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Biomass Energy Production Co-Products

Dairy Feeding Trials

MINNESOTA AGRIPOWER PROJECT
TASK I RESEARCH REPORT

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EVALUATION OF ALFALFA LEAF MEAL FOR DAIRY COWS

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1. SUMMARY

A series of laboratory tests and two feeding experiments were conducted to determine the quality and evaluate the feeding value of alfalfa leaf meal (ALM) for dairy cows. An experiment was also conducted to enhance the protein value of ALM for ruminants.

The fiber content of 6 different samples obtained from the processing plant from November 1996 to August 1997 were variable, ranging from 28.8 to 44.5% of DM for NDF, and from 16.0 to 28.6% of DM for ADF. Ash content ranged from 10.1 to 13.8% of the DM. The protein content of ALM was fairly constant and ranged from 21.8 to 23.6% of DM. Amino acids comprise at least 70% of the total CP in ALM, but essential amino acids comprise only about 35% of the total CP. The amino acid profile of ALM is similar to that of alfalfa hay, but markedly different from that of soybean meal. Overall, ALM produced to date is similar in nutrient content to prime alfalfa hay.

In one of the feeding trials, ALM pellets were used to replace part of the hay in diets for early lactation cows. The results indicate that ALM pellets can make up as much as 16% of the diet DM in replacement of an equivalent amount of high quality chopped alfalfa hay without adverse effects on production or rumen health. In an other study, ALM replaced soybean meal to supply up to 33% of the total CP in the diet without any detrimental effect on production. However, in each study, dry matter intake was reduced when ALM was included in the diet at or above 15 to 16% of the DM. Although this reduction in feed intake did not influence milk production over the short duration of these studies, it is not known what would happen if ALM was fed over long periods of time. Also, these results should not be interpreted to suggest either that ALM may used to replace all the hay in the diets or that ALM in meal form may be used to replace hay in the diets. Moreover, feed consumption by cows used in these experiments was

rather high and somewhat atypical of most cows. It would be difficult to predict what would happen with cows consuming lesser amounts of feed.

Based on cow performance in these studies and using current prices of \$ 130/ton for hay (160RFV), \$ 300/ton for soybean meal, and \$ 2.75/bu for corn, it was estimated that ALM may be worth a maximum of about \$ 163/ton if used to replace hay, or \$ 186/ton if used to replace soybean meal. If the price of hay was \$ 100/ton, then ALM would be worth up to \$ 130/ton as a hay replacement. At prices of \$ 200/ton for soybean meal and \$ 2.30/bu for corn, ALM could be worth up to \$ 145/ton as a soybean meal replacement.

Finally, heating ALM at 160° C for 120 minutes increased the content of bypass protein from 24.1% to 44.2% of CP without compromising protein availability to the animal. However, this treatment may not be practical and further research is needed to find ways to achieve better results in less time. More research is also necessary to find other ways to improve the efficiency with which ALM protein is utilized in the rumen.

2. FEEDING TRIALS (Tasks Ia, Id, and Ie)

2.1. Introduction

Alfalfa leaf meal (**ALM**) may be considered a moderate source of protein in animal diets. Laboratory tests have shown ALM may contain up to 30% crude protein (**CP**) in the dry matter (**DM**). However, the protein value of ALM in dairy diets is not known. If the amino acid composition of ALM is similar to that of alfalfa hay or dehydrated alfalfa, the quality of ALM protein would be lower than that of soybean meal protein. Soybean meal (**SBM**) is often used as a standard to evaluate the quality of other protein supplements. Compared with SBM protein, protein from alfalfa contains less of several essential amino acids, including lysine and methionine. An experiment was designed to determine the protein value of ALM in diets for lactating cows.

Although ALM is often looked at as a protein supplement, low protein (< 25% CP) high fiber leaf meal products might be used to replace some of the forage in ruminant diets. The advantage of replacing alfalfa hay with ALM might be the assurance of consistency in the quality of the product. But because the particle size of ALM is inherently fine in comparison with long or chopped hay, it is not known what effect replacing hay with ALM would have on rumen function and, thus, on milk yield and composition. Another study was conducted to evaluate ALM as a partial replacement for high quality chopped alfalfa hay.

2.2. Evaluation of Alfalfa Leaf Meal Pellets as Hay Replacement in Dairy Diets

Objectives. The objective of this experiment was to study the effect of partial substitution of good quality chopped alfalfa hay with ALM pellets of similar composition on milk yield, milk composition, and rumen function.

Materials and methods. Eighteen multiparous cows were used in a replicated 3 x 3 Latin square design. Cows were divided into 6 groups of 3 so that cows in each group would have similar days in milk, milk yields, and body weights. At the initiation of the trial, cows averaged 36 (ranging from 6 to 59) days in milk, 77 lb of milk/d, 1320 lb of body weight, and a body condition score of 2.5. Within group, cows were randomly assigned to one of 3 treatments.

Treatments consisted of diets in which ALM partially replaced chopped alfalfa hay. Alfalfa leaf meal used in this study was in the form of pellets and contained 23.6% CP, 44.5% neutral detergent fiber (**NDF**), 28.6% acid detergent fiber (**ADF**), and 13.8% ash in the DM (Table 1). Alfalfa hay contained 22.0% CP, 43.9% NDF, and 26.5% ADF in the DM and had a relative feed value of 160, which corresponds to prime quality hay. Treatment diets contained 0, 8 or 16% ALM pellets in the DM. Overall, diets composition (DM basis) was 26% from alfalfa hay plus ALM, 26% from corn silage, and 48% from a grain mixture (Table 2). Water was added to the diets (about 12% of the diet as fed) prior to feeding in an attempt to soften the pellets. Diets were fed as total mixed rations. Cows were fed twice a day ad libitum (i.e, allowed to eat all they could eat) and were milked twice a day.

The study consisted of 3 experimental periods. Periods 1 and 2 were 21 days long (14 days for adaptation to dietary treatments and 7 days for data collection), whereas period 3 was 16 days long (11 days for adaptation and 5 days for data collection).

Feed ingredients were sampled once a week, and composite samples were analyzed for nutrient composition. Measurements were taken for feed intakes, DM and fiber digestibility, and on yield and composition of milk.

Also, in an attempt to assess the impact of feeding ALM pellets on rumen function, eating and chewing activities of cows were monitored for 24 h at the end of each period. Additionally, 2 cows fitted with rumen cannulae were used to examine trends in changes of rumen function parameters due to dietary treatments. The cannulated cows successively received the control diet, the diet containing 8% ALM, and the diet containing 16% ALM. Each diet was fed for a period of 11 days (10 days for adaptation and 1 day for sample collection) and the 2 cows were fed the same diet during each period. Samples of rumen fluid were taken at 0 h (right before feeding), and at 1, 2, 3, 4, 5, 6, and 8 h after feeding. Samples were analyzed for indicators of rumen fermentation (pH and volatile fatty acids (VFA)).

Results and discussion. Chemical composition of the diets was similar across treatments (Table 2). However, ADF contents tended to be lower than commonly recommended.

During preliminary attempts of feeding ALM, diets were formulated so that cows were being fed 2, 6, or 14 lb of ALM/d. However, after 10 days of feeding the diets, it became evident that cows fed 14 lb of ALM/d would not consume this amount of pellets. Pellets were sorted out and feed intake was reduced. At 6 lb of ALM or less per day, cows readily consumed their diets. Based on these observations, diets in this study were reformulated so cows would be fed 0, 4, or 8 lb of ALM pellets daily. Consequently, diets contained 0, 8 or 16% ALM in the DM.

Table 3 summarizes nutrients intakes and digestibility. Dry matter intakes of cows in this study were relatively high, averaging 61.5, 64.5, 58.8 lb/d for cows fed diets containing 0, 8, and 16% ALM pellets in the DM, respectively. Consumption of ALM pellets averaged about 5.3 and 9.8 lb daily for cows fed diets containing 8 or 16% ALM pellets in the DM, respectively. It appeared that at these rates of pellet feeding, sorting was greatly reduced compared to preliminary observations when cows were fed 14 lb of ALM/d, although some individual cows were still sorting the pellets out.

