SUPPLEMENTAL PROTEIN, PROTECTED AMINO ACIDS OR ENERGY FOR LACTATING DAIRY COWS FED WHEAT-BASED CONCENTRATE MIXTURES IN EARLY LACTATION

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CHAPTER I

INTRODUCTION

Large quantities of cereal grains are commonly fed to dairy cows to increase energy intake for increased milk production. Because of surplus wheat production in the United States, wheat is often competitively priced with other cereal grains such as corn and may warrant consideration by dairy farmers as the primary energy source in the ration. Utilization of wheat in dairy cattle rations, as with other feed ingredients, must be price dependent. Faldet et al. (1986b) found a higher return over feed costs when 40% wheat ($3.37/bu) was included in the concentrate mixture of lactating cows compared to a 75% corn ($3.21/bu) ration. When wheat was included at rates of 60 and 80%, however, the return over feed costs declined.

Dairy producers are reluctant to utilize wheat in production rations because of cow health and management concerns. Feed intake may decrease from lower palatability or acceptability of wheat (Waldern, 1970). Decreased ruminal pH (Fulton et al., 1979) and altered volatile fatty acid concentrations (Theurer and Wanderley, 1987) due to altered ruminal fermentation may contribute to this effect. Another concern with feeding wheat is "off-feed" or acidosis. Though acidosis is a concern when high levels of any concentrate are fed to cattle, the problem is more prevalent with wheat because of the high fermentation rate of wheat starch in the rumen (Britton and Stock, 1987). Increased ruminal starch digestion may also decrease milk fat production (Waldo, 1973).

Ruminal undegradable protein can be used to supply a portion of the amino acid requirement of a high-producing dairy cow. Small grains such as barley, oats and wheat contain higher amounts of ruminal degradable protein than corn or milo (Chalupa, 1982a). Barrio et al. (1986) found ruminal nitrogen disappearance of ground wheat to be 89.7% compared to 41.6% for ground corn.

The higher ruminal degradability of wheat protein may reduce the supply of feed protein available for absorption in the small intestine and may result in surplus ruminal ammonia production. Ammonia in excess of microbial requirements would be absorbed through the ruminal epithelium and eventually excreted in urine.

Some studies have found increased milk and milk protein yields when proteins or amino acids bypassed the rumen (Rogers et al., 1983; Sahlu et al., 1983; Schingoethe et al., 1988). Individual amino acids protected from ruminal degradation increased milk protein percentages although milk yield did not change (Donken et al., 1987; Casper and Schingoethe, 1988). Comparatively few studies have evaluated the effects of increasing energy intake or supplementing ruminal undegradable protein and protected amino acids on lactational performance of dairy cows fed wheat-based rations.

The objectives of this research were to:

a) Determine whether ruminal undegradable protein, and additional energy in the form of whole cottonseed, would be beneficial in 60% wheat/alfalfa hay diets in regards to milk yield and composition, and to determine the effect of these diets on ration digestibility and ruminal and blood parameters,

b) Determine whether ruminal undegradable protein with or without ruminally protected lysine and methionine would be beneficial in 60% wheat/sorghum silage/alfalfa hay diets in regards to milk yield and composition, and to determine the effect of these diets on ruminal and blood parameters.

CHAPTER II

LITERATURE REVIEW

Wheat grain has traditionally been utilized for human consumption, and has not been considered a feed grain. Domestic utilization of wheat for human consumption is projected to reach 750 million bushels in 1988 (Wheat Outlook and Situation Yearbook, Sept. 1987), which is 140 million bushels more than in 1980 and almost 233 million bushels more than in 1970. Production of wheat, however, has exceeded domestic and export requirements. This overproduction has led to stocks of wheat which exceeded 1,900 million bushels in 1986. Large surpluses have lowered prices so that wheat has become an economical alternative to corn and milo for livestock feeding. The ability of wheat to compete with other feed grains is not only determined by its price on the open market, but also through governmental policy (Reitz, 1970). Utilization of wheat for livestock feeding reached an all-time high in 1984 of 400 million bushels. Utilization of wheat as a feed grain depends on it's nutritive value for different classes of livestock and the supply of economical wheat.

Characteristics of Wheat as a Feed Grain

Because of the high energy content of wheat, it can be incorporated into high energy rations. Brethour et al. (1985) found hard winter wheat to be higher in net energy for gain than soft red winter wheat in beef cattle finishing rations (1.52 vs 1.47 Mcal/kg, respectively). The United States-Canadian Tables of Feed Composition (1982) report the net energy for lactation of soft wheat to be higher than hard wheat varieties (Table I). Toland (1978) reported starch contents of 66.8 and 65.8% for soft and hard wheat varieties. Starch contents of 57.5% (Fulkerson and Michell, 1985) and 51.5% (Toland, 1976) for soft wheat have also been reported. Decreased starch content may reflect drought conditions during grain production (Toland, 1976). Wheat is often equal to or greater in energy content than other feed grains (Table II). Brethour et al. (1985) calculated that net energy for gain values of the hard and soft red winter wheats were 102 and 99% that of corn when fed as the only grain to finishing beef cattle. Using chemical composition and digestion coefficients, Copeland (1933) determined that wheat and milo contained 84.9 and 83.3 therms of energy, respectively, per 100 pounds of grain when fed to dairy cows.

The crude protein content of wheat is highly variable within type and variety and depends upon location, nitrogen fertilization rate, moisture conditions and other agronomic

TABLE I

NUTRIENT COMPOSITION OF DIFFERENT TYPES OF WHEAT[a]

	Hard		Soft		
Item	Red Spring	Red Winter	Red Winter	White Winter	White Winter[b]
		(% or Mcal/kg, as fed)			
CP	15.10	12.70	11.50	10.10	10.00
NE_1	1.81	1.80	1.82	1.84	1.82
Calcium	.03	.04	.04	.06	.09
Phosphorus	.38	.38	.38	.32	.30
Amino acids					
Lysine	.35	.36	.36	.31	.30
Methionine	.19	.21	.22	.15	.14

[a]United States - Canadian Tables of Feed Composition, 1982 (Third Revision)

[b]Pacific Coast

TABLE II

COMPARATIVE NUTRITIVE VALUE OF GRAINS[a]

Item	Corn	Barley	Sorghum	Oats	Wheat[b]
	(% or Mcal/kg, as fed)				
Crude protein	9.60	11.90	11.10	11.80	12.70
NE_l	1.78	1.71	1.78	1.57	1.80
Calcium	.03	.04	.03	.07	.04
Phosphorus	.26	.34	.29	.33	.38
Amino acids					
Lysine	.25	.39	.25	.39	.36
Methionine	.17	.15	.13	.17	.21

[a]United States - Canadian Tables of Feed Composition, 1982 (Third Revision)

[b]Hard Red Winter

factors (Waldern, 1970). Variation in crude protein content of 12 to 19%, 10 to 15%, and 8 to 12% for hard red spring, hard red winter, and soft wheats, respectively, have been reported (Waldern, 1970). Gluten comprises 80 to 90% of the crude protein in wheat and is insoluble in water and neutral salts (Oltjen, 1970). Gluten is high in glutamic acid and proline, but low in lysine and arginine (Oltjen, 1970).

Because of the higher protein content of wheat, wheat-based rations formulated on a crude protein basis would utilize less cottonseed meal or soybean meal than a corn-based ration. Even though wheat is higher in lysine than corn, the net result would be a wheat ration that contained less lysine than the corn ration. Development of hybrid wheats with higher lysine and(or) methionine content would be beneficial to the livestock industry due to the deficiency of these amino acids in wheat protein (Sullivan, 1970). Development of high lysine corn, sorghum, and barley has already been achieved (Mertz, 1975).

As with many of the cereal grains, wheat is adequate in phosphorus, but low in calcium, magnesium, and potassium and deficient in Vitamins A, D, riboflavin, and B_{12} (Waldern, 1970). Wheat is a good source of most B vitamins and alpha-tocopherol (Sullivan, 1970). Though the chemical composition of wheat is a useful aid in determining its feeding value, other important considerations include palatability, digestibility, productive energy, and it's effect on animal or ruminal health.

The relative feeding value of wheat relative to other grains for dairy cows depends on utilization as well as nutritive content. Wheat starch is rapidly degraded to volatile fatty acids in the rumen (Oltjen, 1970). Wheat and barley starch are more rapidly digested in the rumen than corn or milo starch (Britton and Stock, 1987). Fulton et al. (1979) found that the ruminal pH of cannulated steers consuming wheat-based diets was consistently lower and more variable than for steers consuming corn-based diets. Earlier work by Oltjen et al. (1966) compared diets of 90% cracked corn, 90% cracked wheat or 60:30 combinations of the two grains and found ruminal pH was lower and ammonia concentrations higher for steers fed 60 and 90% wheat rations than for steers fed 60 and 90% corn rations. Steers fed the 60 and 90% wheat diets also had greater concentrations of ruminal volatile fatty acids. Similar observations were made by Axe et al. (1987) with wheat- and sorghum-based rations. Oltjen et al. (1967) compared 92% cracked corn, wheat, barley, or milo rations and reported that total volatile fatty acid concentrations were highest when steers consumed the wheat and barley rations, which resulted in lower ruminal pH with these diets.

Apparent ruminal organic matter digestion (% of intake) was greater with 80 or 40% wheat diets compared to a ration containing 40% sorghum grain (Axe et al., 1987). It was also noted in this study that digestion of organic matter in the small intestine (% of intake) was greater for diets containing 80 or 40% sorghum. Ruminal wheat starch digestion was 93.5%, with only 6.3% of the starch digested in the lower tract.

Type or variety may affect digestibility of wheat. Toland (1978) observed that soft wheat was more digestible (77.5%) than hard wheat (72.6%) even though retention time in the digestive tract and ruminal fermentation rate were similar.

Increased ruminal ammonia concentrations in some studies in which wheat is fed to ruminants (Oltjen et al., 1966; Axe et al., 1987) suggests increased ruminal degradation of wheat protein compared to other grains (Mertens, 1977). Few studies have been conducted to determine the site and extent of wheat protein digestion. Ruminal degradation calculated from protein solubility was higher for wheat protein (65%) than for corn (56%), barley (59%), oats (63%), and milo (52%) protein (Mertens, 1977). Based upon in vivo, in vitro, and in situ information, Satter (1986) estimated the ruminal undegradable portion of wheat protein to be 20% for animals consuming dry matter in excess of 2% of body weight, compared to 50% ruminal undegradable protein for corn and milo protein. Lebzien et al. (1984) observed that the proportion of ruminal undegradable feed protein was 25% for corn compared to 9% for wheat in dairy cows fitted with ruminal and duodenal cannulae. Nitrogen digestibility in the lower tract was similar for the two grains. Although degradation of wheat protein differs dramatically between studies, it appears that wheat protein is more readily deaminated by ruminal microbes than other grain proteins.

Processing of Wheat

For optimum utilization of cereal grains, some form of physical processing should be practiced (Low and Kellaway, 1983). Grain processing, however, exposes the starch and increases ruminal fermentation rate, which can lower ruminal pH and increase digestive disturbances.

Increased ruminal starch digestion can also be detrimental to the lactating cow by decreasing fat content of milk (Waldo, 1973). One theory for low milk fat has been insufficient ruminal acetate production as a result of increased ruminal starch digestion (Van Soest, 1963; Olson, 1984). Acetate is a major precursor for milk fat synthesis (Olson, 1984). Alternatively, the higher proportion of ruminal propionate associated with highly fermentable starch diets may stimulate blood insulin activity and thus decrease the supply of plasma triglycerides required for milk fat synthesis (Beukelen et al., 1982).

Waldern (1970) and Hayden and Monroe (1931) suggested that wheat should be coarsely rolled or ground to maintain maximum intake and prevent formation of a pasty, gummy mass during digestion. Although expensive, pelleting wheat rations also increases acceptability and consumption (Waldern, 1970).

Dry matter disappearance from nylon bags increased from 6% for whole wheat to 74% for rolled (mean particle size of 1.9 mm) wheat (Nordin and Campling, 1976). Dry-rolling increased organic matter digestibility of wheat by 39.4% compared to whole wheat (Toland, 1976). Low and Kellaway (1983) compared whole, cracked, or ammonia-treated whole wheat for steers. In this study, ammonia-treated whole wheat grain was utilized as efficiently as cracked wheat and resulted in fewer digestive disturbances. Apparent nitrogen digestibility was 67, 75, and 81% for whole, cracked, and ammonia-treated whole wheat, respectively. Fulkerson and Michell (1985) reported apparent wheat starch digestibilities of 14.4 and 93.3% for cows fed 2.4 kg/d whole and hammermilled soft white wheat. Differences in production responses between cows fed the whole and hammermilled wheat were comparable to differences in wheat starch digestibilities. Most of this response was attributed to increased milk fat production, because milk yield did not differ between the two treatments.

