for sheep which compared to 82.8% for steers and cows (35).

Problems encountered with feeding liquid whey can usually be overcome with good management. Cattle may tend to reject whey when it is first offered; however, withholding water will arouse interest in whey with subsequent higher consumption (35). Also, by decreasing dry matter intake from other sources, liquid whey consumption will increase (33). As mentioned earlier, excessive urination could present a problem if not handled correctly. In stanchion and free stall systems bedding must be changed more frequently. Another problem with liquid whey is acid fermentation that oxidizes and deteriorates metals that are normally used for feeding water and other liquid supplements. In such cases, corrosion-resistant equipment such as plastic, fiberglass, or stainless steel is required for handling liquid whey (35). Sanitation is very necessary or flies will be a significant problem in warm weather (42). Lastly, due to the large volume of liquid, the feeding of liquid whey should probably only be considered by farmers located close to a cheese plant because of the transportation factor (40).

Feeding Dried Whey in High Grain Restricted Roughage (HGRR) Rations

Many times high producing dairy cows are fed rations which contain high levels of concentrates and restricted amounts of roughage.

Those rations allow greater intakes of energy to meet the increasing demands necessary for milk production; however, those diets also tend to decrease milk fat percentage (5, 7, 10, 17, 20, 24, 50, 52). Storry et al. (50) and Bauman et al. (5) noted as high as 50% reduction in milk fat percent from pretreatment levels.

Changes in rumen fermentation (5, 7, 11, 12, 17, 20, 21, 24, 36, 49, 50, 52, 54) and higher levels of glucogenic metabolites (12, 24) have been offered as factors for milk fat percent decreases in cows fed HGRR rations. Increased rumen propionate due to HGRR rations may divert nutrients for fat synthesis from the mammary gland. Rumen pH was found to be lower in steers fed concentrate rations (54) which may be a factor in altering rumen fermentation patterns.

Starting in the early 1960's, research was conducted feeding bicarbonates or magnesium oxide to increase milk fat percent from cows fed HGRR rations. Feeding small amounts (3% or less of concentrate mix) of either sodium bicarbonate or magnesium oxide prevented milk fat depression (13, 14, 15, 16). Cows fed bicarbonates had higher rumen pH (14) and altered rumen VFA production (13, 15, 16).

Later, dried whey or whey products were also fed in the concentrate mix as an additive to HGRR rations to prevent milk fat depression (22, 23, 37). Probably the main reason dried whey or partially delactosed whey was used as the feed additive was because whey is very palatable; therefore, no decrease in concentrate consumption was likely to occur (40). Morrill and Dayton (28) noted increased consumption when calf starters contained 10% whey and up to 20% did not decrease palatability. Other feed additives, such as bicarbonates or magnesium oxide, that were used to prevent milk fat depression were found to be unpalatable with a resulting decline in concentrate consumption (13, 15, 16, 22). Emery et al. (16) noted a 10 to 20% decrease in concentrate intake in cows fed sodium bicarbonate. When Stout et al. (51) fed cows either 1.5% sodium bicarbonate or 1.5% magnesium oxide in the concentrate mix, cows consumed only 77% and 73% of control levels, respectively.

Huber et al. (23) fed varying amounts of dried whole whey or partially delactosed whey in the concentrate mix of lactating Holstein cows receiving rations of 84% concentrate and 16% hay. Milk fat percent was maintained at pretreatment levels when as little as 10% partially delactosed whey was incorporated into the concentrate mix. There was no significant additional effect on milk fat percent by incorporating 20, 30, or 60% dried whey or partially delactosed whey into the concentrate. Increased rumen butyrate and acetate-to-propionate ratios, along with a decrease in rumen propionate, were associated with maintenance of normal fat percentages in groups fed concentrates containing partially delactosed whey. Subsequent work by Rosser et al. (37) concurred with Huber's results in that 10% partially delactosed whey added to the concentrate ration increased milk fat percentage although not significantly. Increases were also noted in relative amounts of rumen acetate and butyrate while rumen propionate decreased.

A later study by Huber et al. (22) noted an increased linear response in milk fat percent as partially delactosed whey was increased from 0 to 3.6 to 7.3 to 14.6% of the concentrate ration. Concentrate intake and rumen pH were not affected by whey. The whey caused decreased molar percentages of ruminal propionate and increased acetate molar percent, while molar percentages of butyrate increased only at the 14.6% whey level. Milk yields were not affected by whey additions.

In later work, Schingoethe et al. (46) fed either dried whole whey, high mineral whey product, demineralized whey, or lactose in efforts to determine which components in whey were responsible for maintaining milk fat percentages in concentrate mixes. Milk fat percentages for cows receiving the 14% dried whole whey, 5.9% high mineral whey product, and 9.8% lactose rations all decreased less than the control ration cows. Demineralized whey had no effect on percent fat in milk. This indicated whey minerals were most effective in preventing milk fat depression on HGRR rations although lactose had some effect. Lactose, which makes up approximately 70% of dried whole whey, was nearly as effective as whole or high mineral whey. Cows on the control ration were slightly more persistent than those fed rations containing dried whole whey or whey products; however, the differences were not significant.

Studies have indicated that minerals and lactose were the components in whey most responsible for maintaining fat percentage (37, 46). Schingoethe et al. (46) found no protection against milk fat depression when they removed 90% of the whey minerals from the ration.