The dry matter intakes of cows fed a diet containing ALM pellets at 8% of the DM were similar to those of cows fed no ALM pellets. However, when cows were fed ALM pellets at 16% of the DM, dry matter intakes tended to decrease (2.7 lb less/cow/day) compared with cows fed no ALM pellets, and was significantly reduced (5.7 lb less/cow/day) compared with cows fed ALM pellets at 8%. Because diets had similar compositions, differences in dry matter intake were also reflected in CP, NDF, and ADF intakes.

Digestibility of diet DM and fiber was not significantly affected by treatment (Table 3), suggesting that partial substitution of ALM pellets for hay did not affect rumen fermentation. Based on laboratory tests, ALM DM and CP are rapidly and extensively digested in the rumen (Figure 1*)*.

Feeding ALM pellets at 0, 8, or 16% of diet DM in partial replacement of good quality hay had no effect on milk yield or milk composition (Table 4).

Because animal performance was similar across treatments despite the tendency of lower feed consumption for cows fed 16% ALM pellets, one may be tempted to conclude that cows fed this diet were more efficient at converting feed into milk and milk components. However, to reach such a conclusion, we would have to look also at changes in body weights and condition scores of cows used in this study before making any definite statement. Cows often draw on their body reserves to maintain milk production when the diet does not meet the nutrient requirements. If such conditions last long enough, cows will loose body weight and condition. The body reserves would have to be replenished before the cow starts a new lactation cycle, or milk yield would be compromised. In this study, data were collected over short periods of time and changes in body weights or body condition would be difficult to interpret. It is not known what the results would be if cows were fed these diets over a longer period of time. Therefore, the results of this study are to be interpreted with caution.

Replacing alfalfa hay with ALM pellets did not affect the time cows spent eating (Table 5). However, the time cows spent ruminating (chewing the cud) decreased as the amount of ALM pellets in the diet increased. Conversely, the time spent resting (not eating or chewing the cud) increased as the proportion of ALM pellets in the diet increased. This observation could be interpreted to suggest that ALM pellets might not be equivalent to chopped alfalfa hay when it comes to stimulating rumination. If this were true, replacing hay with ALM pellets may lead to less saliva secretion, which may negatively impact rumen buffering, possibly resulting in lower rumen pH. When rumen pH is lowered below 6, fiber digestion is reduced, which may translate into lower milk fat percentage. However, in this experiment, DM and fiber digestion were not affected by treatment (Table 3) and there was no evidence that fat test was different across treatments (Table 4). In addition, pH measurements indicated that regardless of the diet fed, rumen pH did not drop below 6 (figure 2) and stayed within the range of values where fiber digestion is not greatly compromised. Also, total VFA production (figure 3) or the ratio between milk fat precursors (acetate and butyrate) and glucose precursors (propionate) (figure 4) did not appear to decrease when the cannulated cows were fed the diets containing ALM. These observations further demonstrate that replacing alfalfa hay with ALM pellets did not appear to have any adverse effects on rumen fermentation. It should be noted, however, that pH values are averages of measurements taken on 2 cows only, that milk fat test and rumen pH were not measured on the same cows, and that pH was not measured concurrently for the three diets. First, measurements were made when the 2 cows were fed the 0% ALM diet; then cows were switched to the 8% ALM diet and pH measurements for this diet made 10 days later. Finally, the 2 cows were switched to the 16% ALM diet, and pH measurements for this diet made 10 days later. Also, rumen pH and VFA production 8 hours after feeding were not determined when the cannulated cows were fed the control diet due to technical difficulties.

Implications. The results of this study suggest ALM pellets can be included in the diets of dairy cows up to 16% of the DM to replace an equivalent amount of high quality alfalfa hay without compromising production or rumen health. However, these results should not be interpreted to suggest ALM could totally replace all hay in the diets, or that ALM in meal form may be used in place of pellets to replace hay; this experiment was not designed to address these questions. Also, it is not known what would happen if cows were fed these diets over a longer period of time.

Table 1. Composition of alfalfa leaf meal used in dairy feeding studies

Item	Study 1 (hay replacement study)	Study 2 (protein value study)
Dry matter (DM), %	94.91	92.99
Neutral detergent fiber (NDF), % of DM	44.53	39.45
Acid detergent fiber (ADF), % of DM	28.59	21.45
Crude protein (CP), % of DM	23.61	22.40
Rumen degradable protein (RDP), % of CP	72.00	75.90
Total amino acids[1], % of CP	65.63	73.76
Essential amino acids[2], % of CP	31.11	36.07
Ash, % of DM	13.78	10.53
Calcium, % of DM	2.47	1.69
Phosphorus, % of DM	0.34	0.27
Potassium, % of DM	2.21	2.35
Sodium, % of DM	0.05	0.13
Magnesium, % of DM	0.40	0.33
Manganese, ppm	89.69	45.18
Iron, ppm	667.05	329.01
Zinc, ppm	31.42	24.61
Copper, ppm	10.24	12.58

[1] Does not include cysteine, methionine, and tryptophane.
[2] Does not include methionine and tryptophane.

Table 2. Composition of experimental diets (study 1).

Item	Alfalfa leaf meal, % of diet DM		
	0	8	16
Ingredient composition		% of diet DM	
	25.8	26.0	26.0
Alfalfa hay, chopped	25.9	18.5	11.2
ALM pellets	...	7.9	15.8
Grain mix[1]	48.3	47.6	47.0
Chemical composition			
Crude protein	18.8	18.7	18.6
Neutral detergent fiber	31.2	31.4	31.7
Acid detergent fiber	16.8	17.1	17.4
Fat	3.4	3.4	3.5
Nonfiber carbohydrates	37.4	37.0	36.5

[1] Contained (as is) 59.04% cracked corn, 13.00% distillers dried grains, 8.04 wheat midds, 5.30% soybean meal, 4.00% molasses, 2.68% animal fat, 1.34% limestone, 1.32% salt, 1.07% urea, 1.01% trace minerals and vitamins mix, 1.01% sodium bicarbonate, 0.67% dicalcium phosphate, 0.67% dynamate, 0.65% monosodium phosphate, and 0.20% magnesium oxide.

Table 3. Effect of feeding alfalfa leaf meal (ALM) on nutrient intakes and on dry matter and fiber digestibility.

	Alfalfa leaf meal, % of diet DM				
Item	0	8	16	SE	*P*
Dry matter, lb/d	61.5[ab]	64.5[a]	58.8[b]	1.33	0.04
CP, lb/d	11.6[ab]	12.1[a]	11.0[b]	0.24	0.04
NDF, lb/d	19.2	20.3	18.7	0.42	0.08
ADF, lb/d	10.4	11.0	10.3	0.22	0.09
DM digestibility, %	66.4	65.8	65.0	0.95	0.57
NDF digestibility, %	51.0	52.3	52.7	1.52	0.72
ADF digestibility, %	50.7	52.3	53.3	1.48	0.45

[a, b] Means in the same rows without common superscripts differ at $P \leq 0.05$.

Table 4. Yield and composition of milk from cows fed alfalfa leaf meal in partial replacement of alfalfa hay.

	Alfalfa leaf meal, % of diet DM				
Item	0	8	16	SE	*P*
Milk, lb/d	85.5	87.6	87.1	1.45	0.56
Fat, %	3.69	3.49	3.64	0.08	0.34
Protein, %	3.10	3.03	3.07	0.03	0.47
Lactose, %	4.77	4.72	4.75	0.06	0.78
Fat, lb/d	3.12	3.07	3.16	0.07	0.68
Protein, lb/d	2.63	2.67	2.65	0.05	0.88
Lactose, lb/d	4.07	4.17	4.12	0.09	0.90
Milk urea nitrogen, mg/100 ml of milk	15.8	16.9	16.11	0.40	0.23

Table 5. Eating and chewing activities of cows fed diets containing alfalfa leaf meal pellets partially replacing chopped alfalfa hay.

	Alfalfa leaf meal, % of diet DM				
Item	0	8	16	SE	*P*
Time spent eating, min.	208	213	203	5.5	0.49
Time spent chewing, min.	448[a]	425[a]	381[b]	9.0	< 0.01
Time spent resting, min.	646[b]	659[b]	719[a]	9.0	< 0.01

[a, b] Means in the same row without common superscripts differ at $P \leq 0.05$.