Dairy cows consuming a pelleted 98% wheat mixed feed concentrate produced more milk ($P<.10$) than cows consuming the ration in meal form (Waldern and Cedeno, 1970). In an acceptability trial, however, pelleting depressed milk fat percentage (Waldern and Cedeno, 1970).

Feeding Value of Wheat Compared to Other Grains

Brethour et al. (1985) reported lower average daily gain, feed intake and dressing percentage, and poorer feed effieciency when finely rolled wheat replaced finely rolled milo or corn in the concentrate mixture for finishing cattle. Feedlot cattle fed a concentrate mixture containing 80% dry rolled wheat had higher average daily gain and better feed efficiency than cattle fed a 80% high-moisture sorghum grain concentrate (Axe et al., 1987).

In early studies, Hayden and Monroe (1931) fed a corn concentrate mixture (44% corn) or a wheat mixture in which wheat replaced 75% of the corn (33% wheat) in conjunction with alfalfa hay and corn silage to eight Jersey and Holstein cows. The wheat ration was found to be just as palatable as the corn ration. Milk, 4% FCM and milk fat production favored the cows consuming the wheat rations, although differences were not interpreted as significant. Similar quantities of feed were required of both rations to produce 100 pounds of milk. Liveweights were increased on both rations although cows consuming the corn ration gained more weight than cows consuming the wheat ration. The economics of feeding the two rations favored the wheat ration.

Copeland (1933) compared wheat with milo in three double reversal trials. Coarsely-ground wheat or ground milo composed 50% of the concentrate mixture which was fed at the level of one pound for every 2.5 pounds of milk produced. Sorghum silage and alfalfa hay were the forage components. Although cows fed the milo rations produced approximately .75 lb more milk per day than cows fed the wheat ration, Copeland (1933) concluded that the differences were too small to conclude one feed superior to the other. Because there were no significant differences in concentrate or hay intakes and no problems with feed refusal, both rations appeared to be similar in acceptability and palatability. During the first two trials, body weight changes were similar for cows fed the milo or wheat rations. During the third experiment, however, cows fed the milo ration gained an additional pound per day compared to cows fed the wheat ration.

Tommervik and Waldern (1969) compared pelleted grain rations containing 95.7% wheat, corn, barley, milo, oats, or a control mixture (38% barley, 20% millrun, 25% peas, 9.5% molasses, and 3.2% cottonseed meal) for lactating cows. Alfalfa hay, fed in a 53:47 ratio with the concentrate, was restricted to 1.7 kg per 100 kg of body weight. Grain and total dry matter intakes of cows fed the wheat ration were similar to cows fed the other grains. Milk and 4% FCM production did not differ among treatments and averaged 23.6 and 22.3 kg per day, respectively. Although percent milk fat of cows fed the wheat ration did not differ from cows fed the other grains, wheat significantly increased the percent milk protein compared to the oat-based ration. Cows fed the wheat ration also gained more weight than cows fed the corn and milo rations.

In a switch-back trial, Cunningham (1970) compared two varieties of ground wheat containing 14.1 and 18.0% crude protein fed in conjunction with varying amounts of corn and soybean meal to provide isonitrogenous (15.3% crude protein) rations. Corn silage was fed ad libitum and alfalfa hay was fed at .5% of body weight. Dry matter intake and milk production averaged 18.5 and 27.6 kg per day and were similar when the wheat rations were compared to the corn-soybean meal control ration. Intake of wheat on the 66.7% wheat rations averaged 5.8 kg per day. Feed consumption, milk production or composition were not altered by the variety of wheat fed. Cows fed the higher protein wheat, however, lost weight during the study whereas cows fed the normal protein wheat rations gained weight. Grain intake and level of milk production reported in this trial are more similar to current management and production schemes than early wheat-feeding experiments.

Cribeiro et al. (1979) reported no difference in milk production or composition for cows fed 75% corn or 77% wheat concentrate mixtures. Concentrate intake was lower, however, for cows fed the wheat ration than for cows fed the corn ration. Moran (1986) compared rations containing 60% rolled grain (wheat, barley, or oats), 17% oaten silage, and 17% lucerne hay, together with meat and bone meal, urea and mineral supplements. Dietary metabolizable energy, calculated from organic matter digestibility, was highest for wheat (10.8 MJ/kg) compared to barley (10.2 MJ/kg) and oats (9.1 MJ/kg). No differences in dry matter intake were observed. Milk yields were similar for cows fed the wheat and oat rations and higher than the barley ration. Milk fat yields were similar for cows fed the wheat and barley diets and lower than milk fat yields of cows fed the oat diets. Cows fed the wheat ration produced more milk protein (g/d) than cows fed the oat or barley rations.

Recently, Nalsen et al. (1987a) substituted hard red winter wheat for corn on either a weight basis or a protein basis. Grain comprised 75% of the concentrate mixture which was fed in a 50:50 blend with alfalfa hay. When wheat replaced corn pound for pound in the concentrate mixture, the crude protein content of the ration increased from 12.2 to 15.1%, while the net energy for lactation content of the two rations remained the same. In the wheat ration formulated to be equal in crude protein to the corn ration (12.2%), the amount of cottonseed meal was decreased from 12 to 2% and the amount of oats increased from 4 to 14%. Both concentrate and total dry matter intakes were reduced when wheat comprised the major component of the concentrate. Daily milk yields were similar between cows fed the corn ration and the ration in which wheat replaced corn on a weight basis (34.5 and 33.7 kg/d, respectively). Although crude protein content of the corn ration and the wheat ration formulated on a protein basis was similar, milk yield was significantly lower when cows were fed the wheat ration. Decreased feed intake, and thus decreased protein intake with the wheat ration may have attributed to the lower milk production. Percent fat and protein in milk was similar among the three treatments. Ruminal pH was also similar for the three treatments and may have been maintained in the wheat-fed cows by the inclusion of mineral buffers (sodium bicarbonate and magnesium oxide) in the concentrate.

When wheat replaces other grains in the concentrate mixture, particularly corn, the quantity of dietary protein reaching the small intestine should decrease (Nalsen et al., 1987a). Axe et al. (1987) reported decreased solid nitrogen flow to the duodenum when wheat replaced sorghum grain in the concentrate mix for feedlot cattle. Nalsen et al. (1987b) conducted a study with high ruminal undegradable protein (RUP) feeds and protected lysine and methionine for wheat-based rations. Using a switch-back design, the performance of 24 cows was evaluated with: 1) a corn control ration (45% corn and 25% soybean meal); 2) a low RUP wheat ration (60% hard red winter wheat and 20% soybean meal); 3) a low RUP plus protected amino acid wheat ration (60% wheat, 20% soybean meal, .4% protected lysine and methionine), and 4) a high RUP plus protected amino acid wheat ration (60% wheat, 9% corn gluten meal, 2% blood meal, .4% protected lysine and methionine). Calculated RUP and ruminal undegradable lysine for the four concentrate mixtures were

7.56 and .36, 5.41 and .24, 5.55 and .38, and 7.63 and .38%, respectively. The concentrate and sorghum silage were fed in a complete ration at the rate of 45% forage and 55% concentrate on a dry matter basis. Dry matter intakes were similar among treatments, and at no time were digestive disorders encountered. Milk yields were significantly higher for cows fed the corn control ration and the wheat ration containing high RUP and protected amino acids than when cows were fed either of the wheat rations containing low RUP. Supplementation of the low RUP wheat ration with protected amino acids had no effect on milk yield, suggesting amino acids other than lysine and methionine may have limited production. Percent fat and protein of milk did not differ among rations. This study suggests that supplementation of high wheat rations with ruminal undegradable protein sources may restore milk production to levels comparable to high corn rations.

Levels of Wheat in Concentrate Mixtures

Because the interest shown toward wheat as a feed grain is cyclical and coincides with the availability of competetively priced wheat, relatively little research has been conducted on the incorporation of wheat into livestock rations (Riley, 1985). In a review of the early literature on feeding wheat to dairy cows, Waldern (1970) suggested wheat should not exceed 65% of the concentrate mixture. Copeland (1933) concluded that coarsely-ground wheat could replace ground milo pound for pound in dairy rations if not more than fifty percent of the grain mixture was composed of wheat. Hayden and Monroe (1931) observed no off feed conditions or palatability problems when wheat comprised one-third of the concentrate mixture. Tommervik and Waldern (1969) concluded that wheat was a acceptable grain for lactating cows if the grain did not exceed 45% of the total ration. Waldern and Cedeno (1970) compared concentrate mixtures containing 98% barley, 98% wheat-mixed feed, or a control ration containing barley, wheat, peas, and cottonseed meal in meal and pelleted form with 70% alfalfa hay in the diet. When fed in a meal form, wheat-mixed feed was consumed at a lower rate than the other rations indicating lower palatability. In the pelleted form, wheat-mixed feed was comparable to barley and a mixed grain ration as the only concentrate for lactating cows.

Substitution of steam-rolled soft white wheat for 20, 53, 63, 73, 83 or 93% barley in pelleted concentrate rations did not affect dry matter intakes of hay or grain (McPherson and Waldern, 1969). Four percent FCM production averaged 21.7 kilograms across treatments and did not differ between the different levels of wheat. Treatment differences in milk protein and total milk protein production were small and did not differ significantly. In a subsequent acceptability trial, hay was restricted to 1% of body weight while the concentrate mixtures were fed ad libitum. The 93 and 83% wheat rations were slightly less palatable than rations containing less wheat until the cows became adapted to the higher wheat rations. Barley protein is similar to wheat protein in the extent of ruminal breakdown (Satter, 1986; Chalupa, 1982a) which may explain the similarity of results in this study.

Cunningham et al. (1970) compared ground soft red winter wheat at levels of one-third and two-thirds of the concentrate mixture by replacing wheat with ground corn and noticed decreased actual and FCM production and lower milk fat content as wheat increased. Level of wheat, however, did not affect consumption of concentrate or forage.

Cribeiro et al. (1979) replaced corn with 0, 19, 38, 57, and 77% wheat in the concentrate mixture. One cow was removed from the study due to acute digestive upset when the wheat was increased from 0 to 77%. Cows fed rations containing 77 and 57% wheat consumed less concentrate (11.6 and 11.8 kg/d, respectively) than cows fed 38% or less wheat (13.0 kg/d). Forage consumption did not differ between treatments and averaged 25.4 kg/d. Level of wheat did not significantly affect FCM production or milk protein and fat percentage. Recently, Faldet et al. (1986a; 1986b) reported decreased milk production from cows as ground hard red winter wheat was substituted for ground corn in the concentrate mixture. No digestive disturbances or altered intake of hay and concentrate were observed as wheat was increased in the ration. In one trial, milk fat percentage decreased linearly from 2.82 to 2.74, 2.53, and 2.56% as the percentage of wheat in the concentrate was increased from 0 to 40, 60, and 80% (Faldet, 1986b). Milk yields also decreased linearly (P<.08) from 66.9 to 65.5, 65.1, and 63.7 lb/day, respectively. In the other trial, milk yields declined (63.4, 61.5, and 60.0 lb/day) while milk fat percentage tended to increase (3.68, 3.71, and 3.81%) as the level of wheat increased from 0 to 40 and 60% of the concentrate mixture (Faldet et al., 1986a). Milk protein percentage was not affected by level of wheat in either trial.

Some of the reported studies failed to mention the type of wheat fed. Differences in the response to increased wheat in the concentrate mixture may be due to differences in the type of wheat, processing method, forage source and amount, and management. Adequate forage and mineral buffers may alleviate problems with digestive disorder and improve milk fat test when wheat is included in the concentrate mixture.

Protein and Amino Acid Requirements of Lactating Dairy Cows

When feeding ruminants, one must consider the protein requirements of both the animal and the microbial population present in the reticulo-rumen (Tamminga and Van Hellemond, 1977). Microbial protein synthesized in the rumen is one of two main contributors to the quantity and profile of amino acids reaching the small intestine (Tamminga and Van Hellemond, 1977; Berger, 1986).