Rosser et al. (37) fed lactose-hydrolyzed whey and noted a decrease in milk fat percentage indicating lactose maintained fat percentage. However, in conflicting results, Schingoethe et al. (46) maintained fat percentage by feeding lactose in the same amount as contained in dried whey while Rosser et al. (37) could not maintain milk fat percentage by feeding a similar ration.

Work by Metzger et al. (26) indicated responses of rumen microflora to HGRR rations containing whey products. The rumen microbial data were collected from one-half of the cows in the experiment of (46). Lactose fermenters increased in number on all diets containing whey or whey products, but no increase from pretreatment was found with control diet. There were no differences between rations in the numbers of starch digesters or proteolytic organisms. Although some may exist, relationships between rumen microbial populations and rumen VFA and/or milk composition are not readily apparent.

Feeding Dried Whey or Whey Products in Normal Rations

Whey or lactose have also been included in the concentrate mixture of rations supplying ad libitum forage and concentrates fed according to production. These rations contain higher amounts of fiber and are not considered fat-depressing. In initial work by Bowman and Huber (9), they substituted 56% lactose for ground-shelled corn in the concentrate mixture and noted a significantly higher milk fat percentage along with slightly reduced milk yields. Rumen acetate was lower and rumen butyrate was higher on the lactose ration while rumen propionate and acetate-to-propionate ratios were unchanged. Milk protein and solids-not-fat (SNF) were unchanged. They felt the trend toward increased milk fat with the lactose ration may have been due to decreased milk yields and higher concentrations of rumen butyrate.

In later work, Bishop and Bath (8) and Schingoethe et al. (44) fed small amounts of dried whey (5% or less of the concentrate mixture) to lactating dairy cows and noted similar milk production and composition results as found by (9). Schingoethe et al. (44) noted significantly lower rumen propionate in whey-fed cows and trends toward higher butyrate and lower acetate. Bishop and Bath (8) noted significantly higher DMI for whey-fed cows while Schingoethe et al. (44) found no significant difference. All of those trials (8, 9, 44) were short term trials involving 6 to 13 wk experimental periods. Consequently, increased milk fat percentages may have simply been reflecting decreases in milk yield rather than positive responses to whey in the ration (40).

Schingoethe and Rook (45) found that adding 5% dried whey product to the concentrate ration had no great effect on ration digestibility. Mineral absorption and retention did not increase with the dried whey ration probably because the lactose in the small amounts of dried whey fed was fermented in the rumen and therefore, unavailable in the small intestine for aiding in mineral absorption.

Woods and Burroughs (55) successfully fed whey or lactose to growing-finishing steers. They found that as little as 225 grams of whey per day increased daily gains and feed consumption; however, feed efficiency decreased slightly. Steers fed equivalent amounts of lactose as contained in 225 grams of dried whey did not gain as much as with whey. In recent work by Schingoethe et al. (43) growing steers were fed up to 40% of their DM as lactose or 60% as dried whey. Rations containing 30% or more lactose as lactose or dried whey caused decreased feces dry matter percentage and increased urination, but ration digestibilities were not affected.

Feeding large amounts of dried whey or lactose to lactating cows consuming ad libitum amounts of forage has not been studied. It is not known definitely, but data indicate that milk production may decrease when cows consume in excess to 3 to 4 kg/day of lactose or lactose intake of more than 20 to 30% of total dry matter intake (41).

MATERIALS AND METHODS

Trial 1

Twenty lactating Holstein cows were randomly assigned to two groups of ten cows each 3 wk postpartum and continued on experiment for the remainder of their lactation. The control group received the regular herd concentrate mix while the experimental group was fed a 5% dried whey product (DWP) concentrate mix. The DWP replaced portions of the shelled corn, soybean meal, and dicalcium phosphate (Table 1). Rations were balanced for crude protein, energy, calcium, and phosphorus content. Nutrients were present according to National Research Council (29) recommendations.

Concentrates were group fed at 1 kg/3 kg of milk produced. Amounts of concentrate fed were readjusted weekly based on previous week's group milk production. Both groups received 7 kg/hd/day alfalfa-brome hay and corn silage ad libitum. Chemical composition of forages are in Table 2. Both groups were housed in a free stall barn with similar feeding and management for the duration of the experiment.

Cows were weighed 3 consecutive days when they started on experiment, once every 4 wk during the experiment, and 3 consecutive days when taken off experiment at the end of lactation. Individual daily milk weights were recorded. Twenty-four hour pretreatment milk samples (AM-PM composites) were taken just prior to when cows started on experiment with subsequent samples taken every 2 wk throughout the experiment. Milk samples (AM-PM composites) were analyzed for protein

TABLE 1. Concentrate rations fed in trial 1.[a]

	Control	5% Dried whey product
	- - - - - - %	- - - - - -
Ingredient		
Ground shelled corn	41.50	37.50
Rolled oats	41.50	41.50
Soybean meal, (50% CP)	14.50	13.75
Dried whey product[b]	-	5.00
Dicalcium phosphate	1.50	1.25
Trace mineralized salt	1.00	1.00
Analyses		
Dry matter (DM), %	91.2	91.6
Crude protein, % of DM	18.1	18.1
Acid detergent fiber, % of DM	8.0	7.3
Ash, % of DM	4.6	4.9
Ether extract, % of DM	3.3	2.9

[a]Vitamin A, 8800 IU/kg; vitamin D, 2200 IU/kg added to grain ration.

[b]Whey furnished by Foremost Foods Company, San Francisco, CA.

TABLE 2. Average chemical composition of corn silage and alfalfa hay fed in trials 1 and 2.