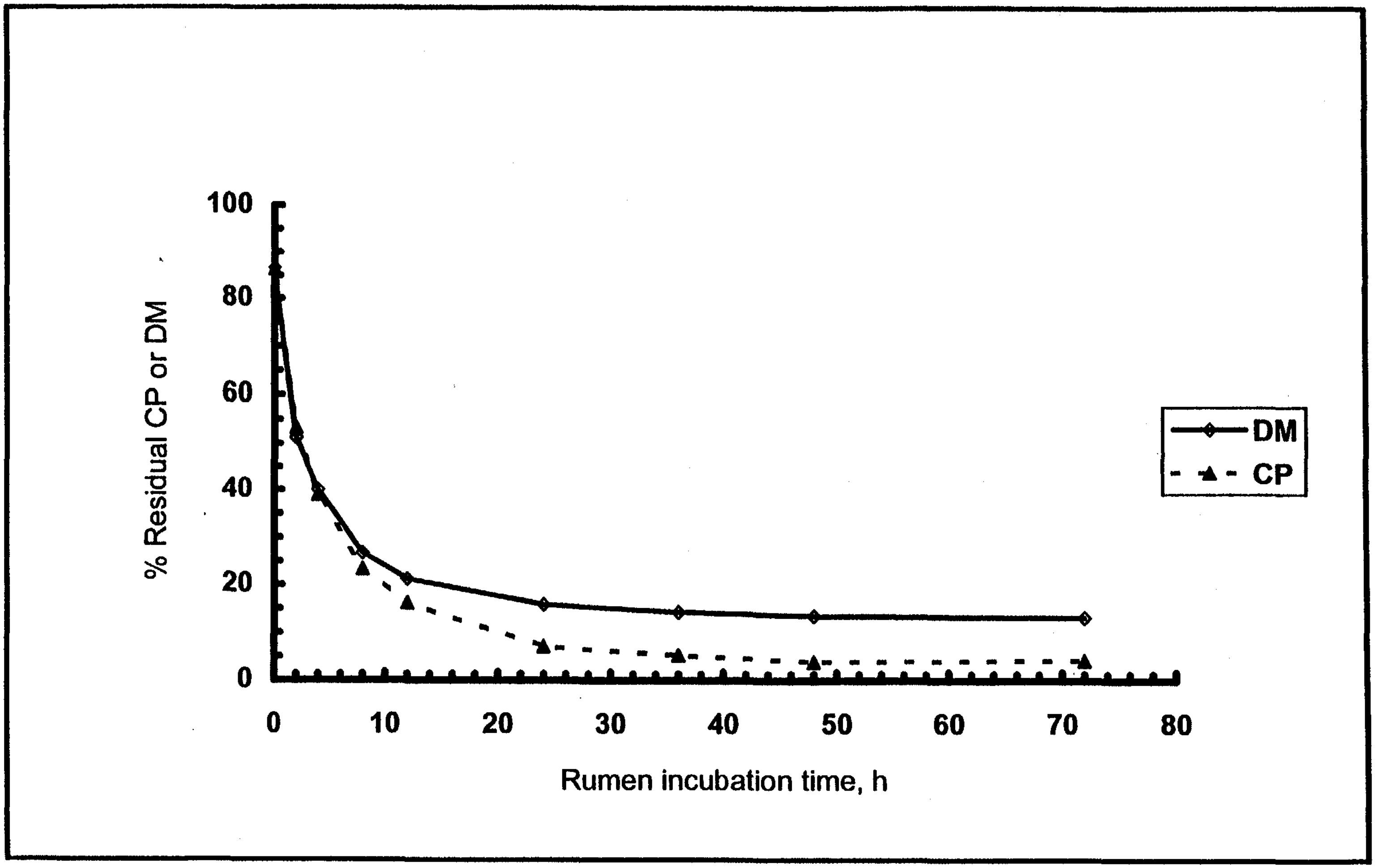

Figure 1. Alfalfa leaf meal dry matter and crude protein disappearance in the rumen.

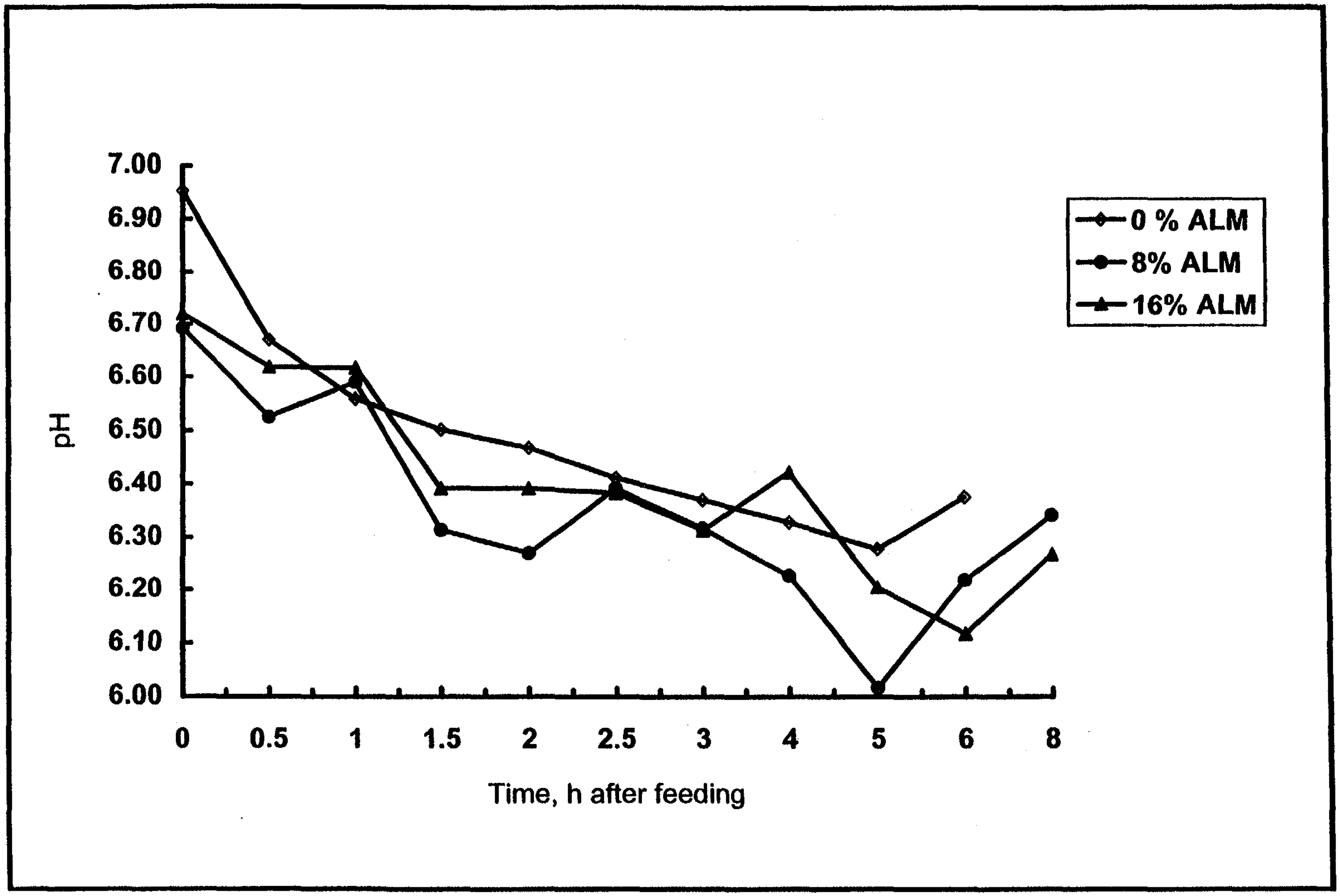

Figure 2. Effect of partially replacing alfalfa hay with ALM pellets on rumen pH.