Microbial protein synthesis is affected by ruminal carbohydrate and nitrogen source, ruminal dilution rate, and dietary sulfur (Stern, 1986). Dietary fermentable carbohydrates provide most of the energy for microbial protein synthesis (Hagemeister et al., 1980), however, amino acids can be utilized as a energy source if a fermentable carbohydrate source is lacking (Nocek and Russell, 1988). In most cases, ammonia is the primary source of nitrogen for microbial proten synthesis (Pilgrim et al., 1970). Ruminal microorganisms use ammonia to a greater extent when the nitrogen content of the host's diet is low (Pilgram et al., 1970). Salter et al. (1979) reported increased incorporation of dietary protein and non-urea nitrogen into bacterial nitrogen as the amount of urea was decreased in the concentrate and the amount of preformed protein increased. There may be a specific requirement for methionine by ruminal microbes (Salter et al., 1979) or ruminal protozoa (Patton et al., 1970).

Crude protein content of ruminal microbes ranges from 20 to 60% on a dry matter basis (Owens and Zinn, 1987). Ruminal bacteria average 50 $\pm$ 5% crude protein, whereas protozoa are much more variable and range between 20 and 60% crude protein (Owens and Zinn, 1987). Bergen et al. (1968) proposed that the amino acid composition of ruminal microbes was not affected by ration composition although the proportion of lysine was higher in protozoa than bacteria. Storm and Orskov (1983) used a large-scale isolation procedure to illustrate that the amino acid composition of ruminal bacteria was very constant.

In a summary of published and unpublished studies, Santos and Satter (1982) reported amino acid flow to the duodenum compared to amino acid intake was relatively high for lysine, methionine and tyrosine, which they attributed to higher content of these amino acids in ruminal microbes. Lysine and methionine were the only amino acids absorbed in excess of their intake. Under most feeding practices, 60 to 85% of the total amino acid nitrogen reaching the small intestine is derived from microbial protein (Stern, 1986; Buttery and Foulds, 1977). This proportion depends on the amount of dietary protein degraded in the rumen and the efficiency of microbial protein synthesis.

The quantity of microbial protein synthesized in the rumen depends on the efficiency with which microbes convert organic matter into microbial cells. Ruminal microbes require dietary carbohydrates as a source of energy and carbon, and nitrogen derived from dietary protein, non protein nitrogen, recycled saliva, or ruminal epithelium (Tamminga and Van Hellemond, 1977). Decreased flow of microbial protein to the small intestine can occur in high yielding dairy cows when the energy demands of ruminal microflora are not met, which may reduce microbial protein synthesis. In addition, decreased ammonia uptake by micro-organisms may increase ruminal ammonia concentrations and blood urea, and decrease milk protein content (Kaufmann, 1982).

Ruminal degradable protein supplied to closely match the availability of fermentable carbohydrates in the rumen will provide a more efficient means of utilizing protein sources (Chalupa, 1984; 1982a). Once the nitrogen requirements of ruminal microbes have been met to maximize microbial protein synthesis, ruminal undegradable protein sources can be used to meet the dairy cows remaining amino acid requirements (Sniffen, 1974). Chalupa (1982b) calculated ruminal undegradable protein requirements of lactating cows as the difference between the metabolizable protein requirement and the intestinal absorption of true microbial protein and ruminal undegradable protein. Satter (1986) described three methods by which ruminal undegradable protein could be incorporated into dairy rations. First, a producer could replace a portion of the conventional protein supplement with a equal portion of ruminal undegradable protein to increase milk yields. Economic returns, however, are not always improved with increased milk yield (Chalupa, 1984). A second method would be to replace the conventional protein supplement with a smaller quantity of a ruminal undegradable protein source. Under these circumstances, milk production should be maintained with less protein. If this approach is used, ruminal degradable protein must supply adequate nitrogen for microbial protein synthesis

(Satter, 1986). Thirdly, a mixture of nonprotein nitrogen such as urea and ground corn could be fed in conjunction with a ruminal undegradable protein source to maintain milk production, with a cheaper protein supplement.

The mammary gland is the major site of protein synthesis in the dairy cow and thus, net amino acid requirements are closely tied to requirements for milk production (Tamminga and Van Hellemond, 1977). The use of amino acids as precursors for gluconeogenesis (Clark, 1975; Tamminga and Oldham, 1980), body maintenance, and protein deposition in muscle or fetus (Tamminga and Oldham, 1980) also needs to be considered. The effects of protein on milk production are to increase the supply of amino acids, increase the amount of available energy, and alter the efficiency with which absorbed nutrients are used (Chalupa, 1984). Utilization of amino acids for milk production comprises the uptake of blood amino acids by secretory cells, followed by the intracellular metabolism of these amino acids in conjunction with those that are synthesized in the secretory cells (Mepham, 1982). Uptake of amino acids is determined by their concentration in the artery and by the rate of mammary blood flow. Based upon the concept that amino acids which are most limiting production will be extracted more efficiently from arterial blood, methionine, phenylalanine, leucine, and threonine are the most limiting amino acids for the mammary gland (Oldham, 1980).

Amino Acid Requirements of Lactating Dairy Cows

In recent years, several methods have been employed to determine amino acid requirements of the lactating cow. One method is based upon the hypothesis that an essential amino acid will not increase in blood plasma until the requirement for that amino acid has been met (Tamminga and Van Hellemond, 1977; Clark, 1975). The concentration of free amino acids in blood plasma is determined by intestinal absorption, endogenous synthesis, and utilization by the animal (Clark, 1975). Using this method, Broderick et al. (1974) determined methionine, lysine, and valine as the most limiting amino acids. Similarly, Rogers et al. (1987) suggested lysine may be used to a greater extent than methionine. The usefulness of plasma amino acid concentrations in the determination of limiting amino acids has been questioned (Foldager et al., 1980) due to factors other than milk production which influence their concentration in blood.

Another method of determining amino acid requirements of the mammary gland is the arterio-venous (AV) difference technique which is based on the differences in free amino acid concentration of arterial and mammary venous plasma combined with measurements of blood flow from the mammary gland (Clark, 1975). A simpler, factorial approach compares the input of amino acids in the blood from the intestine to their output in milk to identify the most limiting amino acids for milk synthesis. From this approach, Foldager et al. (1980) determined that the amino acids exhibiting the lowest ratio of uptake to output in milk were phenyalanine, lysine, methionine, and leucine, and were suggested as the amino acids most limiting for milk synthesis. From estimation of the minimal amount of blood flow needed for output of amino acids in milk, methionine, phenylalanine, threonine, and lysine were in lowest supply. With a group of cows at peak milk production (37 kg/day), Chandler and Polan (1972) determined the minimum transfer efficiencies for methionine, lysine, phenylalanine, tyrosine, and threonine were 96, 89, 76, 80, and 62%, respectively. Transfer efficiencies from cows on lower levels of production (33, 25, and 16 kg/day) still showed methionine as the most critical amino acid, although phenylalanine appeared to be more critical and lysine less critical.

It appears that determination of the first limiting amino acid for milk production is inconclusive. Utilization of methionine for milk protein synthesis and its demand for gluconeogenesis have made it a likely candidate limiting production (Tamminga and Van Hellemond, 1977). Several researchers have determined methionine as first limiting for milk or milk protein production (Chandler and Polan, 1972; Schingoethe et al., 1988; Dingley et al., 1975), while others have suggested lysine as first limiting or colimiting with methionine (Schwab et al. 1976; Rogers et al., 1987).

Other studies have been unable to determine the most limiting amino acids for milk production (Schwab and Satter, 1973).

Increased production responses have been more consistent when casein is administered postruminally than when individual amino acids are allowed to bypass the rumen (Clark, 1975). This may suggest that a combination of amino acids limit production (Tamminga and Van Hellemond, 1977). Tamminga and Oldham (1980) suggested that if one essential amino acid limits milk protein production, it may be caused by requirements of that amino acid for maintenance or gluconeogenesis.

The order of limiting amino acids would also be expected to change with the type of diet. Casper and Schingoethe (1988) found methionine and leucine to be most limiting when cows were fed barley and corn silage diets, whereas Schwab et al. (1976) concluded that lysine and methionine were first and second limiting, or colimiting, with diets high in corn and corn silage.

Utilization of Amino Acids for Milk Production

At high levels of production, microbial protein synthesis cannot meet the nitrogen requirements of the mammary gland. Consequently, a form of dietary protein must be fed to augment microbial protein supply to the small intestine (Orskov, 1970; Berger, 1986). Because excess ruminal ammonia is absorbed through the ruminal wall and converted to urea in the liver, degradable protein that exceeds the nitrogen requirements of the ruminal microbial population is wasted (Chalupa, 1984). Ruminal ammonia concentrations of 3 to 8 mg per 100 ml appear to be adequate for optimal synthesis of bacterial protein (Kaufmann and Lupping, 1982). Provided that the ration contains sufficient amounts of degradable protein to meet the requirements of ruminal microbes, increased dietary undegradable protein should increase the amount of amino acids available for absorption in the lower tract (Chalupa, 1982a). Kaufmann (1982) calculated the optimal ruminal degradability of feed protein was 65% in high yielding cows with a normal energy supply. However, during periods when dietary energy is inadequate, protein degradability should decline to less than 60%. Chalupa (1982b) and Orskov et al. (1981) suggested that the energy status of the cow also affects the amount of degradable protein required in the ration. A cow in negative energy balance would require a higher concentration of dietary crude protein, and the protein should be more undegradable than when the cow is in positive energy balance. This concept is based on the theory that body reserves provide more energy than protein and that energy from body reserves is used for tissue rather than ruminal microbial protein synthesis. During negative energy balance, energy would limit microbial protein synthesis and more dietary protein would need to bypass the rumen for absorption in the small intestine. Therefore, during early lactation when cows are mobilizing body tissue for milk production, the proportion of undegradable protein in the ration should be highest.

Newer systems of evaluating the protein requirements of ruminants (NRC, 1985; Burroughs et al., 1975) take into consideration microbial and dietary sources of protein, and recognize that the rate of degradation of protein sources differs greatly and influences the quantity of amino acids reaching the small intestine. Under most feeding conditions, the extent of ruminal protein degradation is a function of rate of proteolysis, ruminal retention time (Chalupa, 1984) and deamination rate (Satter, 1986). Lewis and Emery (1962) concluded that amino acids could be grouped according to their relative rate of deamination. They found that serine, cysteine, aspartic acid, threonine, and arginine were attacked most completely by ruminal micro-organisms. Glutamic acid, phenylalanine, lysine, and cystine formed an intermediate group, while tryptophan, methionine, alanine, valine, isoleucine, glycine, and proline formed a group in which deamination was slower.

The chemical nature of crude protein in a feed will determine whether it is converted to ammonia in the rumen or escapes to the lower tract (Berger, 1986). From results of solubility and kinetic studies, Pichard and Van Soest (1977) categorized nitrogen into three groups. Fraction A is composed of water-soluble nonprotein nitrogen and includes ammonia, amines, nitrate, and free amino acids. Fraction B includes true protein, which is degraded at a slower rate than fraction A nitrogen. There are many types of protein in the B fraction, and each has its own degradation rate. Fraction C includes unavailable nitrogen derived from heat damage or is indigenous to forage.

Determination of the extent of ruminal protein degradation in vivo is difficult because dietary and microbial protein must be quantified at the duodenum (Mertens, 1977). In addition, flow measurement and representative sampling of abomasal or duodenal digesta is difficult (Satter, 1986). Recent methods for evaluation of ruminal protein degradation involve in situ ruminal incubation of porous bags containing samples of the protein source. The disappearance of nitrogen from the bag during incubation is assumed to be degradable protein (Broderick, 1982). One advantage of the in situ method over in vivo methods is that the estimates of protein degradation are not biased by inaccuracies of microbial protein analysis. (Tamminga, 1979). Feedstuffs enclosed within a porous bag, however, are not entirely subjected to the dynamic state of the rumen.