Item	Corn silage		Alfalfa hay	
	Trial 1	Trial 2	Trial 1	Trial 2
Dry matter (DM), %	38.7	41.3	91.2	89.3
Cell wall constituents, % of DM	47.1	47.2	38.9	37.9
Acid detergent fiber, % of DM	23.8	24.2	29.2	29.3
Hemicellulose, % of DM	23.3	23.0	9.7	8.6
Lignin, % of DM	5.1	4.4	7.9	6.5
Cellulose, % of DM	17.6	18.2	21.1	20.6
Protein, % of DM	10.1	9.2	18.8	19.8
Ash, % of DM	5.4	4.7	7.4	7.7
Ether extract, % of DM	2.3	2.3	1.6	1.4

using the Kjeldahl method (4). Mojonnier total solids were determined by (30) and milk fat percent determined using the Milko-Tester MK-II[1]. Pretreatment and every 4 wk milk samples were also analyzed for nitrogen fractions using the Rowland method (38). Samples of hay, silage, and concentrate were taken once each wk and frozen for later analyses. Samples were composited into 4 wk lots, oven-dried at 57° C for 48 h and ground in a Wiley Mill through a 2 mm screen. Usual proximate analyses were then conducted. Re-composites utilizing equal aliquots from groups of four original composites were used in analyzing for neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and lignin (18).

Samples of rumen fluid were taken using a suction strainer apparatus via esophogeal tube (34) during months 3, 6, and 8 of the experiment. Samples were put into 100 ml sample jars containing .5 ml of saturated mercuric chloride. Samples were analyzed for pH using a conventional glass electrode pH meter then strained through four layers of cheese cloth. Rumen fluid samples were deproteinized by adding 2 ml of 25% metaphosphoric acid to 10 ml of sample. After 30 min the samples were centrifuged for 20 min at 12,000 rpm at 3° C using an International Refrigerated Centrifuge, Model B-20. The samples were immediately frozen for later volatile fatty acid (VFA) analysis by gas-liquid chromatography (6) using a stainless steel column (3.2 mm OD by 152.0 cm) containing neopentylglycol succinate.

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[1]N. Foss Electric, Hillerod, Denmark.

All of the milk and VFA data from the lactation trial were analyzed by using the least-squares analysis of variance procedure described by Steel and Torrie (48). Due to mastitis problems with two cows, data analysis was limited to only eight cows in the control group. Mean squares for the statistical analysis are listed in Appendix Tables 1 through 8.

Trial 2

Twenty cows were divided into two groups of ten cows per group by pairing the cows on the basis of production, stage of lactation, and lactation number, and assigning one cow from each pair to a treatment group. The two treatment groups were also balanced with equal numbers of type and production cows. Treatment groups were fed either herd concentrate mix or a concentrate mix containing 65% dried whole whey (DWW) (Table 3). It was estimated that DWW would account for nearly 25% of the cow's daily dry matter intake. Following a 2 wk adjustment period, a 16 wk continuous lactation trial was utilized to evaluate milk production and milk composition response to the concentrate mixtures. Pretreatment milk samples were taken from the PM and AM milkings just prior to the adjustment period. All pretreatment and subsequent milk samples were obtained and analyzed as in Trial 1.

Hay, silage, and concentrate samples were taken once each wk and frozen for later analyses. Samples were composited into 4 wk lots, oven-dried at 57^{o} C for 48 h, and ground in a Wiley Mill through a 2 mm screen. Usual proximate analyses were then conducted on the feed samples. Chemical composition of forages are in Table 2.

TABLE 3. Concentrate rations fed in trial 2.[a]

	Control	65% Dried whole whey
	- - - - - - % - - - - - - -	
Ingredient		
Ground shelled corn	41.5	-
Rolled oats	41.5	25.38
Soybean meal, (50% CP)	14.5	9.62
Dried whole whey[b]	-	65.00
Dicalcium phosphate	1.5	-
Trace mineralized salt	1.0	-
Analyses		
Dry matter (DM), %	91.6	95.9
Protein, % of DM	18.0	16.9
Acid detergent fiber, % of DM	9.3	6.2
Ash, % of DM	4.7	5.7
Ether extract, % of DM	3.7	1.5

[a]Vitamin A, 8800 IU/kg; vitamin D, 2200 IU/kg added to grain ration.

[b]Whey furnished by Associated Milk Producers Inc., Clarkfield, MN.

Rumen samples were taken during wk 8, 11, and 13 of the experiment 2 to 4 h after feeding. All samples were taken and analyzed as in Trial 1. Feces samples were taken the last week of the experiment and analyzed for dry matter.

All of the milk and VFA data from the lactation trial were analyzed by using the least-squares analysis of variance procedure described by Steel and Torrie (48). Data were analyzed for only nine of the ten pairs of cows since one cow in the dried whey group had difficulty with mastitis. Consequently, her data and that of her pairmate had to be discarded.

RESULTS AND DISCUSSION

Trial 1

Milk production was the same for cows fed control and DWP rations, although DWP-fed cows had greater ($P<.01$) yields of solids-corrected milk (SCM) and protein and increased ($P<.05$) output of fat, total solids, and solids-not-fat (Table 4). Actual milk yields do not agree with the decreased yields noted by (8, 44). The higher SCM, protein, total solids, and solids-not-fat may have been attributed to higher ($P<.01$) percent protein, total solids, and solids-not-fat in milk from DWP-fed cows. However, these higher values may have simply indicated higher pretreatment values since increases in protein and solids-not-fat percentages during the trial were less ($P<.05$ and .01, respectively) for DWP than for control cows. Others (8, 44) noted increased fat percent while this study only showed a trend toward higher fat percent. Change from pretreatment for fat percentage was higher ($P<.05$) for cows fed DWP. However, this increase was attributed to increases by only three of the DWP-fed cows with the remaining seven cows showing no definite response to the DWP in terms of fat percent. This possible bias may also partially explain a smaller decrease from pretreatment values for FCM ($P<.05$) and SCM for cows fed DWP.