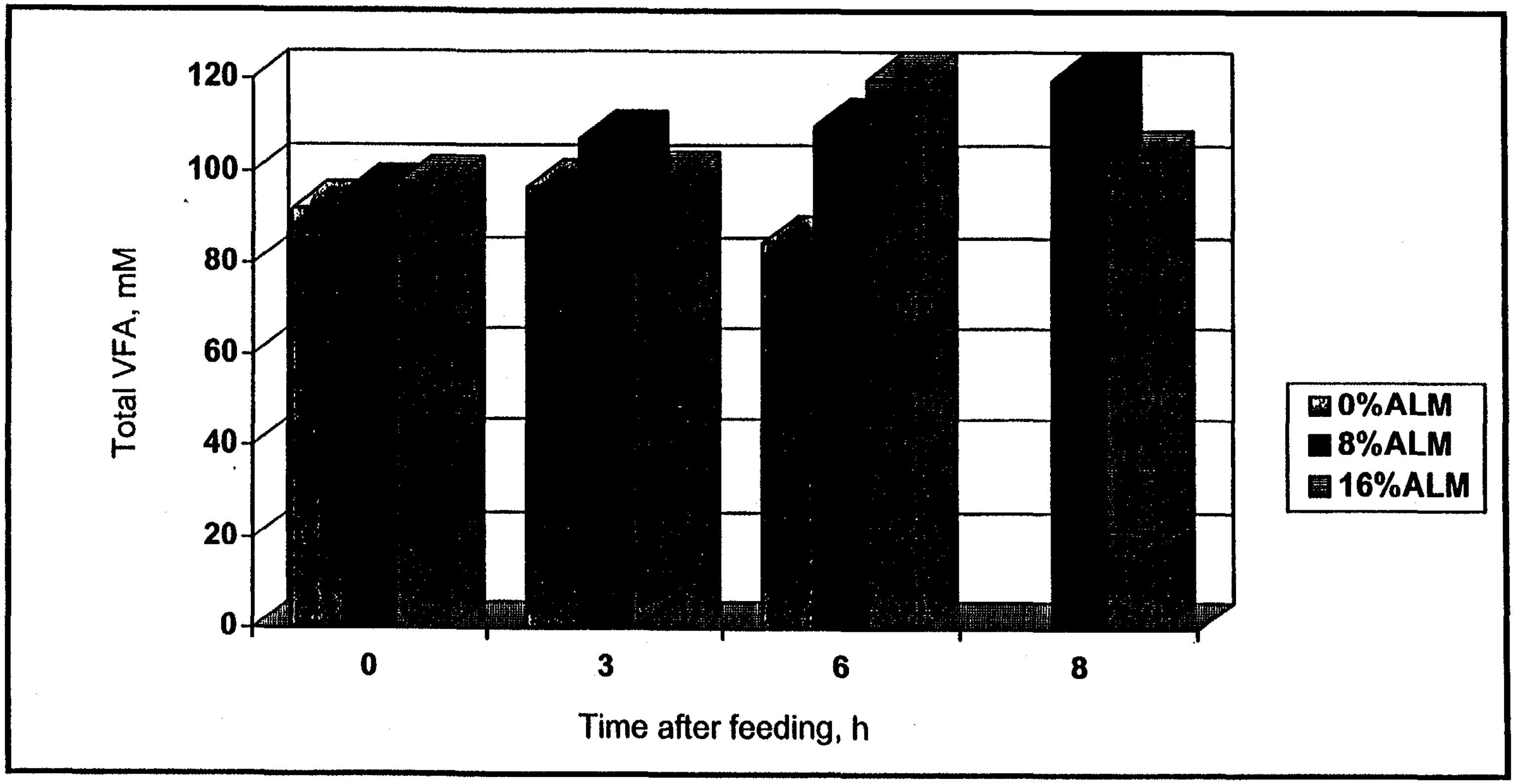

Figure 3. Effect of partially replacing alfalfa hay with ALM pellets on production of volatile fatty acids in the rumen.

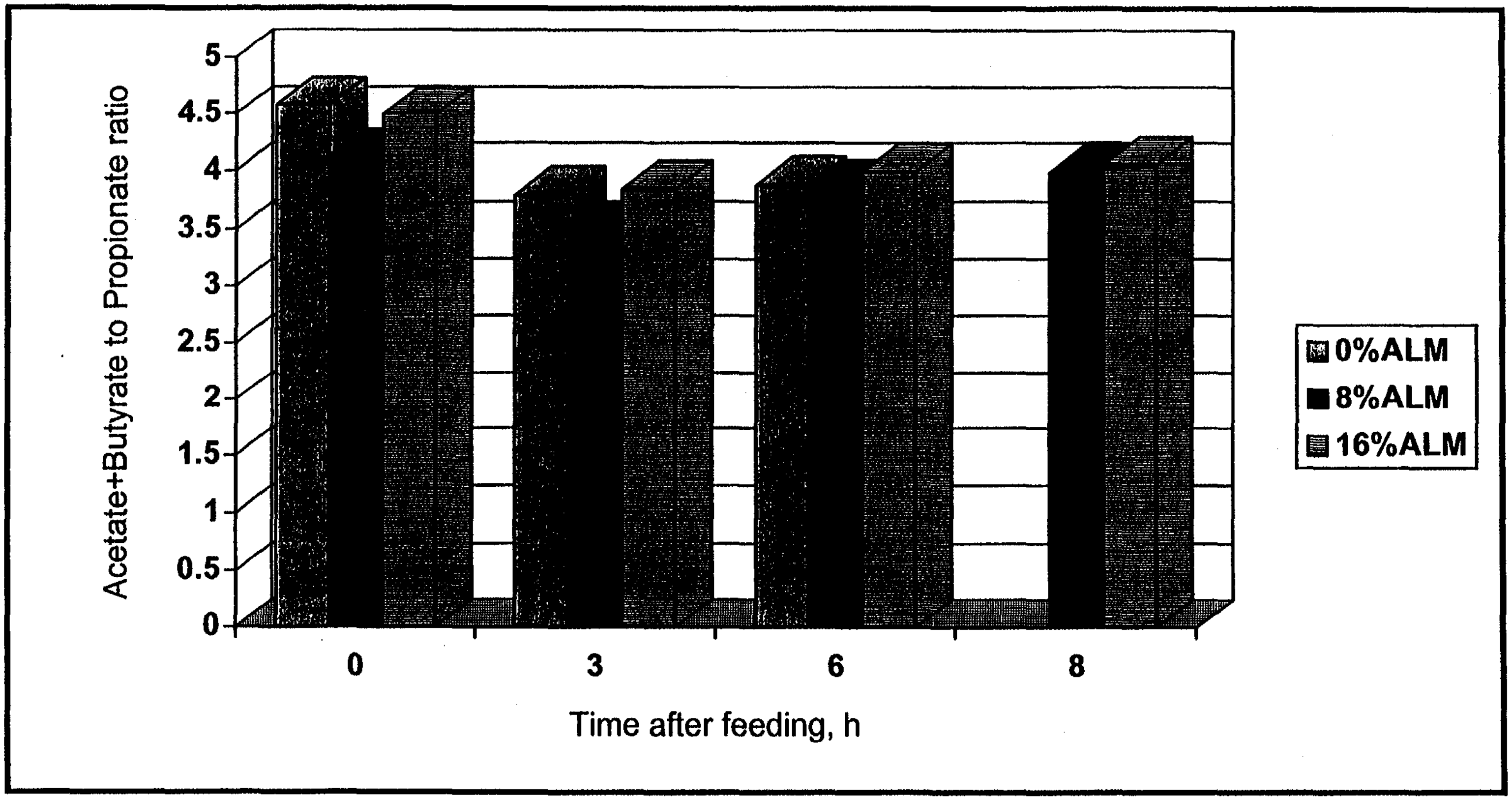

Figure 4. Effect of partially replacing alfalfa hay with ALM pellets on the ratio of acetate plus butyrate to propionate.

2.3. Evaluation of the Protein Value of Alfalfa Leaf Meal for Dairy Cows.

Objective. The objective of this study was to evaluate ALM as a replacement for SBM in dairy diets.

Experimental Design and Methodology. Twenty multiparous Holstein cows were divided into 5 groups of 4 cows with similar days in milk, milk yields, and body weights. At the initiation of the study, cows averaged 124 days in milk (ranging from 6 to 213), 83.8 lb of milk daily, and 1395 lb of body weight. Within groups, cows were randomly assigned to one of four treatments.