Because of the difficulty in determination of protein degradability from in vivo and in situ methods and the impracticality of using these methods for routine feed analysis, in vitro methods measuring the solubility of feed proteins in mineral buffers or ruminal fluid have been developed. Waldo and Goering (1979) analyzed 15 feeds for protein solubility using four different techniques and suggested autoclaved ruminal fluid may be superior to mineral buffer solutions. Crooker et al. (1978) reported comparable results with autoclaved ruminal fluid and mineral buffer solutions. The solubility of protein from a feed is largely determined by the protein classes contained in it (Chalupa, 1982a). Wohlt et al. (1973) reported higher nitrogen solubility of feeds containing larger proportions of albumins and globulins than those containing larger proportions of prolamins and glutelins. However, albumins and globulins are usually higher quality proteins (Chalupa, 1982a). In most cases, when the solubility of a protein is low, the extent of ruminal degradation is reduced. However, high solubility of a protein does not guarantee, nor is it required, for degradation in the rumen (Chalupa, 1984; Clark and Davis, 1980). Broderick (1982) concluded that nitrogen solubility was a useful method of predicting ruminal protein degradation if the solvent used could accommodate the wide variation in protein degradation among feedstuffs, and if solubility data were correlated to in vivo estimates. Wohlt et al. (1973) concluded that nitrogen solubility could be of nutritional significance if a uniform procedure could be accepted which would give repeatable results and be duplicated readily in any laboratory.

Numerous studies have been conducted to determine the extent of degradation of different feedstuffs in the rumen, and summaries of these results have been reported by Satter (1986), Burroughs (1975), and the National Research Council (1985). In general, by-product feeds (dried brewers grains, corn gluten meal, fish meal, meat and bone meal, feather meal) contain less degradable protein than cereal grains or oilseed meals (Chalupa, 1982a). Loerch et al. (1983) concluded that escape protein was lowest for soybean meal (28.7%) and highest for blood meal (81.7%), whereas dehydrated alfalfa (66.3%) and meat and bone meal were intermediate (49.3%). Firkins et al. (1984) reported ruminal protein escape values of 54, 47, 26, and 14% of total protein for dried distillers grains, wet distillers grains, wet corn gluten feed, and dry corn gluten feed, respectively for steers consuming dry matter at 1.2% of body weight. Using lactating dairy cows consuming dry matter at approximately 2% of body weight, Santos et al. (1984) found higher ruminal protein degradation as a percent of dietary crude protein with rations containing soybean meal (70%) than for rations containing corn gluten meal (45%), wet brewers grains (52%), or distillers dried grains (46%). Rations were formulated so that each protein source provided approximately 50% of the total dietary protein. Zinn et al. (1981) concluded that the portion of protein escaping ruminal degradation was higher for corn gluten meal than soybean meal or cottonseed meal (46% vs 15 and 24%, respectively) when dry matter intakes of steers were 1.7% of body weight. When dry matter intakes reached 2.2% of body weight, 18% of the protein in soybean meal escaped ruminal degradation, whereas 61% of the protein in cottonseed meal and corn gluten meal escaped ruminal degradation (Zinn et al., 1981). Ruminal escape of meat and bone meal and linseed meal was 70 and 44% of supplemental protein. The decreased degradation of cottonseed meal and corn gluten meal protein as feed intakes were increased may have been related to increased ruminal passage rate (Ganev et al., 1979; Miller, 1973). Summarizing unpublished studies, Miller (1973) concluded that 69% of the protein in Peruvian fish meal was undegradable in the rumen of sheep fed at maintenance. At ad libitum intakes, the fish meal protein was completely undegraded in the rumen. Stern et al. (1983) concluded that 57% of the protein in corn gluten meal was undegradable in the rumen of lactating cows consuming dry matter in excess of 3% of body weight. Ruminal bypass values of 43, 50, 76, and 73% were reported by Zinn and Owens (1983) for soybean meal, cottonseed meal, meat and bone meal, and dry-rolled corn when steers consumed dry matter at 1.9% of body weight. In a second trial however, the proportion of ruminal undegradable protein of dry-rolled corn was 58% (Zinn and Owens, 1983). Using an in situ method, Barrio et al. (1986) reported that the proportion of ruminal undegradable protein from ground corn and ground wheat was 58 and 10%, respectively, after a 12-hour incubation.

Though extensive work has been conducted on the extent of ruminal protein degradation of different feedstuffs, the intestinal availability of high bypass proteins has been ignored. Loerch et al. (1983) showed that the percentage of nitrogen escaping ruminal degradation was significantly lower for soybean meal than blood meal, meat and bone meal, and dehydrated alfalfa (28.7 vs. 81.7, 49.3, and 66.3%, respectively). Even though bypass of nitrogen was highest for blood meal and lowest for soybean meal, apparent total tract nitrogen digestibility of blood meal and soybean meal were similar (80.4 vs. 82.1%). Apparent total tract nitrogen digestibility was intermediate for meat and bone meal (78.3%) and lowest for dehydrated alfalfa meal (71.2%). Santos et al. (1984) found that amino acid absorption from the small intestine was 70, 77, 71, and 66% of the amino acids entering the duodenum for diets containing soybean meal, corn gluten meal, wet brewers grains, and distillers dried grains, respectively. The quantity of amino acids absorbed per day was lowest for the soybean meal diet. This study indicates that even though ruminal degradation of the grain by-product proteins was lower than soybean meal, protein availability in the small intestine was not impaired.

Ration formulation to regulate the ruminal soluble or degradable component of crude protein in the diet could improve animal performance by management of the supply and balance of amino acids presented to the small intestine

(Clark and Davis, 1980;). Dingley et al. (1975) reported that increased proportion of soluble protein in the concentrate mixture significantly reduced the amount of essential and total amino acids presented to the mammary gland. Rogers et al. (1984) observed a 6.9 and 9.9% increase in milk yield and milk protein by infusion of sodium caseinate into the abomasum of lactating cows compared to cows fed supplemental protein and postruminally infused with water. Smaller increases in milk yield (4.9 and 1.6%) and milk protein yield (5.7 and 4.2%) were also noted with postruminal infusions of soybean meal and cottonseed meal when compared with postruminal water infusions. Postruminal infusions of the different protein sources did not significantly affect 4% FCM production, milk fat percentage or yield, or percent protein in milk.

Majdoub et al. (1978) found milk yields and milk composition were significantly increased when the diets of cows were formulated to contain high crude protein (15.3%) and low nitrogen solubility (21.8% of crude protein) rather than formulating the ration to contain high crude protein and high nitrogen solubility (42.3% of crude protein). Though nonsignificant, cows consuming the diet formulated to be low in crude protein (12.2%) and nitrogen solubility (22% of crude protein) yielded more milk and FCM than cows consuming diets formulated to contain higher crude protein with high nitrogen solubility and diets containing lower crude protein with high nitrogen solubility. They concluded that rations balanced for nitrogen solubility could reduce the absolute quantity of crude protein required, reduce the cost of the ration, and still maintain adequate milk production. Similar findings were reported by Murphy et al. (1986).

Holter et al. (1985) concluded that utilization of corn gluten meal to reduce the nitrogen solubility of silage-based diets could increase milk production per unit of grain fed. Polan et al. (1985) reported higher milk yields when cows were fed high-moisture corn concentrate mixtures containing wet brewers grains or dried brewers grains than when fed a high-moisture corn concentrate mixture containing soybean meal. Milk production was similar between cows fed wet and dried brewers grain, however, cows fed the wet brewers grain had higher milk protein concentrations. Broderick and Ricker (1988) fed supplements containing solvent-extracted soybean meal, expeller soybean meal and a blend of corn gluten meal and distillers dried grains with high-moisture corn and alfalfa haylage. Performance of cows fed the three rations was similar, even though the expeller soybean meal and the blend of corn gluten meal and distillers dried grains contained 60% of the crude protein supplied by the solvent-extracted soybean meal supplement.

Protein solubility can be decreased by heating the feedstuff. Heating proteins coagulates the higher quality albumin and globulins, while having little effect on the prolamine and glutelin fractions (Mertens, 1977). Kung and

Huber (1983) reported that heating soybean meal for 2 hours at 149 C reduced nitrogen solubility in Burrough's buffer from 26.5 to 3.9% and decreased nitrogen disappearance from nylon bags from 76.9 to 36.3%. Heating the soybean meal for 4 or 6 hours produced similar results as the 2 hour treatment except acid detergent insoluble nitrogen greatly increased from the 4 to the 6 hour treatment (8.9 vs. 19.7% of total nitrogen). Stern et al. (1985) compared ruminal protein degradation of concentrate mixtures containing either 32% soybean meal, 40% whole soybeans, or 38% whole soybeans extruded at temperatures of 132 or 149 C and reported that the proportion of protein degraded in the rumen was 73, 80, 66, and 60% of dietary protein. Absorption of essential amino acids in the small intestine (percent entering and grams/day) was highest for lactating cows fed diets containing extruded soybeans. Excessive heat can increase the irreversible binding with sugars (Broderick, 1975) and decrease lysine availability to the animal (Faldet et al., 1988). This response could decrease milk production if lysine is a limiting amino acid for milk production.

Schingoethe et al. (1988) utilized soybean meal heat treated by extrusion or a extruded blend of soybeans and soybean meal as a protein source for lactating cows. Total milk and 4% FCM increased when compared to normal, solvent extracted soybean meal. Percentages of fat and protein were lower when the extruded blend of soybean meal and soybeans was fed. Part of this decrease was explained by the higher fat content of soybeans. Sahlu et al. (1984) reported increased milk and 4% FCM production from cows fed extruded and heat treated soybean meal in comparison to cows fed regular soybean meal as a protein source. Most of the increase in production occurred prior to the eighth week of lactation, which would be when nutrient demands relative to milk production are highest. Percentages of protein and fat were not affected by the type of soybean meal fed. Similarly, Kung and Huber (1983) reported an advantage of 1.2 kg of milk per day when heated soybean meal provided a source of ruminal undegradable protein for lactating cows.

Formaldehyde or tannins have been used to chemically decrease ruminal protein degradation. These chemical agents form reversible cross linkages with amino acids which prevents the utilization of the protein by ruminal microbes, but is available to the animal when low abomasal pH breaks the cross linkages (Chalupa, 1982a). In a literature summary, Barry (1976) concluded that formaldehyde treatment increases total essential amino acid absorption from the small intestine, with little response or decreased absorption of some individual amino acids. Favorable production responses have been observed when formaldehyde treated soybean and rapeseed meal (Verite and Journet, 1977) and formaldehyde treated casein (Kenna and Schwab, 1981) have replaced conventional oil meals.

Although some studies illustrated an increased production response to ruminal undegradable protein (Majdoub et al., 1978; Murphy et al., 1986; Schingoethe et al., 1988; Polan et al.,1985; Verite and Journet, 1977), others (Orskov et al., 1981; Erdman and Vandersall, 1983) observed no response. Orskov (1981) suggested that when energy intakes of lactating cows were high, or energy was not limiting, the effect of protein source (high or low degradability) was minimal. When energy intakes were low, however, or cows were mobilizing body stores, supplementation with an undegradable protein source (fish meal) enhanced milk production. One explanation for this response was that when body tissue is mobilized, more energy than protein is made available for incorporation into milk production and thus, protein would be limiting at the small intestine. Erdman and Vandersall (1983) suggested that in their study, the amount of nitrogen or organic matter available for microbial growth may have been limiting, or specific amino acids, rather than total protein, was limiting.

Provision of ruminal undegradable protein to high producing dairy cows in early lactation could elucidate a production response if ruminal degradable protein supply satisfies microbial nitrogen requirements. Clark and Davis (1980) suggested that ruminal undegradable protein sources should be selected to supply amino acids that will complement the amino acids supplied by microbial protein.

Care should also be taken that overprotection or underprotection of the protein source does not occur (Crooker et al., 1983). Because wheat and barley protein is more rapidly degraded in the rumen than corn protein, utilization of ruminal undegradable protein supplements may be useful when barley or wheat grain comprise the major energy source in the ration. Axe et al. (1987) reported decreased solid nitrogen flow and increased liquid and total nitrogen flow to the duodenum when steers were fed an 80% wheat concentrate than when fed an 80% sorghum grain concentrate. If ruminal microbes are associated with the liquid phase during passage through the duodenum (Bergen, 1982), then the nitrogen digestibility of the liquid phase should be considered. Microbial protein is less digestible in the small intestine than feed protein (Berger, 1986).

With indirect methods, several researchers (Broderick et al., 1974; Chandler and Polan, 1972; Foldager et al., 1980) have suggested specific amino acids limit the milk production of lactating cows. The production response to ruminal undegradable protein sources could be the result of increased supply of limiting amino acids to the small intestine (Clark, 1975). Instead of increasing the supply of protein to the lower tract by utilizing high bypass proteins, newer methods which improve the quality of protein supplied to the small intestine have been evaluated. Since methionine and(or) lysine appear to limit milk production (Rogers et al. 1987; Broderick et al., 1974; Chandler and

Polan, 1972), recent work has been directed toward provision of these amino acids at the site of absorption.