Daily milk yield is plotted by week of lactation in Figure 1. Although some lactations continued for 51 wk, this figure stops at 40 wk because that was when some cows went off experiment. There were no week x treatment differences; therefore, any responses

TABLE 4. Yield and composition of milk from cows fed control and 5% dried whey product (DWP) concentrate rations.

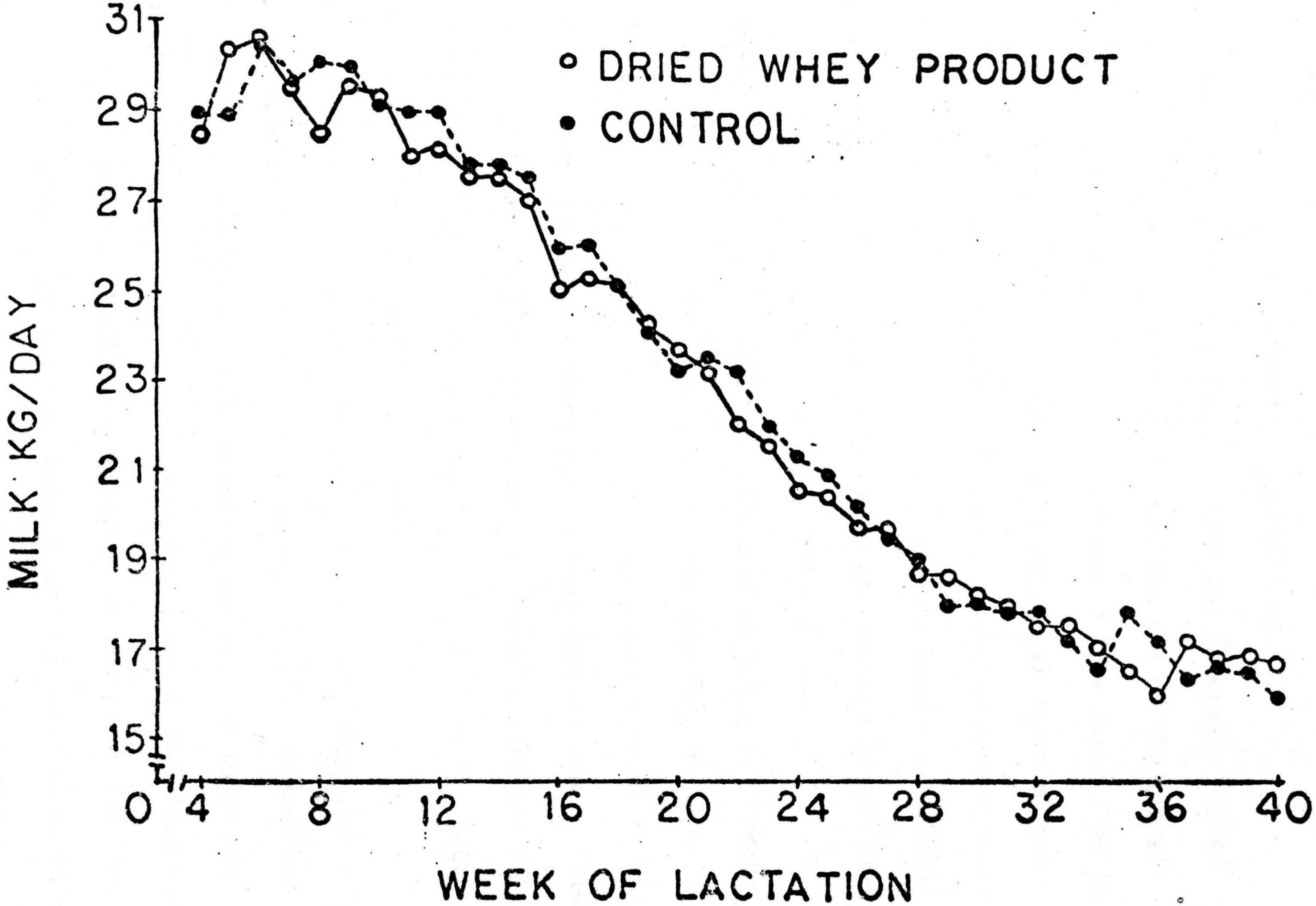
Item	Ration	
	Control	DWP
Milk yield, kg/day	21.3 (-6.73)[a]	21.3 (-7.08)
Fat-corrected milk, kg/day	19.6 (-6.57)	20.0 (-5.48*)
Solids-corrected milk, kg/day	19.3 (-5.98)	20.1** (-5.37)
Fat, %	3.58 (.04)	3.68 (.28*)
Protein, %	3.10 (.33)	3.27** (.25*)
Total solids, %	12.12 (.33)	12.50** (.46)
Solids-not-fat, %	8.54 (.29)	8.82** (.18**)
Fat, kg/day	.74 (-.26)	.76* (-.18**)
Protein, kg/day	.64 (-.13)	.69** (-.16**)
Total solids, kg/day	2.54 (-.76)	2.63* (-.74)
Solids-not-fat, kg/day	1.80 (-.51)	1.87* (-.57)

[a]Values within parenthesis indicate changes from pretreatment.