Treatments consisted of a control diet containing no ALM in which SBM was the main source of supplemental protein, and three test diets in which ALM gradually replaced SBM and supplied 11, 22, or 33% of the total dietary CP. In the diet containing no ALM, soybean meal supplied about 24% of the total CP in the diet. This contribution decreased to 17, 9, and 0% as the contribution of ALM increased in the test diets. The ALM used in this study was in meal form and contained 22.4% CP, 39.5% NDF, 21.5% ADF, and 10.5% ash, DM basis (Table 1). The composition of the experimental diets is shown in Table 6. Alfalfa leaf meal was included in the diet as part of grain mixtures, the composition of which is given in Table 7. Diets were fed as total mixed rations. Cows were fed twice a day ad libitum (i.e, allowed to eat all they could eat) and milked twice daily.

The experiment consisted of four periods of 21 days each (14 days for adaptation to treatment, followed by 7 days for data collection). Feed ingredients were sampled once weekly; composites were made and analyzed for chemical composition. Measurements were taken for dry matter and nutrient intakes, milk yield, and milk composition.

Results and discussion. Crude protein of diets were similar as intended; however, NDF, ADF, fat, and NFC contents were different among diets. These variations were the results of changes in ingredient makeup of diets imposed by the need to balance diets to meet animal requirements and study objectives.

The effect of feeding ALM on nutrient intake is shown in Table 7. In this study, when ALM supplied 0, 11, 21, or 33% of the total dietary CP, then diet DM contained 0, 7.5, 14.6, and 23.5% ALM, respectively. Dry matter intakes of cows decreased in a linear fashion as the amount of ALM in the diet increased. Compared with the SBM control, feeding ALM at 7.5%

of dietary DM had little effect on dry matter intake. At this level, cows consumed about 4.8 lb/d of ALM. At 14.6% or 23.6% ALM in diet DM, cows consumed 9.1 and 14.4 lb/d of ALM and total dry matter intake significantly declined by 2.8 and 3.9 lb/d, respectively.

Despite the decrease in DMI, the yield of milk, solids-corrected milk, or fat-corrected milk from cows fed ALM were similar to those of cows fed the SBM control diet (Table 9). Milk composition also was not affected by treatment except milk protein percentage which was slightly reduced when ALM supplied 22% of dietary CP compared with the SBM control. Reasons for this reduction in milk CP percentage with this particular treatment are not clear.

Results of this experiment are in some ways similar to those observed in the study where ALM pellets partially replaced alfalfa hay in the diet. In the present study, dry matter intake decreased when ALM was included in the diet at or above 15% of diet DM. In the hay replacement study, dry matter intake was significantly affected when the diet contained 16% ALM pellets. In both studies, the reduction in dry matter intake had no effect on milk yield or composition. One possible explanation is the relatively large dry matter intakes of cows in both studies. Average daily intakes ranged from 58.8 to 64.5 lb of DM in the hay replacement study, and from 56.8 to 60.8 lb of DM in the present study (Tables 3 and 8). At such high intakes, cows will most likely meet their nutrient requirements, unless diets are extremely deficient in some critical nutrients. Diets used in these studies were well balanced and the observed results are not very surprising given the observed levels of feed intake. However, these levels of intakes are probably not typical of most cows and what might happen if intakes were not as high is open to speculation.

In this study, as in the hay replacement study, the lack of treatment effect on milk yield along with decreased dry matter intake as ALM increased in the diet give the impression that cows fed diets containing ALM were more efficient converting nutrients into milk and milk components. As noted in the first experiment, one would need to look at the overall picture before making such an inference. Cows will often draw on body reserves to maintain milk production when the diet does not meet the requirements. If such conditions last long enough, cows will loose body weight and condition. The body reserves would have to be replenished before cows start a new lactation cycle, or milk yield would be compromised. Because data were collected over short periods in this study, it was impossible to make any inference about treatment effects of body weight or body condition, and it is not known what would happen if cows were fed these diets over a longer period of time.

Implications. The results of this study indicate that ALM can replace SBM in diets to supply up to 33% of dietary CP for midlactation cows without any detrimental effects on milk yield or composition. However, in our experience, it would be quite difficult to supply a larger proportion of dietary CP from ALM, especially in early lactation diets, unless CP content of ALM is substantially increased.

Table 6. Ingredient and chemical composition of experimental diets (study 2).

Item	Proportion of dietary CP from ALM			
	0%	11%	22%	33%
Ingredient composition:	% of diet DM			
Hay	17.3	17.5	17.4	14.5
Corn Silage	32.0	32.9	32.7	26.9
Grain Mix	50.7	49.6	49.9	58.6
Chemical composition:				
Dry matter	58.7	58.3	58.6	62.7
Crude protein	16.3	15.9	16.0	15.9
Neutral detergent fiber (NDF)	31.8	35.4	37.2	34.3
Acid detergent fiber (ADF)	15.2	17.1	19.4	18.0
Ash	7.7	7.6	7.9	7.8
Fat	2.7	3.3	3.9	4.2
Nonfiber carbohydrates	41.5	37.8	35.0	37.7

Table 7. Ingredient composition of the grain mixtures used in experimental diets.

Ingredient	Proportion of dietary CP from ALM			
	0%	11%	22%	33%
	% of DM			
Alfalfa leaf meal	0.0	15.1	29.3	40.3
Soybean meal	15.4	10.8	5.7	0.0
Barley	20.9	17.2	14.0	13.0
Cracked Corn	31.1	25.6	20.9	19.3
Whey	7.5	7.4	7.1	6.6
Distillers dried grains	18.5	18.1	18.0	16.6
Animal fat	2.2	2.2	2.2	2.2
Trace mineralized salt	0.7	0.7	0.7	0.7
Dicalcium Phosphate	0.4	0.4	0.4	0.4
Limestone	2.2	1.4	0.6	0.0
Trace minerals +Vitamins Mix	1.1	1.1	1.1	0.9

Table 8. Nutrient intakes of cows fed diets containing alfalfa leaf meal.

	Proportion of dietary CP from ALM					
Item	0%	11%	22%	33%	SE	P
Dry matter, lb/d	60.8[a]	59.2[ab]	58.0[b]	56.8[b]	0.97	.05
Crude protein, lb/d	9.9[a]	9.4[b]	9.4[b]	9.1[b]	0.15	< .01
Neutral detergent fiber, lb/d	19.3[c]	20.4[b]	21.9[a]	19.8[bc]	0.35	< .01
Acid detergent fiber, lb/d	9.2[c]	10.1[b]	11.4[a]	10.4[b]	0.18	< .01

[a,b, c] Means in the same row without common superscripts differ at $P \leq .05$)

Table 9. Yield and composition of milk from cows fed diets containing alfalfa leaf meal.

	Proportion of dietary CP from ALM					
Item	0%	11%	22%	33%	SE	P
Milk, lb/d	76.0	74.5	75.1	75.0	1.41	0.91
Solids-corrected milk, lb/d	75.8	71.3	73.2	74.5	1.36	0.14
3.5% Fat-corrected milk, lb/d	80.4	80.1	80.5	78.2	1.45	0.45
Fat, %	3.87	3.84	4.00	3.79	0.07	0.23
Protein, %	3.18[a]	3.17[a]	3.10[b]	3.14[ab]	0.02	0.05
Lactose, %	4.57	4.56	4.56	4.58	0.02	0.81
Fat, lb/d	2.93	2.82	2.95	2.79	0.07	0.27
Protein, lb/d	2.42	2.33	2.31	1.33	0.04	0.21
Lactose, lb/d	3.52	3.41	3.43	3.48	0.07	0.73

[ab] Means in the same row with no common superscripts differ ($P \leq .05$)

2.3. Estimated Price for Alfalfa Leaf Meal.

From the results of the feeding trials, we attempted to estimate the economic value of ALM. To arrive at this, we calculated the cost of each experimental diet using current prices for each ingredient in the experimental diets leaving out ALM for which we did not have a price. We then calculated the difference between the cost of the control diet (containing no ALM) and the cost of test diets. Since animal performance was similar across treatments, it was decided that the cost of the test diets should not exceed that of the control diet. Therefore, the difference between the cost of the control diet and that of the test diet was assumed to be equal to the cost of the amount of ALM included in the test diet being considered. The results of the calculations are presented in tables 10 and 11.