Schwab et al. (1976) compared the production response of cows fed a corn-based ration during abomasal infusion with different combinations of amino acids. Abomasal infusion of methionine had no effect on milk yield or secretion of milk fat or protein, while lysine infusion accounted for 16% of the total response in milk protein yield that was found with the ten essential amino acids. Infusion of lysine and methionine together accounted for 43% of the total response, which led them to suggest lysine and methionine as first and second limiting or colimiting for milk protein production when rations consist primarily of corn, corn silage, and alfalfa-grass hay. Little effect on milk yield with abomasal infusion of other amino acids was reported except for a small increase in milk yield with the infusion of phenylalanine and threonine in combination. Similarly, Schwab and Satter (1974) found increased milk protein secretion when lysine and methionine were infused into the abomasum without affecting feed intake, milk yield, or milk fat secretion. However, in an earlier study, Schwab and Satter (1973) did not observe a response to abomasal infusion of amino acids. In a recent study, Schwab et al. (1988) supplied 12 grams of DL-methionine, 30 grams of L-lysine, or a combination of the two amino acids to the small intestine of lactating cows by duodenal infusion, and reported that yields of milk and milk protein during infusion of methionine plus lysine were greater than during methionine infusion alone.

Rapid deamination rates of amino acids by ruminal microbes (Lewis and Emery, 1962) would prevent intestinal absorption of orally administered amino acids, thus means of protecting amino acids from deamination in the rumen have been devised. One method has been to modify the amino acid by blocking the amino group, or blocking the carboxyl group by formation of a ester, or by making a analogue. With this method of protecting amino acids, it is essential that the compound not only escape ruminal degradation, but also be readily converted to the parent amino acid in the small intestine (Buttery and Foulds, 1977). Many methionine analogs have been found to be unstable in the rumen (Chalupa, 1975). A second approach is to coat the amino acid core with a lipid, or pH-sensitive copolymer. Papas (1984) reported methionine encapsulated in a pH-sensitive copolymer was 94% stable at ruminal pH, but released 94% of the methionine at abomasal pH. Similar results were reported by Rogers et al. (1987) with encapsulated methionine and lysine. Another approach has been to attempt to inhibit the deamination activity of the ruminal microbes (Chalupa, 1975).

Schingoethe et al. (1988) reported 15 g/head/d of ruminally protected DL-methionine increased daily milk production of cows from 32.2 to 33.8 kg/d when fed in conjunction with soybean meal. Although milk fat percentages were not affected by methionine supplementation, milk protein percentages were increased (2.99 vs 3.05%). Protected methionine supplementation for diets containing heat-treated soybean meal or an extruded blend of soybeans and soybean meal did not alter milk production, suggesting methionine was not limiting in those diets. Milk production response was similar between cows fed diets containing solvent-extracted soybean meal plus protected methionine and diets containing the other two forms of soybean meal. In a similar study, Illg et al. (1987) also found increased milk and 4% FCM production from cows supplemented with protected methionine. Milk protein percentage was also increased, while percentage milk fat was similar among methionine and non-methionine supplemented cows. In contrast, Casper et al. (1987) reported that supplementation of the same amount of protected DL-methionine had no effect on milk yield or milk fat percentage, but did increase the percentage of protein in milk. In this study, the amino acid content of feed relative to the amino acid content of milk protein indicated methionine as first limiting with lysine almost colimiting. If lysine was colimiting in this study, methionine supplementation would have made lysine first limiting which may have prevented a possible response.

Donken et al. (1987) reported no effect of supplementing cows with 15 g/d of ruminal protected methionine and 40 g/d of ruminal protected lysine on milk yield or milk fat percentage. The addition of these two protected amino acids did increase milk protein percentage and yield. The cows used during this trial were in mid-lactation, and the protein supplied by ruminal microbes may have been adequate for their level of production. Rogers et al. (1987) supplemented cows with different amounts of ruminal protected DL-methionine and L-lysine, but reported milk and 4% FCM production were similar between the control and amino acid supplemented cows. Ruminal protected lysine supplementation, however, increased milk and FCM production linearly within the treatment groups. Ruminal protected methionine and lysine were successful in increasing production of milk protein and they suggested that lysine improved the utilization of methionine.

Corn-corn silage based rations supplemented with the amino acid analogs di-hydroxymethyl-L-lysine-Ca and N-hydroxymethyl-DL-methionine-Ca separately or in combination had no effect on milk production or milk composition (Kenna and Schwab, 1981). Because the corn silage, concentrate, and amino acid derivatives were mixed together at feeding, the lack of response was attributed to the low pH of the ration, which could have resulted in dissociation of the amino acid derivatives prior to their consumption. Kaufmann and Lupping (1979), however, reported increased milk and milk protein yields, and Ward et al. (1988) reported milk, FCM, and milk fat production increased 3.6, 7.4, and 5.3%, respectively with the same methionine analog. Other studies with methionine hydroxy analog have reported increased milk fat production with no effect on milk production (Holter et al., 1972; Polan et al., 1970; Huber et al., 1984), while Griel et al. (1968) reported increased 4% FCM production. Increased milk fat content reported in these studies may have been due to altered lipid synthesis in the rumen (Buttery and Foulds, 1977; Oldham, 1980). Patton et al. (1970) reported that a major effect of methionine in the rumen was to stimulate the formation of polar lipids. Most of the increase in these lipids was associated with the protozoal population, which lends evidence to suggest methionine is limiting for ruminal protozoa. Holter et al. (1972) reported increased digestibility of fiber and fat with methionine hydroxy analog supplementation. Alternatively, methionine may be donating methyl groups for lipid synthesis at the mammary gland (Huber et al., 1984).

Amino acid supplementation studies have been conducted with corn-based diets. In comparison with other cereal grains, corn is lower in lysine and methionine than wheat. Because corn protein is slowly degraded in the rumen, microbial protein synthesis may be reduced with corn diets. This may also reduce lysine and methionine supply to the small intestine since lysine and methionine content of ruminal microbes is relatively high (Santos and Satter, 1982). Because feed proteins differ in amino acid content and extent of ruminal degradation, ration composition may influence which amino acids are limiting milk production and (or) milk protein synthesis (Schwab et al. 1976).

Comparatively fewer studies have been conducted with rations containing more rapidly degraded grain sources such as wheat or barley. Casper and Schingoethe (1988) supplemented cows fed barley-based diets with 15 grams of protected DL-methionine and reported increased milk protein percentages but no effect on milk production or milk fat percentage. With 60% wheat-based concentrate mixtures fed to lactating cows, Nalsen et al. (1987b) reported no effect of supplementation with .4% (as-fed) of a ruminal protected amino acid source containing 37% lysine and 11.8% methionine. Wheat and barley protein is degraded more rapidly in the rumen than corn protein (Chalupa, 1982a) which may increase microbial protein flow, and therefore lysine and methionine flow to the small intestine than is encountered with normal corn-soybean meal rations. However, the potential of increasing the production response of cows fed wheat-based diets by supplying additional lysine and methionine at the site of absorption may exist.

CHAPTER III

SUPPLEMENTAL ENERGY VS BYPASS PROTEIN FOR LACTATING DAIRY COWS FED HIGH WHEAT CONCENTRATE MIXTURES

Abstract

Twenty-four multiparous Holstein cows were fed 60% grain concentrate mixtures containing corn supplemented with cottonseed meal (control) or wheat supplemented with cottonseed meal, whole cottonseed, or corn gluten meal and blood meal. The concentrate mixtures and alfalfa hay were fed separately in a 50:50 ratio. Cows fed the control ration consumed more dry matter per day (23.7 kg) than cows fed the wheat rations containing cottonseed meal (22.0 kg) or whole cottonseed (21.8 kg). Daily milk yields were highest for cows fed the corn ration (30.4 kg), lowest for cows fed wheat supplemented with cottonseed meal (27.4 kg), and intermediate for cows fed wheat supplemented with whole cottonseed (28.6 kg) or corn gluten meal and blood meal (28.4 kg). Whole cottonseed tended to increase percentage of milk fat, while corn gluten meal and blood meal tended to increase percentage of milk protein. Blood urea-nitrogen concentrations were significantly higher for cows fed wheat.

Ruminal acetic to propionic acid ratio was highest with the control ration. Ruminal pH appeared to decrease with wheat feeding. Supplemental ruminal undegradable protein or energy appears to aid in restoring milk yield with wheat diets.

Introduction

There has been increasing interest in utilizing wheat for livestock feeding due to declining wheat prices caused by surplus wheat production. Previous work has evaluated the feeding value of the softer wheat varieties. McPherson and Waldern (1969) reported that dry matter intake, milk yield and milk protein content of lactating dairy cows were not altered by level of rolled soft white wheat in the grain mix. Intake of forage and concentrate was similar when ground soft red wheat comprised one-third and two-thirds of the concentrate mixture, although milk yield and milk fat content declined with increased wheat (Cunningham et al., 1970).

When the percentage of hard red winter wheat in the concentrate mixture increased from 0 to 80%, milk yield decreased linearly (Faldet et al. 1986b). Nalsen et al. (1987a) substituted hard red winter wheat for corn on a weight or a protein basis. As-fed protein content of the three concentrate mixtures were 12.2, 15.1 and 12.2% and ruminal undegradable protein concentrations were 6.2, 3.8 and 2.6% respectively. Milk yield was lowest when wheat was added on an equal protein basis but was intermediate when wheat was substituted for corn on a weight basis.

During early lactation, microbial protein flow to the small intestine may not be sufficient to meet requirements for milk production (Orskov, 1970). Adding a source of protein that escapes ruminal digestion may increase the supply of protein available for absorption in the small intestine. Because wheat contains a larger proportion of ruminal degradable protein than corn (Mertens, 1977), a supplemental protein source that is resistant to ruminal degradation may maintain milk yield when wheat comprises the major energy source in the ration.

High producing cows are usually in a negative energy balance in early lactation. Dietary fat may increase the caloric intake of lactating dairy cows without increasing the proportion of concentrate in the ration. Increasing the proportion of concentrate above 60% of the total ration, can increase the problems associated with ruminal starch fermentation, such as ruminal acidosis, milk fat depression, and displaced abomasums (Clark and Davis, 1980). Some studies have reported increased milk (Anderson et al., 1979) and fat-corrected milk (Smith et al., 1981; Horner et al., 1986) production with whole cottonseed feeding. The effects of increasing the energy density of wheat-based rations using whole cottonseed on lactational performance has not been documented. The objective of this experiment was to determine whether ruminal undegradable protein or additional energy would be beneficial in 60% wheat-based concentrate mixtures in regards to milk yield and composition, and to compare the effect of these diets on ration digestibility and ruminal and blood parameters.

Materials and Methods

Twenty-four Holstein cows in their second or greater lactation were started on a 12-week feeding trial 6 to 8 weeks postpartum. A switchback design with three 4-week periods was used (Lucas, 1956). The first two weeks of each period were allowed for adjustment to rations and prevent carry-over effects, whereas the last two weeks of each period were used to compare treatments. Cows were assigned by calving date to one of twelve treatment sequences (Appendix, Table XIV). Each treatment sequence included two treatments, one of which was applied during the first and third period, while the other was applied during the second period.

Treatments consisted of four concentrate mixtures (Table III). The control ration was a 60% corn-based concentrate mixture. Previous work (Nalsen et al., 1987a) has shown intermediate milk yield when wheat replaces corn on a weight basis, rather than balancing the concentrate mixtures for equal protein, therefore, the three wheat-based mixtures contained 60% ground hard red winter wheat. The wheat-based concentrate mixtures were calculated to contain similar amounts of total protein. Sources of protein

TABLE III

CONCENTRATE MIXTURES FED WITH ALFALFA HAY[1]

Composition	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)
	RATION			
Ingredients, % as-fed				
Corn	60.0	--	--	9.0
Wheat[2]	--	60.0	60.0	60.0
Sorghum (Milo)	5.5	5.5	5.5	--
Cottonseed meal	10.0	10.0	--	--
Blood meal	--	--	--	1.5
Corn gluten meal	--	--	--	5.0
Whole cottonseed	--	--	20.0	--
Soybean hulls	15.0	15.0	5.0	12.0
Cottonseed hulls	--	--	--	3.0
Fixed portion[3]	9.5	9.5	9.5	9.5
Calculated analysis, as-fed				
Net energy, Mcal/100 kg	163.5	163.5	173.6	162.9
Crude fiber, %	7.9	8.4	6.9	7.7
Total protein, %	12.0	14.3	13.7	14.2
Rumen undeg. protein, %	5.54	3.60	3.32	4.99
Rumen undeg. lysine, %	.19	.13	.12	.16
Rumen undeg. methionine, %	.09	.05	.06	.08
Actual analysis, % as-fed				
Crude protein	10.9	14.3	13.0	14.8
Dry matter	88.0	88.9	89.3	88.9
Total ration				
Calculated analysis, as-fed				
Net energy, Mcal/100 kg	138.2	138.2	143.3	137.9
Crude fiber, %	17.0	17.3	16.5	16.9
Crude protein, %	13.9	15.0	14.7	15.0
Rumen undeg. protein, %	4.74	3.77	3.63	4.47
Rumen undeg. lysine, %	.20	.17	.16	.18
Rumen undeg. methionine, %	.07	.05	.05	.06

[1]Concentrate:forage, 50:50 (dry basis).