*Different from control, $P<.05$.

**Different from control, $P<.01$.

FIGURE 1. Daily milk production by week of lactation for cows fed control and dried whey product concentrate rations.


DRIED WHEY PRODUCT
CONTROL
MILK KG/DAY
31
29
27
25
23
21
19
17
15
0
4
8
12
16
20
24
28
32
36
40
WEEK OF LACTATION

to feeding DWP were consistent throughout the trial. Weekly differences between groups were generally within 1 kg.

The average fat percent for cows fed DWP was generally higher than that of control cows from wk 11 through the end of the experiment (Fig. 2) after being lower in wk 5 through 9 (the first 5 wk in which experimental rations were fed). This effect is again caused by low fat values of three DWP-fed cows which increased dramatically after being on experiment 4 wk. Treatment effects cannot be totally discounted; however, an explanation is difficult because of the lack of a similar response from the other seven DWP-fed cows.

Nitrogen distribution in milk is presented in Table 5. Casein nitrogen was higher ($P<.05$) in the milk of cows fed DWP; however, this is essentially nullified because DWP cows showed a trend toward a smaller increase from pretreatment values than control cows. This indicates that the cows fed DWP simply had more casein nitrogen in their milk at the onset of the experiment, and maintained the higher casein concentrations throughout their lactations.

Individual and total rumen VFA concentrations and molar percentages (i.e. moles per 100 moles of VFA) are in Table 6. Concentrations of acetate, propionate, isobutyrate, valerate, and total VFA were higher ($P<.05$) in cows fed DWP. However, these differences may have been due to generally low concentrations in the first sampling from the control cows which may have been caused by water consumption prior to sampling of rumen contents. In this instance, a more accurate measure of ruminal response to rations would be molar

FIGURE 2. Milk fat percent by week of lactation for cows fed control and dried whey product concentrate rations.

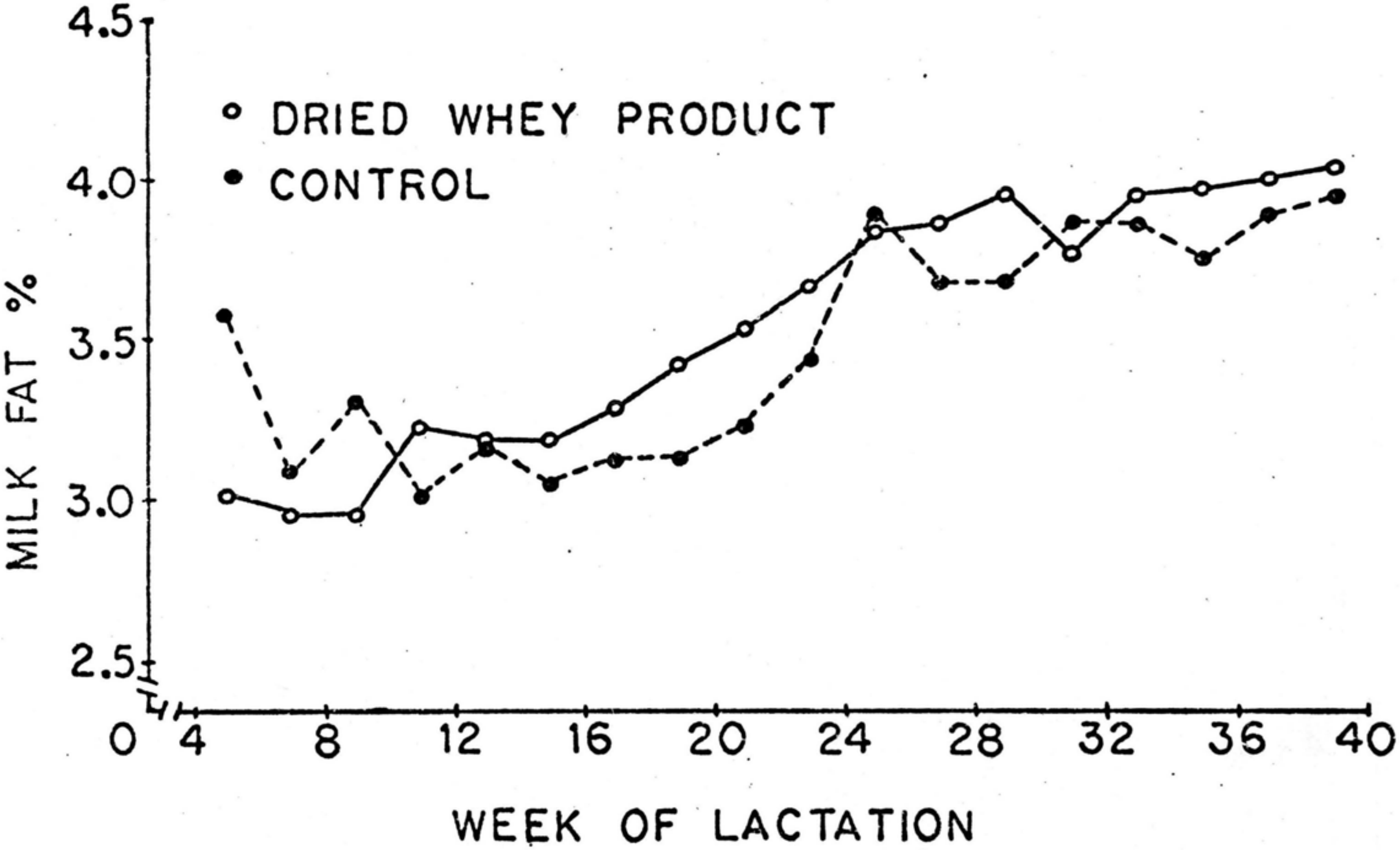

o DRIED WHEY PRODUCT
• CONTROL
MILK FAT %
4.5
4.0
3.5
3.0
2.5
0 4 8 12 16 20 24 28 32 36 40
WEEK OF LACTATION

TABLE 5. Nitrogen (N) distribution in milk from cows fed control and 5% dried whey product (DWP) concentrate rations.