Under these assumptions and based on prices of $130/ton for hay, $ 2.75/bu for corn, and $ 300/ton for SBM, it was estimated that the maximum price one may be willing to pay for ALM used as hay replacement is about $ 163/ton. If the price of hay is changed to $ 100/ton while maintaining the cost of the other ingredients constant, then maximum estimated value of ALM as hay replacement is $ 131/ton. Its value would increase to a maximum of about $ 195/ton if the price of hay increased to $ 160/ton.

Based on similar calculations and using diets fed in the SBM replacement study, the value of ALM as a protein supplement was estimated to be about $ 186/ton maximum if SBM and corn cost $ 300/ton and $ 2.75/bu, respectively. Using typical prices of $ 200/ton for soybean meal and of $ 2.30/bu for corn, the value of ALM was estimated to be a maximum of about $ 146/ton.

These estimates are to be used with great caution, however, because they are based on calculations that ignore many of the factors that influence the market value of any product. Consumers will eventually decide how much they would be willing to pay for ALM based on availability and cost of numerous other competing products.

Table 10. Estimated cost of alfalfa leaf meal used as a hay replacement in dairy diets.

Ingredient	ALM pellets, % of diet DM 0	8	16	$/ton as fed
	------ % of diet DM ------			
Alfalfa Leaf Meal	0.00	7.93	15.81	???
Corn Silage	25.58	26.12	26.10	25.00
Hay (160 RFV)	26.02	18.46	11.23	**130.00**
Soybean Meal	6.27	5.65	4.98	**300.00**
Grain Mix	42.13	41.84	41.88	**158.60**
Cost of diet[2], $/cwt. DM	7.33	6.64	5.98	
Differential	0.00	0.65	1.35	
Estimated Price of ALM[1]		**131.05**	**129.35**	
Estimated Price of ALM[2]		**162.69**	**160.39**	
Estimated Price of ALM[3]		**194.34**	**191.44**	

[1] Based on average price of $100/T Hay
[2] Based on average price of $130/T Hay
[3] Based on average price of $160/T Hay

Table 11. Estimated value of alfalfa leaf meal used as a soybean meal replacement

Ingredient	Dietary protein from ALM 0%	11%	21%	$/ton as fed
	------ % of diet DM -----			
Hay (120 RFV)	17.3	17.5	17.4	**130.00**
Corn Silage	32.0	32.9	32.7	25.00
Alfalfa Leaf Meal	0.0	7.5	14.6	???
Soybean Meal	7.8	5.4	2.8	**300.00**
Barley	10.6	8.5	7.0	106.00
Cracked Corn	15.8	12.7	10.4	**98.00**
Whey	3.8	3.7	3.5	470.00
Distillers' Dried Grains	9.4	9.0	9.0	150.00
Limestone	1.1	0.7	0.3	88.50
Salt	0.4	0.4	0.4	100.00
TM-VIT Mix	0.6	0.6	0.6	460.00
Tallow	1.1	1.1	1.1	520.00
Dicalcium Phosphate	0.2	0.2	0.2	380.00
Cost of diet, $/cwt. DM	7.49	6.75	6.05	
Differential, $/cwt. DM	0.00	0.74	1.44	
Estimated Price of ALM[1], $/ton		**185.93**	**185.48**	
Estimated Price of ALM[2], $/ton		**145.30**	**144.23**	

[1] Based on current prices of $300/T Soybean Meal and $2.75/bu Corn
[2] Based on average prices of $200/T Soybean Meal and $2.30/bu Corn

3. VALUE-ADDED PROCESSING OF ALM (Tasks Ib and Ic).

3.1. Introduction.

The major limitations to using ALM as a protein supplement in ruminant diets are 1) the high solubility and degradability of the protein in the rumen, 2) the low CP content compared with other protein supplements commonly used such as SBM, and 3) the relatively low protein quality. Based on amino acid composition of alfalfa hay, ALM would be expected to contain less of most of the essential amino acids than SBM. Therefore, to improve the protein value of ALM for ruminants, it would be necessary to decrease the protein degradability in the rumen and improve the amino acid composition of the product by combining it with other products having a better or complimentary amino acid composition.

3.2. Assessment of the Quality of Alfalfa Leaf Meal Protein

Alfalfa leaf meal is a new product and little is known about its nutritive qualities, especially the quality of the protein. A series of laboratory tests were performed to assess the nutrient composition of ALM with particular emphasis on protein quality.

Objectives. To assess the nutrient composition of ALM and the quality of ALM protein.

Materials and methods. Samples from 6 different batches of ALM used in various feeding studies from October 1996 to August 1997 were analyzed for nutrient content. All samples were analyzed for CP, fiber, and total ash content. Three of the samples were also analyzed for mineral content, whereas only 2 of the samples were also analyzed for protein fractions and amino acids.

Results and discussion. Table 12 summarizes the nutrient composition of the ALM samples analyzed. Samples 1 and 6 of ALM were received in the form of pellets, whereas ALM in the other samples was in meal form.

Fiber content of ALM has been variable, ranging from 28.6 to 44.5% of DM for NDF, and from 16.0 to 28.6% of DM for ADF. Crude protein and ash content on the other hand have been relatively constant, ranging from 21.8 to 23.6% of DM for CP, and from 10.1 to 13.8% of DM for ash. However, it should be noted that CP content has been consistently lower than theoretical values of 28 to 30% of DM. The quality of the leaf meal produced to date is comparable to that of high quality hay, indicating stem contamination.

As anticipated, ALM protein is rapidly and extensively degraded in the rumen. The rumen undegradable (bypass) protein content of ALM was determined using the nylon bag technique. In this technique, samples of the material to test are placed into bags that are indigestible by rumen microbes. The bags containing the samples are then suspended in the rumen for various lengths of time. At the end of each incubation time, bags are retrieved from the rumen, thoroughly washed, and analyzed for CP remaining. These values are subsequently used to calculate the rate and extent of CP degradation in the rumen. In the case of ALM, estimates of rumen undegradable protein ranged from 28% of CP for one sample (ALM pellets ground to pass through 1 mm screen) to 24.1% of CP for another (ALM, meal form). These values are markedly lower than 35.1% obtained by Taylor and coworkers in a previous study (USDA, NSP, and EPRI feasibility study). However, Taylor and coworkers used a combination of manual and mechanical separation to produce ALM. This process was very different from the industrial-scale process used for ALM production in current studies.

Table 13 shows the amino acid composition of ALM protein. The amino acid profiles of some other feedstuffs are also included in the table for comparison purposes. Tryptophane and cysteine were not determined due to procedural limitations. Also, methionine values were abnormally low for reasons that are not clear and have not been included.

Amino acid composition of ALM samples analyzed was similar to that of alfalfa hay. The content of essential amino acids in ALM protein is lower than that in SBM protein. It can also be seen from Table 13 that ALM contains more lysine. The amino acid profile of ALM protein is fairly similar to that of meat and bone meal, a product recently banned from cattle feeding because of concern about "Mad Cow Disease".

Implications. Increasing the bypass content of ALM or combining ALM with other feeds that have complementary or better amino acid profile such as distillers or brewers dried grains, whole soybeans, brewers yeast, etc. may add to the protein value of ALM.

Table 12. Nutrient composition of alfalfa leaf meal used in various feeding trials from November 96 to August 97.