[2]Hard red winter wheat, test wt. 61 lb/bu.

[3]Fixed portion of concentrate mixture: Molasses 5.0, dicalcium phosphate 2.0, sodium bicarbonate 1.25, salt .75, magnesium oxide .5%.

supplied in the mixtures varied in order to obtain different amounts of energy and ruminal undegradable protein (RUP). The corn control concentrate and the wheat concentrate containing cottonseed meal (CSM) were identical except wheat was substituted for corn on a weight basis. The wheat ration containing whole cottonseed (WCS) utilized 20% whole cottonseed in the concentrate mixture, to maintain a whole cottonseed level commonly used by dairy producers. Utilizing 20% whole cottonseed reduced total protein content of the concentrate mixture compared to the wheat ration containing cottonseed meal; however, it provided additional energy (NE_1) and maintained crude fiber at an acceptable level. Five percent corn gluten meal and 1.5% blood meal was used in the fourth wheat concentrate mixture (High RUP) to provide protein similar to the CSM ration while also more closely matching the RUP content of the control ration.

Alfalfa hay was the only source of forage, and was fed separately from the concentrate mixture. The concentrate and forage were fed twice daily in individual stanchions at 12-h intervals, the hay being fed three h after the concentrate feeding. Each cow was fed to appetite and feed intakes were recorded daily. Daily weigh-back of hay and concentrate were composited weekly for analysis of dry matter (DM) and crude protein (CP). The rations were adjusted every two days based upon the amount of weigh-back of hay or concentrate in order to maintain a 50:50 concentrate to forage intake (DM basis). Weekly samples of alfalfa hay and the four concentrates were also taken for analysis of DM (forced-air oven, 60 C^{o}, 48 h) and CP by macro-kjeldahl (AOAC., 1975).

Cows were milked twice a day and milk weights were recorded at each milking. On four consecutive milkings of each week, milk samples were obtained to determine fat and protein content. Concentrations of fat and protein in milk were determined by the Oklahoma State DHIA Laboratory. Each cow was weighed on two consecutive days prior to the trial and on the last and first day of each period. The cows were weighed just prior to milking, therefore, the milk weight of the following milking was deducted from the respective cow's body weight. When cows were not in the milk parlor or feeding they were confined in a large open pen with access to an open-faced shed.

At the end of each period, ruminal fluid samples were taken by stomach tube 3 to 4 h after the morning concentrate feeding to determine ruminal pH, ammonia-N and volatile fatty acid concentrations. A minimum of 300 ml of ruminal fluid was strained through a double layer of cheesecloth, and pH measured immediately with a pH meter. Two hundred ml of ruminal fluid were acidified (8 ml 50% hydrochloric acid) and frozen (-20 C^{o}) for later analysis of ammonia-nitrogen by the hypochlorite procedure (Broderick and Kang, 1980). One hundred ml of ruminal fluid was mixed with 1 ml of saturated mercuric chloride and then frozen (-20 C^{o}) for later determination of volatile fatty acid (VFA) concentrations. Later, these samples were thawed and centrifuged (2,000 x g) for 10 min. One ml of 25% (w/v) meta-phosphoric acid was then added to 5 ml of the supernatant solution and centrifuged a second time for 20 min at 25,000 x g. One ml of supernatant was then withdrawn, combined with .2 ml of 2-ethylbutyric acid (internal standard), vortexed, and subjected to gas chromatography. During ruminal fluid sampling, blood samples were obtained from the median caudal vein. Oxalic acid (.15 ml 1.12 M) was added to prevent coagulation. Blood samples were chilled (0 C^o), centrifuged (2,000 x g for 30 min), frozen (-11 C^o), and later analyzed for blood urea-nitrogen (urea-N) concentration (Fawcett et al., 1960).

To determine digestibility of DM, neutral detergent fiber (NDF), and CP, .28% chromic oxide (Cr_2O_3) was added to the four concentrate mixtures during the last three weeks of the second and third period. Fecal grab samples were taken from 16 cows for 4 days at 4 h intervals (0350, 0750, 1150, 1550, 1950, and 2350 h). Chromium content of fecal, grain, and weigh-back samples were determined by spectrophotometry using a modification (Stevenson, 1962) of Stevenson and de Langen (1960). Neutral detergent fiber content of grain, hay, and fecal samples collected during the digestibility study were determined by the method of Goering and Van Soest (1970).

During the study, severe mastitis was encountered with four cows. Data collected on one cow which encountered mastitis was excluded from the analysis. Data collected in the period in which the other three cows became infected with mastitis were excluded from the analysis. Lung edema encountered with one cow during the trial made it necessary to exclude her from the period this problem was encountered.

Period means for intake, milk yield, milk composition, and ruminal and blood data for each cow were subjected to least squares analysis with period, cow and treatment included in the model. The model for the digestibility data contained cow, block, and treatment in the model, with milk yield and concentrate and hay intake of the respective cow included as covariates. Treatment comparisons were made using a protected LSD.

Results and Discussion

Total dry matter consumption was higher ($P<.05$) for cows fed the corn-based concentrate mixture (23.7 kg/d) than for cows fed the wheat-based mixtures containing CSM and WCS (21.9 kg/d, Table IV). Dry matter intakes for cows fed the wheat ration containing High RUP were intermediate (22.8 kg/d). Previous reports have shown decreased dry matter intake when wheat comprised greater than 50% of the concentrate mixture (Cribeiro et al., 1979; Nalsen et al., 1987a). In contrast, Faldet et al. (1986b) reported similar dry matter intakes of cows fed concentrate rations containing up to 80% wheat. Although wheat intake averaged 7.7 kg/d, no problems were noted with palatability or

TABLE IV

FEED INTAKE OF LACTATING COWS FED CONCENTRATE MIXTURES CONTAINING CORN OR WHEAT WITH DIFFERENT PROTEIN SOURCES

	RATION				
Item	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)	SE
Dry matter intake, kg/d					
Concentrate mixture	12.2[a]	11.2[b]	11.2[b]	11.6[ab]	.24
Alfalfa hay	11.5[a]	10.7[b]	10.7[b]	11.2[ab]	.20
Total	23.7[a]	21.9[b]	21.9[b]	22.8[ab]	.39
Intake, % of body weight					
Actual	3.80[a]	3.50[b]	3.56[b]	3.60[b]	.063
Calculated[1]	3.28[a]	3.06[c]	3.16[b]	3.14[bc]	.031
Calculated NE_l intake, Mcal/d					
Concentrate mix	22.37[a]	20.50[b]	21.68[ab]	21.29[ab]	.440
Hay	14.44[a]	13.37[b]	13.47[b]	13.99[a]	.246
Total	36.82[a]	33.87[b]	35.14[ab]	35.28[ab]	.624
Protein intake, kg/d					
Concentrate mix	1.54[c]	1.80[b]	1.64[c]	1.95[a]	.038
Hay	2.50	2.31	2.35	2.43	.052
Total	4.04[b]	4.11[b]	3.98[b]	4.38[a]	.074
Requirement[2]	2.98[a]	2.72[c]	2.83[b]	2.84[b]	.030
% of requirement[2]	137[b]	152[a]	142[b]	155[a]	2.6
Calculated RUP intake, kg/d					
Total	1.26[a]	.92[c]	.87[c]	1.13[b]	.019
Requirement[2]	1.08[a]	.99[c]	1.02[b]	1.03[b]	.010
% of requirement[2]	117[a]	94[c]	87[d]	111[b]	1.8

[1]From McCullough (1981).

[2]From NRC (1988).

[abcd]Means within a row with different superscripts differ, (P<.05).

acceptability. Increasing the energy content of the wheat ration (WCS) did not appear to affect dry matter intake. Similarly, utilizing whole cottonseed to increase the energy density of barley (Anderson et al., 1979) and corn (Horner et al., 1986) diets did not affect feed intake of lactating cows. Coppock et al (1985), however, reported a linear decrease in dry matter intake as whole cottonseed was increased in the ration.

Calculated NE_l intake was highest ($P<.05$) for cows fed the corn ration (36.82 Mcal/d) and lowest for cows fed the CSM ration (33.87 Mcal/d, Table IV). Calculated NE_l intake was intermediate for cows fed the WCS and High RUP rations (35.14 and 35.28 Mcal/d). Though calculated NE_l content was highest for the WCS ration, the lower intake of this diet resulted in intermediate intake of NE_l.

Protein intake exceeded NRC (1988) requirements for all treatments (Table IV). Protein content of the alfalfa hay utilized in this study was higher (21.34% CP) than anticipated (17.5% CP). This, along with the higher than expected feed intake (Table IV), attributed to the underestimation of protein intake. The calculated daily intake of RUP paralleled the calculated RUP content of the concentrate mixtures. Daily intake of RUP exceeded NRC (1988) requirements when cows were fed the corn ration and the wheat ration containing blood meal and corn gluten meal (High RUP). When cows consumed the wheat rations containing

CSM and WCS, RUP intakes were below requirements (NRC, 1988).

Apparent digestibilities of DM, CP, and NDF were lower for cows fed the corn-based ration ($P<.05$), than for cows fed the wheat-based rations (Table V). DePeters and Taylor (1985) reported apparent digestibilities of 67, 66, and 51% for DM, nitrogen, and NDF, respectively, when lactating cows were fed a concentrate containing 65% corn (DM-basis) in a 50:50 ratio with alfalfa hay. Daily DM intakes in their study averaged 18.5 kg/day, whereas cows fed the corn-based diet in this study consumed 23.8 kg/d. Higher intake may have increased passage of feed particles and depressed digestion (Coppock, 1985). Increasing feed intake of lactating cows affects digestibility of starch and crude fiber more than other feed components (Robertson et al., 1974). The inclusion of 15% soybean hulls in the corn concentrate mixture, may have also depressed digestibility (Van Soest, 1982).

Supplemental protein source did not alter the digestibility of the wheat rations (Table V), even though the High RUP ration contained high bypass protein sources (corn gluten meal and blood meal). Loerch et al. (1983) concluded that total tract digestibility of blood meal and soybean meal was similar. Santos et al. (1984) reported that amino acid absorption in the small intestine was similar for diets containing soybean meal and corn gluten meal. The lower protein digestibility, coupled with the

TABLE V

RATION DIGESTIBILITY AND AVAILABILITY OF NITROGEN WITH LACTATING COWS FED CONCENTRATE MIXTURES CONTAINING CORN OR WHEAT WITH DIFFERENT PROTEIN SOURCES

	RATION				
Item	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)	SE
Apparent digestibility, %					
Dry matter	54.7^{b}	66.8^{a}	62.3^{a}	66.7^{a}	1.73
Crude protein	53.1^{b}	69.3^{a}	67.2^{a}	71.4^{a}	2.58
NDF	36.2^{b}	51.1^{a}	54.2^{a}	50.7^{a}	3.31
Calculated available[1]					
Crude protein, %	8.21	11.61	11.02	11.94	
Lysine, %	.36	.51	.48	.50	
Methionine, %	.12	.15	.15	.16	

[1]From calculated ration composition and crude protein digestibility.

[ab]Means within a row with different superscripts differ, (P<.05).

lower protein content of the corn ration (Table III) would reduce the percentage of protein, lysine and methionine available to cows in comparison to the wheat rations (Table V). The calculated percent available protein, lysine, and methionine was highest with the High RUP ration, assuming lysine and methionine digestibility paralleled crude protein digestibility. Digestibility of lysine and methionine may be higher than that of crude protein (Storm et al., 1983).