Component	Ration	
	Control	DWP
	- - - - - - - - - - %	- - - - - - - - -
Protein N	.462 (.053)[a]	.478 (.034)
Casein N	.361 (.036)	.377* (.022)
Non-casein N	.132 (.020)	.131 (.014*)
Serum protein N	.101 (.016)	.101 (.012)
Non-protein N	.030 (.005)	.030 (.002**)

[a]Values within parenthesis indicate changes from pretreatment.

*Different from control, P<.05.

**Different from control, P<.01.

TABLE 6. Rumen volatile fatty acids (VFA) and pH in cows fed control and 5% dried whey product (DWP) concentrate rations.

VFA	Ration	
	Control	DWP
	- - - - (μm/ml) - - - - -	
Acetate	29.8	32.6*
Propionate	11.3	12.8*
Isobutyrate	.4	.5*
Butyrate	8.2	9.1
Isovalerate	.8	.8
Valerate	.8	.9*
Total	51.3	56.7*
Acetate/propionate	2.90	2.63**
	- - - -(mole %) - - - - -	
Acetate	59.2	58.0
Propionate	21.2	22.4*
Isobutyrate	1.0	1.0
Butyrate	15.4	15.7
Isovalerate	1.7	1.4*
Valerate	1.5	1.6
	- (pH of rumen fluid) -	
	7.02	6.92

*Different from control, P<.05.

**Different from control P<.01.

percentages. Cows fed DWP were higher ($P<.05$) in propionate and isovalerate. Previous work by Schingoethe et al. (44) showed lower concentrations of propionate ($P<.01$) in DWP-fed cows; however, no difference in molar percentages were noted. The ratio of acetate to propionate was lower ($P<.01$) for DWP-fed cows which disagrees with previous work (44). Previous trials involved with feeding whey or lactose have often noted higher butyrate (1, 9, 22, 23, 37, 46). The trend in this trial was toward higher butyrate although the trend was not significant ($P>.05$). No difference in ruminal pH was noted between groups.

Average daily dry matter intakes (DMI) and body weight changes are presented in Table 7. There were no significant differences in feed intake and weight gains between the two groups. This agreed with both trials conducted by Schingoethe et al. (44).

Trial 2

Actual milk yield was less ($P<.05$), while FCM and SCM simply showed a trend of less production for cows fed the 65% DWW concentrate mix (Table 8). Levels of milk, FCM, and SCM tended to decrease more from pretreatment levels for cows fed DWW than for control cows. This agreed with previous work by Bowman and Huber (9) with cows fed a 56% lactose concentrate mix. Percentages of fat, protein, solids-not-fat, and total solids tended to be higher in milk from cows fed DWW, which is the type of response usually observed when milk yields decrease. Nitrogen distribution in milk (Table 9) was not altered between groups other than lower non-protein nitrogen ($P<.05$) in milk

TABLE 7. Average dry matter intake (DMI) and body weights of cows fed control and 5% dried whey product (DWP) concentrate rations.[a]

Item	Control	DWP
Concentrate (kg/day)	6.5	6.5
Hay (kg/day)	7.0	6.8
Silage (kg/day)	6.7	6.6
Total DMI (kg/day)	20.2	19.9
Body wt (kg)	670.3	664.6
DMI (kg/100 kg body wt)	3.0	3.0
Body wt gain (kg/day)	.46	.33

[a]Based on group feed intake.

TABLE 8. Yield and composition of milk from cows fed control and 65% dried whole whey (DWW) concentrate rations.

Item	Ration: Control	Ration: DWW	SE
Milk yield, kg/day	25.3 (-2.25)[a]	22.1* (-3.73)	.94 (.58)
Fat-corrected milk, kg/day	23.1 (-2.92)	21.2 (-2.98)	.78 (.77)
Solids-corrected milk, kg/day	23.2 (-2.22)	21.3 (-2.44)	.79 (.64)
Fat, %	3.46 (-.18)	3.77 (.13)	.10 (.17)
Protein, %	2.97 (.19)	3.10 (.29*)	.07 (.03)
Total solids, %	12.15 (.12)	12.61* (.52)	.13 (.18)
Solids-not-fat, %	8.68 (.30)	8.84 (.39)	.05 (.03)
Fat, kg/day	.87 (-.14)	.82 (-.10)	.03 (.44)
Protein, kg/day	.75 (-.01)	.68 (-.04)	.03 (.02)
Total solids, kg/day	3.06 (-.25)	2.77 (-.33)	.11 (.07)
Solids-not-fat, kg/day	2.20 (-.11)	1.95 (-.23)	.08 (.04)

[a]Values within parenthesis indicate changes from pretreatment.

*Different from control, $P<.05$.