Sample	1	2	3	4	5	6	Average
Site of use	St. Paul	Crookston	St. Paul	Gd Rapids	St. Paul	Morris	
Date received	Nov. 96	Nov. 96	Nov. 96	Dec. 96	Feb. 97	Aug. 97	
Item[1]							
Dry matter, %	94.9	96.8	93.8	...	93.0	90.0	93.7
NDF, % of DM	44.5	32.7	28.6	33.6	39.5	37.5	36.1
ADF, % of DM	28.6	19.2	16.0	20.7	21.5	23.7	21.6
CP, % of DM	23.6	22.8	21.8	22.1	22.4	22.2	22.5
RDP, % of CP	72.0	...	...	...	75.9	...	74.0
RUP, % of CP	28.0	...	...	...	24.1	...	26.0
Total AA,[2] % of CP	65.6	...	...	...	73.8	...	69.7
Essential AA,[3] % of CP	30.8	...	...	...	33.1	...	32.0
Ash, % of DM	13.8	10.9	10.1	10.8	10.5	12.4	11.4
Calcium, % of DM	2.47	...	...	...	1.69	1.93	2.03
Phosphorus, % of DM	0.34	...	...	...	0.27	0.29	0.30
Potassium, % of DM	2.21	...	...	...	2.35	2.17	2.24
Sodium, % of DM	0.05	...	...	...	0.13	0.10	0.09
Magnesium, % of DM	0.40	...	...	...	0.33	0.41	0.38
Manganese, ppm	89.69	...	...	...	45.18	64.84	66.57
Iron, ppm	667.05	...	...	...	329.01	477.24	491.10
Zinc, ppm	31.42	...	...	...	24.61	42.98	33.00
Copper, ppm	10.24	...	...	...	12.58	16.77	13.20

[1] NDF = neutral detergent fiber; ADF = acid detergent fiber; CP = crude protein; RDP = rumen degradable protein; RUP = rumen undegradable protein; AA = amino acids.
[2] Does not include methionine, tryptophane, and cysteine.
[3] Does not include methionine and tryptophane.

Table 13. Alfalfa leaf meal protein composition in comparison with the composition of protein from various feeds[1]

Item[2]	**Alfalfa Leaf Meal (22.9% CP)**	Dehydrated alfalfa (20% CP)	Alfalfa hay (19% CP)	SBM (50% CP)	soybeans (38% CP)	DDG (25% CP)	Brewers' dried grains (27.9% CP)	Fish meal (67% CP)	Meat and bone meal (50% CP)	*Brewers' dried yeast (45% CP)*
RDP, % of CP	**75.9**	41.0	72.0	65.0	74.0	44.0	43.0	35.0	50.0	*58.0*
RUP, % of CP	**24.1**	59.0	28.0	35.0	26.0	56.0	57.0	65.0	50.0	*42.0*
IAP, % RUP	**65.0**	...	...	90.0	...	81.0	77.0	80.0	55.0	...
IAP, % CP	**15.6**	...	...	22.0	...	46.0	44.0	52.0	33.0	...
Essential amino acids, % of CP										
Methionine	...	1.65	1.45	1.48	1.42	1.80	2.15	2.9	1.34	*2.22*
Lysine	**4.16**	4.35	4.31	6.59	6.32	3.60	3.23	7.58	5.20	*7.56*
Tryptophane	...	2.30	1.00	1.59	1.37	0.84	1.43	1.16	0.52	*1.78*
Threonine	**3.72**	4.40	3.95	3.86	4.45	1.20	3.58	3.77	3.26	*5.56*
Isoleucine	**3.65**	4.90	4.00	5.68	5.74	3.72	7.17	4.56	3.40	*4.89*
Histidine	**1.68**	2.10	1.84	2.50	2.66	2.40	1.68	2.32	1.92	*2.89*
Valine	**4.43**	5.95	5.20	5.45	5.32	4.80	6.06	5.53	4.50	*5.27*
Leucine	**6.26**	7.50	6.84	7.73	7.37	10.40	11.47	8.06	6.40	*7.11*
Arginine	**3.81**	4.90	3.10	7.73	7.37	4.00	4.66	5.21	6.70	*4.89*
Phenylalanine	**4.28**	5.20	4.43	5.00	5.53	2.40	6.52	3.62	3.40	*4.13*
Total[3]	**32.00**	43.25	36.12	47.61	47.53	35.16	47.96	44.71	36.64	46.29

[1] ALM = alfalfa leaf meal; SBM = soybean meal; DDG = distillers dried grains;
[2] RDP = rumen degradable protein; RUP = rumen undegradable protein; IAP = intestinally available protein.
[3] Does not include methionine and tryptophane for ALM.

3.3. Enhancing the Protein Value of Alfalfa Leaf Meal Through Heat Treatment.

Objectives. The objective of this experiment was to reduce the degradability of ALM protein in the rumen by means of heat treatment. By adding moisture or a source of sugars to ALM, another objective was to reduce the time needed to heat ALM to attain a given level of bypass protein.

Experimental design and methodology. Alfalfa leaf meal used in this experiment was the same material used in the second dairy feeding study (Table 1). Treatments consisted of heating ALM at 160° C for 30, 60 or 90 minutes after addition of water (0 or 20%) and molasses (0, 10, or 20%). Thus, treatments were arranged in a 2 x 3 x 3 factorial (2 levels of moisture, 3 levels of molasses, and lengths of heat exposure time). Each treatment was replicated 3 times. Because the number of treatments was rather large (a total of 20) and because we were mostly interested in testing the effect of heat and the interaction between moisture, molasses and heat on protein degradation, the study was designed so that only these effects would be estimable. Therefore, a split-split plot design was used. Samples of treated material were analyzed for contents of rumen undegradable protein (RUP) and indigestible protein (ADIP), and for intestinal availability of the bypass protein.

Results and discussion. The effects of treatments on ALM protein degradation in the rumen are shown in Table 14. The RUP content in untreated ALM was about 24.1% of CP. The RUP in ALM increased as time of heat exposure increased (Table 14); the highest RUP value (44.2 % of CP) was observed when the leaf meal was heated for 120 minutes. In a similar experiment, Taylor and coworkers observed RUP content of 46.5% of CP after heating the leaf meal for 120 minutes at 150° C.

Rumen undegradable protein consists of a fraction that is potentially digestible in the intestine or available to the animal, and a fraction that is indigestible in the intestine (i.e, unavailable to the animal). To distinguish these 2 fractions, acid detergent insoluble protein (ADIP) is often used as an estimate of indigestible protein, whereas estimates of intestinal availability of bypass protein (IAP) may be obtained using special techniques. In our experiment, ADIP also increased as time of heat exposure increased, as did RUP (Table 14). However, the increase in digestible RUP was greater than the increase in indigestible RUP, because estimates of IAP for samples with highest ADIP were similar to that of the untreated control (Table 14).

The Maillard reaction is another process by which protein degradability is altered. In this process, protein reacts with certain types of carbohydrates (sugars) to form chemical bonds that are resistant to breakdown by rumen microbes. In the present experiment, water and molasses were added to ALM in an attempt to speed up the Maillard reaction. Usually, this reaction is faster in the presence of water or when the amount of reacting sugars increase in the medium, so that the same results would be achieved in less time. Unfortunately, this did not happen in our experiment. Indeed, as we added moisture or molasses to the leaf meal, RUP content achieved at any time of heat exposure appeared to decrease in comparison with that achieved by heating ALM to which no water or molasses was added (figure 5). Subsequent analyses revealed that the molasses used in this experiment contained very little reducing sugars, which are the reacting sugars in the Maillard reaction. We have no explanation for the lack of interaction between moisture and heat.

Implications. The similarities between the results of the present experiment and those in the study by Taylor and coworkers, and the relatively small standard deviations observed across replicates in the present study suggest that heat treatment of ALM to decrease CP degradation in the rumen gives results that are consistent and repeatable. However, heating ALM for 2 hours to achieve 44.2% bypass protein may be impractical in an industrial production setting. Possibilities of reducing the time needed to protect ALM protein against rumen microbes need to be investigated further. Other methods of improving the efficiency with which ALM protein is utilized in the rumen such as supplementation with sources of fermentable energy to maximize microbial protein synthesis need to be investigated.

Table 14. Effect of heat treatment of alfalfa leaf meal with or without addition of moisture or molasses on contents of rumen undegradable protein (RUP), acid detergent insoluble protein (ADIP), and bypass protein available in the intestine (IAP).