Summarizing earlier studies, Palmquist and Jenkins (1980) concluded that dietary fat can depress ruminal fiber digestion. This has also been demonstrated in vitro (Chalupa et al., 1984). Several studies (Palmquist and Conrad, 1978; Palmquist and Conrad, 1980; Smith et al., 1981; van der Honing et al., 1981), however, have shown no effect of dietary fat on ruminal fiber digestion. Similarly, whole cottonseed did not depress neutral detergent fiber digestibility in the present study (Table V).

Cows fed the corn ration produced more milk ($P<.05$) than cows fed the wheat-based rations (Table VI). Cows fed the wheat concentrate containing WCS and High RUP produced significantly more milk than cows fed the 60% wheat mixture with CSM. The wheat-based concentrates containing WCS and RUP supported similar milk production. Decreased milk yield with the wheat-based diets may be attributed, in part, to the lower intake of these diets. Consequently, the efficiency of converting feed DM into milk (kg milk/kg feed

TABLE VI

WEIGHT CHANGE, MILK PRODUCTION AND COMPOSITION OF LACTATING COWS FED CONCENTRATE MIXTURES CONTAINING CORN OR WHEAT WITH DIFFERENT PROTEIN SOURCES

	Ration				
Item	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)	SE
Milk yield					
kg/day	30.6[a]	27.5[c]	28.7[b]	28.9[b]	.42
kg/kg feed DM	1.28	1.25	1.29	1.28	.025
Fat test, %	3.55	3.38	3.48	3.43	.102
FCM, kg/day	28.4[a]	24.8[c]	26.4[b]	26.3[b]	.46
Protein, %	3.14	3.15	3.12	3.20	.028
Body weight changes					
kg/4 wk period	-3.3	14.4	23.1	10.8	7.21

[abc]Means within a row with different superscripts differ ($P<.05$).

DM) was similar among the four rations. The increased production response to bypass protein supplementation agrees with studies utilizing RUP sources with corn-based diets (Kung and Huber, 1983; Holter et al., 1985; Broderick and Ricker, 1988). Nalsen et al. (1987b) reported increased milk yield when cows were fed a wheat-based ration containing corn gluten meal, blood meal, and protected lysine and methionine compared to cows fed a wheat-based ration containing soybean meal or soybean meal plus protected lysine and methionine. In the present study, RUP intake of cows fed the wheat ration containing High RUP exceeded the NRC (1988) requirement, but did not restore milk yield to that of cows fed the corn-based ration.

The production response observed with cows fed the WCS ration may have been due to increased calculated NE_l intake in comparison to cows fed the CSM ration (Table IV). Anderson et al. (1979) reported increased milk production in two trials where whole cottonseed replaced an equivalent amount of the concentrate mixture. In the first study, the increased intake of digestible energy accounted for 75% of the production response. In the second study, replacement of 20% of the regular concentrate elicited a production response over that of cows fed the control ration. When whole cottonseed were supplied to provide energy equivalent to the control ration, milk production was intermediate.

Because milk fat percentage did not differ statistically between treatments, fat corrected milk (FCM) production paralleled actual milk production (Table VI). Rapid degradation of wheat starch in the rumen could decrease milk fat production, however, the addition of mineral buffers to the ration (Table III), and adequate intake of alfalfa hay may have prevented this problem. Fat supplementation has decreased milk fat concentration (van der Honing et al., 1981; Steele, 1984), however, Anderson et al. (1979) reported that milk fat concentrations were increased by increasing the energy density of rations using whole cottonseed, possibly due to partial bypass of the oil in the seed (Palmquist and Jenkins, 1980). Palmquist and Conrad (1980) reported increased milk fat percentage by utilizing fat rather than grain to increase energy content of rations.

Milk protein percentages did not differ statistically among treatments, however, concentrations tended to be lower with the WCS ration and higher with the High RUP ration (Table VI). Increased milk protein concentration would suggest increased amino acid absorption from the small intestine with cows fed the High RUP ration. Other studies have reported increased milk protein concentrations when proteins bypassed the rumen (Polan et al., 1985; Erdman and Vandersall, 1983; Majdoub et al., 1978). Anderson et al. (1979) found no effect of whole cottonseed on fat or protein percentage. However, Smith et al. (1981) and DePeters et al. (1985) reported increased milk fat percentage and decreased milk protein percentage with whole cottonseed.

Milk protein content is determined by lactose and protein secretion from the alveolar secretory cells (Thomas, 1983). Smith et al. (1978) suggested that when protected fats are fed to ruminants, the availability of glucose for lactose synthesis is reduced.

Body weight changes within periods were highly variable, therefore, statistical differences among treatments were not detected (Table VI). There was, however, a tendency for cows to gain weight during periods of wheat feeding. Cows fed the WCS ration appeared to gain more weight than other cows.

Ruminal pH appeared to decline when cows were fed the wheat rations (Table VII). This was more apparent with the CSM ration. Within the wheat-based rations, ruminal pH was highest among cows fed whole cottonseed and similar to cows fed the corn ration. As previously mentioned, mineral buffers were added to all rations, which may have minimized changes in ruminal pH so that problems with digestive disorders did not occur. Faldet et al. (1986b) noted a linear decrease in ruminal pH as the proportion of wheat was increased.

Total VFA concentrations tended to increase with wheat feeding, which may have decreased ruminal pH (Table VII). There was a inverse correlation between ruminal acid concentrations and ruminal pH (r=-.81). Increased ruminal VFA concentrations and decreased ruminal pH have been reported when wheat was fed to steers (Axe, 1987; Oltjen,

TABLE VII

RUMINAL AND BLOOD PARAMETER RESPONSES OF LACTATING COWS FED CONCENTRATE MIXTURES CONTAINING CORN OR WHEAT WITH DIFFERENT PROTEIN SOURCES

Item	RATION				
	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)	SE
Ruminal fluid pH	6.26	5.95	6.24	6.15	.095
Ruminal volatile fatty acids					
Total conc., mm/l	221.9	272.5	235.0	253.2	20.48
Molar %					
Acetic	64.4	61.6	61.2	61.1	1.54
Propionic	21.7	22.9	24.8	23.9	1.82
Butyric	11.5	12.4	11.1	11.9	.94
Isobutyric	.42	.22	.03	.27	.094
Valeric	1.12	.90	.88	1.11	.165
Isovaleric	.93[b]	2.07[a]	2.04[a]	1.72[a]	.219
Acetic to propionic ratio	3.1	2.9	2.7	2.7	.27
Ruminal NH_3-N, mg/dl	5.0	6.4	6.0	6.4	1.05
Blood urea-N, mg/dl	11.8[b]	16.7[a]	15.6[a]	16.8[a]	1.15

[ab]Means within a row with different superscripts differ (P<.05).

1966; Oltjen, 1967). Although molar percentages of acetic and propionic acids did not differ significantly among treatments, the wheat rations appeared to decrease acetate and increase propionate compared to cows fed the corn control ration. Thus, conditions for milk fat synthesis were more favorable for the corn diet. Similarly, Axe et al. (1987) reported decreased molar proportions of acetate and increased molar proportions of propionate in ruminal fluid of steers when wheat replaced sorghum grain in the concentrate mix. There was a tendency for higher proportions of propionate in ruminal fluid of cows fed the WCS ration, which may have resulted in higher weight gains with cows fed whole cottonseed. A decreased acetate:propionate ratio would decrease body fat mobilization and increase tissue fat synthesis (Van Soest, 1963; Palmquist and Jenkins, 1980). Ruminal isovaleric acid concentrations were higher ($P<.05$) when cows were fed the wheat-based rations than when fed the corn control ration. Leucine is deaminated and decarboxylated to isovalerate in the rumen (Menahan and Schultz, 1964). Increased ruminal degradation of leucine with the wheat rations may have resulted in increased concentration of isovaleric acid.

The decreased feed intake of cows fed the wheat-based rations in this trial may have been due to altered ruminal fermentation with wheat. Wheat starch is more readily fermented in the rumen than corn starch (Axe et al., 1987) which may be related to decreased feed intake in feedlot cattle (Britton and Stock, 1987). Fulton et al. (1979) used four cannulated steers in a fermentation and intake study comparing corn- and wheat-based diets. Of the parameters monitored, ruminal pH was most closely related to the decreased intakes reported with the wheat-based diet. Depressed feed intakes were related to low ruminal pH with sheep fed wheat (Lee et al., 1982). In the present study, consumption of the wheat-based diets resulted in nonsignificant decreases in ruminal pH. The role of volatile fatty acids on feed intake may also need to be considered (Theurer and Wandely, 1987).

Ruminal ammonia-N concentrations tended to increase with the wheat-based rations, suggesting increased ruminal protein degradation with wheat grain (Table VII). Wheat also increased ($P<.05$) blood urea-N concentrations compared to cows fed the corn-based ration, suggesting that the amount of ruminal degradable protein in wheat exceeded the ability of ruminal microbes to assimilate ammonia. Neither added energy nor bypass protein significantly altered the ruminal ammonia-N or blood urea-N of cows fed the wheat-based rations, however, there was a tendency for reduced blood urea-N concentrations and ruminal ammonia-N concentrations for cows fed the wheat ration containing WCS in comparison with the wheat ration containing CSM. The lower protein content of the wheat ration with WCS may have contributed to this effect. Alternatively, protein in whole cottonseed may be degraded at a slower rate than cottonseed meal protein.

The economic feasibility of 60% wheat concentrate mixtures (Table VIII) was determined using 10 year average (1978 to 1987) feed prices for corn, wheat, milo, cottonseed meal, blood meal, corn gluten meal, and molasses, and current prices (September, 1988) for other feed ingredients. A 10 year average (1978 to 1987) milk price was also used. Because of the price differential between wheat and corn ($6.13 vs $4.67/cwt), the greatest return over feed costs/cow/day was found with the corn control ration. Among the wheat-based rations, the greatest return over feed costs was found with the WCS and High RUP rations. Alternative protein sources fed with wheat-based diets appear to be more economically feasible than conventional protein sources such as cottonseed meal. The effect of altering the price of wheat and corn on the difference one might expect in return over feed costs was evaluated for the corn ration vs the CSM, WCS, and High RUP rations (Appendix, Table XVIII). For example, if the price of wheat was $3.00/cwt and corn was $3.00/cwt, and other feed prices remained unchanged, the return over feed costs/cow/day would be $.83 higher with the corn ration than with the CSM ration. Similarly, by altering the price of cottonseed meal, whole cottonseed, blood meal, and corn gluten meal, comparisons between the WCS and CSM ration (Appendix, Table XIX), the High RUP and WCS ration, and the High RUP and CSM ration (Appendix, Table

TABLE VIII

ECONOMICS OF FEEDING WHEAT WITH DIFFERENT PROTEIN SOURCES

	RATION			
Item	Corn Control	Wheat (CSM)	Wheat (WCS)	Wheat (High RUP)
Milk yield, lb/cow/day	67.32	60.50	63.14	63.58
Value of milk, \$/day[a]	8.66	7.62	8.06	8.06
Feed costs[b]				
Conc. mix., \$/cwt	5.03	5.91	6.55	6.19
Alfalfa, \$/cwt	3.96	3.96	3.96	3.96
Ration consumed, \$/day	2.68	2.69	2.88	2.88
Return over feed costs/cow, \$	5.98	4.93	5.18	5.18

[a]Milk priced at \$12.79/cwt (1978 to 1987 average) for 3.5% test, with \$.16 differential.

[b]Ten year average (1978 to 1987) ingredient prices when available: Hard red winter wheat @ \$6.13 and corn @ \$4.66/cwt.

XX) were made. The economics of feeding a blend of blood meal and corn gluten meal or whole cottonseed with wheat were very similar. A greater return over feed costs with feeding bypass protein rather than supplemental energy, however, may be more apparent in states where a premium is paid for milk protein.

This study suggests that feeding bypass protein or supplemental energy with wheat-based rations increases milk yield, improves the conversion of feed into milk, and is more economical than feeding cottonseed meal with wheat rations. Corn was still superior to wheat in regards to milk yield, partly due to higher feed intake. Milk protein percentage tended to decline with whole cottonseed feeding and was highest when cows were fed bypass protein, which may be a critical factor as the milk industry moves toward increased milk protein output. Ruminal parameters were not altered significantly by grain, protein, or supplemental energy, though ruminal characteristics for milk fat production favored the corn ration.