TABLE 9. Nitrogen (N) distribution in milk from cows fed control and 65% dried whole whey (DWW) concentrate rations.

Component	Ration		SE
	Control	DWW	
	- - - - - % - - - -		
Protein N	.443 (.032)[a]	.459 (.044)	.009 (.005)
Casein N	.364 (.033)	.375 (.038)	.008 (.006)
Non-casein N	.106 (.0002)	.109 (.005)	.004 (.002)
Serum protein N	.079 (-.001)	.084 (.005)	.003 (.002)
Non-protein N	.027 (.001)	.025* (-.0003)	.0006 (.0009)

[a]Values within parenthesis indicate changes from pretreatment.

*Different from control, $P<.05$.

from cows fed the DWW ration.

Rumen VFA concentrations are in Table 10. Cows fed DWW had significantly lower (P<.01) molar percentages of acetate, propionate, and isobutyrate along with higher (P<.01) molar percentages of butyrate and valerate. This agreed with earlier work (9) that found decreased acetate (P<.05) and increased butyrate (P<.01) when cows were fed large amounts of lactose. Previously gathered evidence (39) suggests that acetate was the primary end-product of lactate metabolism. If this be the case, higher acetate values would have been expected. However, Satter and Esdale (39) found that oxidation of lactate to pyruvate dictated the synthesis of butyrate from acetate to maintain an oxidation-reduction balance. Consequently, butyrate is the ultimate end-product of lactate metabolism. They (39) noted that formation of acetate and buyrate are pH dependent. Formation of acetate increases at pH 7.4 while butyrate increases at pH 6.2. Ruminal microorganisms possibly synthesize butyrate from acetate when threatened by high acidity, thereby decreasing acidity by 50% by turning two acidic molecules into one. The higher butyrate values in this trial agree with Satter and Esdale (39) and also with previous studies in which liquid whey, dried whey, or lactose were fed to ruminants (1, 9, 22, 23, 37, 46).

Average daily DMI and body weight changes are presented in Table 11. There was no difference in feed intake between the two groups. There was also no difference in body weight gains between groups. Huber et al. (9) observed that cows fed a 56% lactose

TABLE 10. Rumen volatile fatty acids (VFA) and pH in cows fed control and 65% dried whole whey (DWW) concentrate rations.

VFA	Ration: Control	Ration: DWW	SE
	- - - ($\mu m/ml$) - - - -		
Acetate	38.0	36.4	1.30
Propionate	16.3	15.1	.78
Isobutyrate	.6	.5	.03
Butyrate	12.1	19.8**	.89
Isovalerate	1.8	1.7	.10
Valerate	1.3	2.6**	.13
Total	70.1	76.0	2.74
Acetate/propionate	2.43	2.47	.08
	- - -(mole %) - - - -		
Acetate	54.4	48.2**	.62
Propionate	23.2	19.7**	.69
Isobutyrate	.8	.7**	.04
Butyrate	17.2	25.8**	.61
Isovalerate	2.5	2.2	.10
Valerate	1.8	3.3**	.12
	- (pH of rumen fluid) -		
	6.56	6.59	.05

**Different from control, P<.01.

TABLE 11. Average dry matter intakes (DMI) and body weights of cows fed control and 65% dried whole whey (DWW) concentrate rations.[a]

Item	Control	DWW
Concentrate (kg/day)	7.7	7.1
Hay (kg/day)	3.6	3.6
Silage (kg/day)	9.4	9.5
Total DMI (kg/day)	20.7	20.2
Body wt (kg)	610.1	604.2
DMI (kg/100 kg body wt)	3.4	3.3
Body wt change (kg/day)	.24	.24

[a]Based on group feed intake.

concentrate mix lost weight.

Some problems were encountered with feeding the 65% DWW concentrate mix. The concentrate was extremely powdery and dusty which made conditions during grinding undesirable. Caking could be a problem if a mixture of this type was put in a gravity flow bin. The DWW concentrate mix was not consumed as readily as the control concentrate mix. Since this trial was conducted during summer months, flies were present in large numbers around the DWW concentrate mix. Fly problems have been previously reported when feeding liquid whey (2), but the problem had not been reported previously when feeding dried whey.

Dried whole whey and lactose comprised 22.9 and 16.3%, respectively, of the total DMI of the cows fed DWW, comparable to amounts fed in previous studies (9, 23). Cows in this study consumed 4.6 and 3.3 kg/cow/day of DWW and lactose, respectively. The percentage of lactose in the ruminant diet which will cause rumen bypass of lactose, is not known and may vary with total dry matter intake. It is not known if lactose, which enters the small intestine, will be digested, or if not digested, cause diarrhea due to its osmotic properties. The possibility of induced intestinal lactase activity to digest excess lactose has been considered (41). However, research by Schingoethe et al. (43) indicated that dry matter content of feces from steers was slightly reduced when fed rations containing 30% or more lactose as lactose or dried whey. Grab feces samples from cows used in this trial indicated dry matter percentages of 17.1 for control cows and 13.6 for cows fed the 65% DWW concentrate mix. The lower percentage for the DWW-fed cows was significant ($P<.01$). Lactose intakes by cows in this trial were essentially the same as steers fed 30% or more lactose (43) when values were expressed as lactose intake per unit of metabolic size (i.e., body weight$^{.75}$).