Treatment factors			N	Protein fraction		
% added moisture	% added molasses	Time of heat exposure, min.		RUP, % of CP	ADIP, % of CP	IAP, % of RUP
0	0	0	3	24.1	4.69	65.0
0	0	30	3	28.3	7.16	71.1
0	0	60	3	34.7	12.97	69.3
0	0	90	3	39.3	19.22	65.4
0	0	120	3	44.2	14.72	66.5
0	10	30	3	29.1	7.64	69.9
0	10	60	3	33.5	13.32	67.9
0	10	90	3	38.4	22.32	66.7
0	20	30	3	23.7	6.90	71.3
0	20	60	3	29.4	14.07	69.6
0	20	90	3	34.5	21.18	66.5
20	0	30	3	28.2	5.75	65.1
20	0	60	3	26.5	6.64	67.2
20	0	90	3	33.1	10.70	65.9
20	10	30	3	23.2	5.41	66.2
20	10	60	2	23.8	6.70	66.9
20	10	90	3	31.8	10.32	64.5
20	20	30	3	21.2	4.95	65.2
20	20	60	3	23.0	6.56	64.8
20	20	90	3	26.8	9.97	65.6

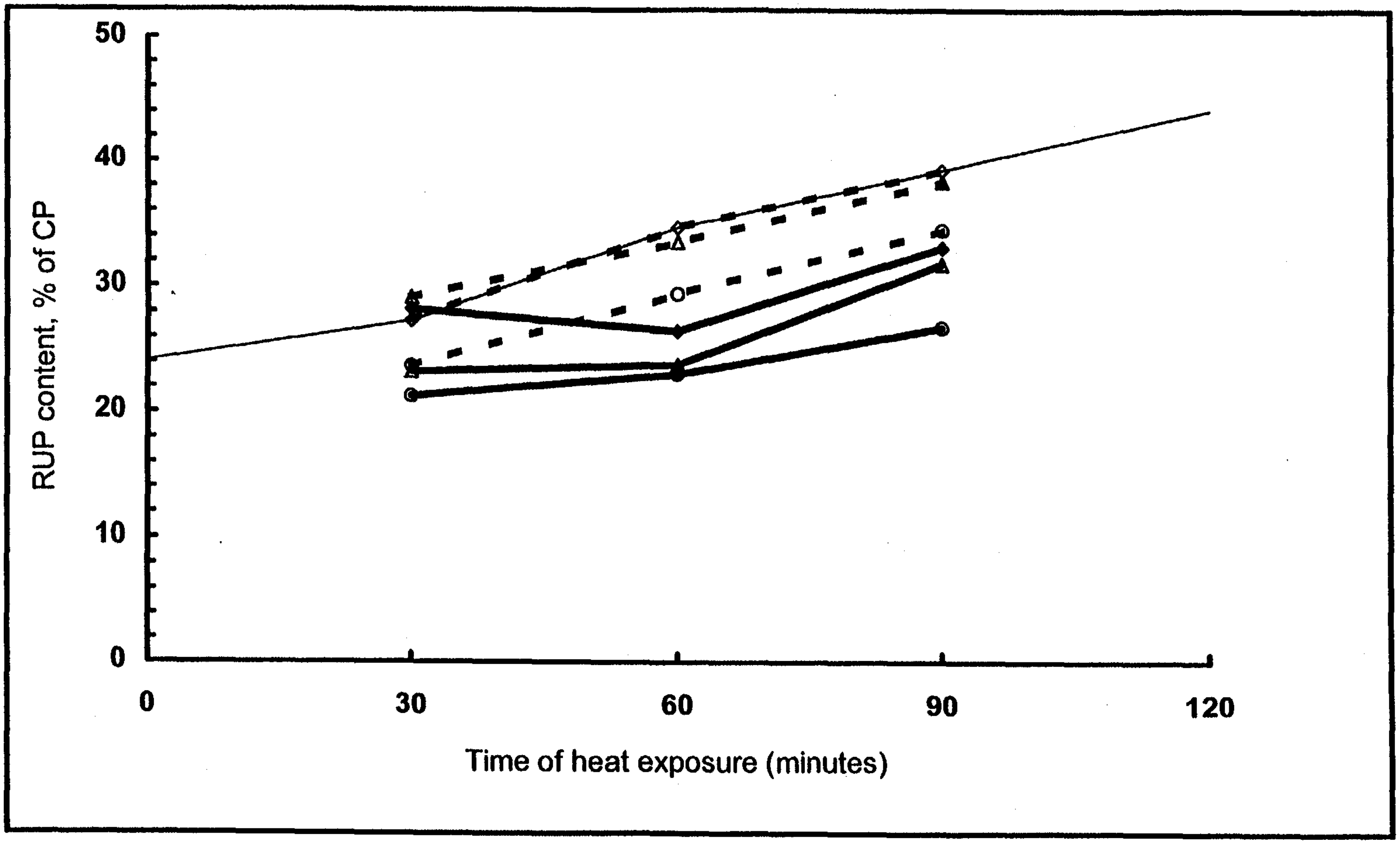

Figure 5. Effect of heating ALM with or without addition of moisture or molasses on rumen undegradable protein (RUP) content. Heat treatment without added moisture is represented by the thin solid line (—). For the other treatments, the levels of added moisture are 0% (broken lines, - - - -) or 20% (thick solid lines, ▬); the levels of added molasses are 0% (◊), 10% (Δ), or 20% (o).

3.4. Influence of Processing of Alfalfa Leaf Meal on Protein Degradation in the Rumen.

Objectives. The objective of the experiment was to determine the effect of form or particle size of ALM on protein degradation in the rumen.

Materials and methods. Alfalfa leaf meal pellets were ground to pass a 1 mm screen, crushed to obtain crumbles of different particle sizes, or left intact. Table 15 shows the different particle sizes used in this experiment. Samples from each particle size category were analyzed for soluble CP and degradability of CP in the rumen.

Table 15. Influence of particle size on protein solubility and degradability in the rumen.

		Protein fraction[1], % of CP		
ALM sample type	Particle size	Soluble CP	RDP	RUP
meal	≤ 1 mm	. . .	75.9	24.1
ground pellets	≤1 mm	23.6	72.0	28.0
crushed pellets	> 2 mm and < 4 mm	23.5	68.0	32.0
crushed pellets	> 4 mm and < 5.6mm	24.1	65.9	34.1
whole pellets	> 5.6 mm	8.7	56.0	44.0

[1] Soluble CP = protein soluble in borate phosphate buffer; RDP = rumen degradable protein; RUP = rumen undegradable protein.

Results and discussion. The results indicate that the rate of protein degradation was not influenced by particle size, but protein solubility and, as expected, protein degradability in the rumen tended to decrease as particle size increased (Table 15). The RUP value was 28% of CP when ALM pellets were finely ground (1 mm particle size). This value is similar to that determined for ALM obtained in meal form from the processing plant (24.1%), indicating that the pelleting process had very little protective effect on ALM protein against degradation in the rumen. One might think that the heat produced during pelleting may reduce protein degradability. However, the effect of heat on protein degradability depends on factors such as temperature and time of heat exposure. It is possible that the heat produced during pelleting is not high enough or, most likely, that the leaf meal material is exposed to the heat for too short a time to exert any significant effect on the protein.

The RUP value of whole pellets was determined to be about 44%, which is similar to the values of 46.5% and 44.2% obtained by heat treatment for 2 h at 150° or 160° C, respectively. Pellets are probably not swallowed intact, so this value may be misleading. However, it may be reasonable to hypothesize that if ALM was pelleted after it has been heat-treated, its baypass value may actually be higher than what it would otherwise be without pelleting. It should be mentioned, however, that it is not known how long ALM pellets remain in the rumen. The longer the residence time in the rumen, the more extensive protein degradation will be.

Implications. For practical purposes, ALM will likely be commercialized in the form of pellets. Pelleting after heat treatment of ALM may be another way to add to the protein value of ALM.

4. FUTURE RESEARCH

There is need to investigate ways by which the utilization of ALM protein in the rumen is improved. Possibilities include matching energy availability and protein degradation in the rumen in order to optimize microbial protein synthesis. To achieve this, several sources of fermentable energy would be screened to find ones that match the rate of ALM protein degradation. Also, it will be necessary to reduce the time needed for heat treatment of ALM to increase the bypass content, or to find other more efficient ways to reduce ALM protein degradability. Developing value-added products through combination of ALM with other products still needs to be researched. In terms of feeding ALM, it will probably be necessary to examine animal response over long periods. Additionally, ALM could also be evaluated in calf starters, especially if combined with energy rich products such as whole soybeans.