Summary

Although these two trials were different in terms of amount of dried whey fed, they both were an attempt to find a needed outlet for a valuable by-product which is presently being wasted. Trial 1 dealt with the possible therapeutic effect that a small amount of dried whey (1.6% of total DMI) could have on milk production and composition. Trial 1 indicated no adverse effect and if anything a possible increase in milk fat percent for whey-fed cows. Positive responses such as increased weight gains, feed efficiency, mineral absorption and retention, protein and fat digestibility, and nitrogen retention have been previously noted for nonruminants and steers fed small amounts of dried whey (41).

Trial 2 gave information about lactational response of cows fed high levels of dried whey (22.9% of total DMI) in order to help determine how much dried whey could be fed when the price is right. While decreased milk production by the dried whey group was not statistically significant, under practical conditions, this level of dried whey in the ration is not recommendable. A decrease of 3 kg milk/day/cow will add up to a large financial loss to the dairy farmer at today's milk prices. Coupling this with potential problems of feed handling, diarrhea, and fly control during summer months makes feeding this high amount of dried whey undesirable. Possibly levels in the range of 10 to 15% dried whey of the total ration would be more feasible.

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APPENDIX

APPENDIX TABLE 1. Least-squares analysis of variance for milk yield data in trial 1.

		(kg/day)						
Source	Degrees of freedom	Milk	FCM	SCM	Fat	Prot.	TS	SNF
		mean squares						
Total	746							
Week	47	409.13	190.38	184.45	.148	.190	3.88	2.53
Treatment	1	.16	22.10	82.19	.091	.294	1.27	.68
Week x treatment	47	2.27	4.04	2.96	.012	.002	.038	.015
Remainder	650	17.13	12.95	12.28	.022	.012	.212	.116

APPENDIX TABLE 2. Least-squares analysis of variance for changes from pretreatment of milk yield data in trial 1.

		(kg/day)						
Source	Degrees of freedom	Milk	FCM	SCM	Fat	Prot.	TS	SNF
		mean squares						
Total	750							
Week	51	358.75	174.11	169.41	.15	.167	3.50	2.26
Treatment	1	18.57	174.40	54.37	.96	.127	.08	.52
Week x treatment	47	4.90	6.08	4.46	.014	.003	.06	.03
Remainder	650	28.79	27.35	23.40	.069	.019	.36	.19

APPENDIX TABLE 3. Least-squares analysis of variance of milk composition data in trial 1.

Source	Degrees of freedom	Fat	Prot.	TS	SNF
		- - - - - - - - % - - - - - - - - -			
		- - - - - mean squares - - - - -			
Total	371				
Week	45	1.29	.44	2.78	.33
Treatment	1	.67	1.86	9.50	5.14
Week x treatment	45	.14	.03	.23	.04
Remainder	279	.27	.08	.63	.15

APPENDIX TABLE 4. Least-squares analysis of variance for changes from pretreatment of milk composition data in trial 1.

Source	Degrees of freedom	Fat	Prot.	TS	SNF
		- - - - - - - - - % - - - - - - -			
		- - - - - mean squares - - - - -			
Total	373				
Week	47	1.11	.40	2.26	.24
Treatment	1	3.69	.42	1.10	.81
Week x treatment	45	.16	.05	.28	.06
Remainder	279	.83	.09	1.11	.09

APPENDIX TABLE 5. Least-squares analysis of variance for milk nitrogen data in trial 1.

Source	Degrees of freedom	NPN	NCN	Casein N	Serum Prot. N	Prot. N
		- - - - - - % - - - - - -				
		- - - - - - mean squares - - - - - -				
Total	182					
Week	41	.000075	.00076	.0039	.00064	.0065
Treatment	1	.000000	.00001	.0072	.00001	.0068
Week x treatment	31	.000007	.00009	.0008	.00008	.0012
Remainder	108	.000017	.00025	.0015	.00022	.0019

APPENDIX TABLE 6. Least-squares analysis of variance for changes from pretreatment of milk nitrogen data in trial 1.

		%				
Source	Degrees of freedom	NPN	NCN	Casein N	Serum Prot. N	Prot. N
		mean squares				
Total	161					
Week	41	.00007	.0006	.0032	.0004	.0056
Treatment	1	.00020	.0010	.0051	.0003	.0094
Week x treatment	35	.00001	.0001	.0007	.0001	.0012
Remainder	83	.00002	.0002	.0016	.0002	.0024

APPENDIX TABLE 7. Least-squares analysis of variance for rumen volatile fatty acid data expressed as micromoles per milliliter (µm/ml) in trial 1.

		µm/ml							
Source	Degrees of freedom	C2	C3	IC4	C4	IC5	C5	Total	C2/C3
		mean squares							
Total	54								
Treatment	1	103.47	30.11	.117	9.92	.00006	.196	384.21	1.006
Time	2	282.63	185.62	.117	157.22	.225	1.348	1826.80	5.529
Treatment x time	2	62.87	36.31	.013	7.11	.009	.108	272.24	1.861
Remainder	48	21.85	5.67	.020	5.14	.076	.041	82.74	.114

APPENDIX TABLE 8. Least-squares analysis of variance for rumen volatile fatty acid data expressed as molar percentages (mole %) in trial 1.

			mole %					
Source	Degrees of freedom	pH	C2	C3	IC4	C4	IC5	C5
		mean squares						
Total	54							
Treatment	1	.116	18.49	17.58	.0006	.71	.97	.055
Time	2	.205	313.12	95.84	2.6241	136.50	5.23	1.172
Treatment x time	2	.207	51.22	43.38	.5334	4.54	.91	.025
Remainder	48	.042	6.81	4.13	.0708	3.76	.17	.052