CHAPTER IV

PROTEIN AND AMINO ACID SUPPLEMENTATION OF WHEAT-BASED RATIONS FOR LACTATING DAIRY COWS

Abstract

Twenty-four lactating Holstein cows were used to compare wheat-based concentrate mixtures supplemented with different protein sources, with or without protected amino acids. Treatments were concentrate mixtures composed of: a) 45% corn with cottonseed meal, b) 60% wheat with cottonseed meal, c) 60% wheat with blood meal and corn gluten meal, d) treatment "c" plus protected lysine and methionine. The complete rations contained 55% concentrate, 30% sorghum silage, and 15% alfalfa hay. Daily dry matter intake was highest for cows fed the corn control ration. Milk yields averaged 34.3, 32.3, 31.5, and 32.3 kg/d, respectively, and were highest for cows fed the corn ration, and similar for cows fed wheat-based rations. Cows fed bypass protein, however, converted feed more efficiently into milk. Milk fat percentages were similar among treatments and averaged 3.64%. Milk protein content was highest with the wheat ration containing supplemental lysine and methionine.

Ruminal acetate percentages were highest from cows fed the corn ration. Ruminal pH and ammonia-nitrogen concentrations tended to decrease, while blood urea-nitrogen tended to increase with wheat feeding. Feeding corn was more economical than feeding wheat. Although milk yields were not affected by bypass protein or protected lysine and methionine, this study suggests an advantage in feed conversion with bypass protein. In addition, lysine and methionine appear to limit milk protein synthesis with wheat-based diets.

Introduction

Earlier research has shown that wheat can constitute a substantial portion of the concentrate mixture for dairy cows in early lactation without creating "off feed" or acidotic conditions (Faldet et al., 1986a; Faldet et al., 1986b; Cunningham et al., 1970). Faldet et al. (1986b) fed up to 80% hard red winter wheat in the concentrate mixture and did not observe digestive disorders among lactating dairy cows.

Tommervik and Waldern (1969) and McPherson and Waldern (1969) reported no difference in dry matter intake or 4% fat-corrected milk production among cows fed varying levels of soft wheat in the concentrate mixture. Utilization of hard red winter wheat, however, generally decreases milk yield (Faldet et al., 1986a; Faldet et al., 1986b; Nalsen et al., 1987a; Nalsen et al., 1987b). When the protein content of wheat diets was increased (Nalsen et al. 1987b), or ruminal undegradable protein was added (Nalsen et al., 1987a), milk yields tended to increase.

Ruminal degradation of wheat protein is faster than corn protein (Chalupa, 1982a) which may alter amino acid flow to the small intestine. Increased milk yield with ruminal undegradable protein may be due to increased supply of limiting amino acids to the small intestine (Clark, 1975). Lysine and methionine probably limit milk production or milk protein synthesis with corn-based diets (Rogers et al., 1987; Broderick et al., 1974; Schingoethe et al., 1988). Supplementation of wheat-based diets with protected lysine and methionine, however, did not increase milk yield or composition above nonsupplemented diets (Nalsen et al., 1987a).

The objective of this study was to determine whether ruminal undegradable protein with or without ruminally protected lysine and methionine would be beneficial in 60% wheat-based concentrate mixtures in regards to milk yield and composition, and to compare the effect of these diets on ruminal and blood parameters.

Materials and Methods

A 12-week feeding trial was conducted with 24 Holstein cows in their second or greater lactation. Cows were started on the trial 5 to 7 weeks postpartum. The trial was a switchback design with three 4-week periods (Lucas, 1956) to account for the natural decline in milk yield as lactation progressed. The first two weeks of each period were used to adjust cows to their ration and prevent carry-over effects between periods. The final two weeks of each period were used to compare response variables among treatments. Cows were assigned by calving date to 1 of 12 treatment sequences (Appendix, Table XIV). Two treatments were included in each treatment sequence, one treatment was applied in the first and third period while a second treatment was applied in the second period.

Four different concentrate mixtures were utilized in this study (Table IX). The control ration (Corn) was a 45% corn and 21.5% barley concentrate mixture utilizing cottonseed meal (CSM) as the protein source. The remaining three concentrates contained 60% hard red winter wheat as the primary energy source, but varied in protein and amino acid supplementation. The wheat ration containing CSM (Low RUP) was formulated to be equal in total protein content to the other rations, but lower in RUP and ruminal undegradable lysine and methionine. The third concentrate (High RUP) utilized a blend of corn gluten meal and blood meal to provide equal total protein but RUP similar to the corn ration. The fourth concentrate (RUP+AA) was similar to the

TABLE IX

CONCENTRATE MIXTURES FED WITH SORGHUM SILAGE AND ALFALFA HAY[1]

	RATION			
Composition	Corn Control	Wheat (Low RUP)	Wheat (High RUP)	Wheat (RUP+A.A.)
Ingredients, % as-fed				
Corn	45.0	6.0	8.5	10.6
Wheat[2]	--	60.0	60.0	60.0
Barley	21.5	6.0	--	6.5
Sorghum (Milo)	--	--	8.5	--
Cottonseed meal	18.0	12.5	--	--
Blood meal	--	--	2.0	2.0
Corn gluten meal	--	--	5.5	5.0
Fixed portion[3]	15.5	15.5	15.5	15.5
Protected amino acids[4]	--	--	--	.4
Calculated analysis, as-fed				
Net energy, Mcal/100 kg	161.9	164.8	165.2	165.2
Crude fiber, %	5.9	5.4	3.9	4.1
Total protein, %	15.0	15.0	15.0	15.0
Rumen undeg. protein, %	5.9	4.0	5.7	5.6
Rumen undeg. lysine, %	.20	.13	.17	.31
Rumen undeg. methionine, %	.09	.06	.09	.13
Actual analysis, % as-fed				
Crude protein	14.76	15.50	15.86	15.90
Dry matter	88.25	88.90	88.48	88.53
Total ration				
Calculated analysis, as-fed				
Net energy, Mcal/100 kg	81.7	82.4	82.7	82.6
Crude fiber, %	8.7	8.5	8.0	8.0
Crude protein, %	7.1	7.1	7.1	7.1
Rumen undeg. protein, %	2.51	1.90	2.44	2.42

[1]Concentrate:silage:hay, 55:30:15 (dry matter basis).

[2]Hard red winter wheat, test wt. 60 lb/bu.

[3]Fixed portion: Molasses 6, soybean hulls 5, dicalcium phosphate 2.0, sodium bicarbonate 1.25, salt .75, magnesium oxide .5%.

[4]Product of Eastman Chemicals Division, Eastman Kodak Co., Rochester, NY; 37% lysine and 11.8% methionine content.

High RUP with .4% ruminally protected lysine and methionine[1] added to provide the highest amount of ruminal undegradable lysine and methionine of the four treatments.

The concentrates were fed in a complete mixed ration with sorghum silage and chopped alfalfa hay in a 55:30:15 ratio, respectively, on a dry matter (DM) basis. Cows were fed equal portions of the complete ration three times daily in individual stanchions at 8-h intervals. Feed intake was recorded daily. To maintain maximum feed intake and prevent excessive weighback, the concentrate was increased or decreased .45 kg and the forage a proportional amount depending on the DM content, if a cow consumed all or left a portion of her ration for two consecutive days.

During the last two weeks of each period, daily weighbacks were composited weekly for analysis of DM and crude protein (CP). Samples of the concentrates, silage, and hay were taken each week for DM and CP analysis. Dry matter content of the concentrates, hay samples, and weighbacks were determined by drying the samples in a forced-air oven at 60° C for 48 h. Dry matter content of sorghum silage was determined with toluene distillation (AOAC., 1975). Crude protein content of samples were obtained by macro-kjeldahl (AOAC., 1975).

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[1]Supplied by Eastman Kodak Co., Rochester, NY; composed of polymer coated cores containing 37.2% L-lysine and 11.8% DL-methionine to provide 36.4% and 11.6% ruminally protected lysine and methionine.

Cows were milked twice daily, with milk weights recorded at each milking. Milk samples were obtained on four consecutive milkings each week for determination of fat and protein content at the Oklahoma State DHIA laboratory. To determine weight changes within periods, cows were weighed on two consecutive days prior to the trial and on the last and first day of each period. Because cows were weighed prior to milking, the milk weight of the following milking was deducted from the cow's body weight.

At the end of each period, a ruminal fluid sample was obtained from each cow 3 to 4 h after the morning feeding. Samples were taken by stomach tube for determination of ruminal pH, ammonia-nitrogen (NH_3-N) and volatile fatty acid (VFA) concentrations. A minimum of 300 ml of ruminal fluid was strained through two layers of cheesecloth, and pH immediately determined. Two hundred ml of ruminal fluid was then acidified with 8 ml of 50% hydrochloric acid and frozen (-20° C) for later analysis of NH_3-N concentration (Broderick and Kang, 1980).

To determine VFA concentrations, 100 ml of strained ruminal fluid was mixed with 1 ml of saturated mercuric chloride and frozen (-20° C). These samples were later thawed and centrifuged (2,000 x g) for 10 min. Five ml of the supernatant were drawn off and centrifuged with 1 ml of 25% meta-phosphoric acid for 20 min at 25,000 x g. One ml of the supernatant was then mixed with .2 ml of 2-

ethylbutyric acid as a internal standard. These samples were then subjected to gas chromatography.

During ruminal sampling, blood samples were obtained from the median caudal vein to determine urea-nitrogen (urea-N) and nonesterfied fatty acid (NEFA) concentrations. Samples were withdrawn into 15 ml vacutainer tubes, mixed with .15 ml of oxalic acid (1.12 M) to prevent coagulation, and placed in an ice water bath (0° C). Samples were centrifuged (2,000 x g) for 30 min, decanted and frozen (-11° C). Samples were later analyzed for urea-nitrogen (urea-N) concentration (Fawcett et al., 1960), and NEFA concentrations using an enzymatic-colorimetric method[2].

Two cows were excluded from the study. One cow died during the study due to hardware disease, while the other was excluded due to mastitis. Data collected during the last period from two other cows were excluded because of mastitis and bloat.

Period means for DM intake, milk yield, milk composition, and ruminal and blood data for each cow were subjected to least squares analysis with period, cow, and treatment included in the model. Treatment comparisons were made using a protected LSD.

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[2]NEFA C kit (Code No. 990-75401) manufactured by WAKO Pure Chemical Industries, Ltd., Higashi-Kuosaka, Japan.

Results and Discussion

Cows fed the corn ration consumed more ($P<.05$) concentrate, silage, and hay than cows fed the wheat-based rations (Table X). Other studies have shown no change in DM intake when softer wheat varieties were fed to lactating cows (Cunningham et al., 1970; Tommervik and Waldern, 1969). Nalsen et al. (1987b) reported similar concentrate and silage intakes among cows fed concentrate mixtures containing 60% hard red winter wheat and 45% corn. When 75% hard red winter wheat was fed, however, concentrate intake decreased (Nalsen et al., 1987a). In the present study, intake was lowest for cows fed the High RUP. Silage and hay DM intakes were intermediate for cows fed RUP+AA.

Cows fed the corn ration consumed more CP than cows fed High RUP (Table X). Although concentrate CP intake did not differ among treatments, the increased intake of sorghum silage and alfalfa hay for cows fed the corn ration increased CP intake from these components, and thus increased total CP intake. Total CP intakes were similar between cows fed the corn ration and the wheat rations with Low RUP and RUP+AA even though CP intake from the forage components were lowest with the wheat-based diets. Calculated RUP intake was highest for cows fed the corn ration and intermediate for cows fed the wheat rations containing High RUP and RUP+AA.

TABLE X

FEED INTAKE OF LACTATING COWS FED CORN OR WHEAT WITH RUMINAL UNDEGRADABLE PROTEIN WITH OR WITHOUT RUMINALLY PROTECTED LYSINE AND METHIONINE

	RATION				
Item	Corn Control	Wheat (Low RUP)	Wheat (High RUP)	Wheat (RUP+A.A.)	SE
Dry matter intake, kg/day					
Concentrate mixture	15.2[a]	14.4[b]	13.4[c]	14.0[bc]	.21
Sorghum silage	8.3[a]	7.8[b]	7.3[c]	7.6[bc]	.11
Alfalfa hay	4.2[a]	3.9[b]	3.7[c]	3.8[bc]	.06
Total	27.7[a]	26.1[b]	24.4[c]	25.4[bc]	.38
Intake, % of body weight					
Actual	4.34[a]	4.03[b]	3.81[c]	3.94[bc]	.065
Calculated[1]	3.48[a]	3.35[b]	3.34[b]	3.38[b]	.027
Protein intake, kg/day					
Concentrate mix	2.51	2.49	2.40	2.52	.049
Sorghum silage	.49[a]	.46[b]	.43[c]	.45[bc]	.007
Hay	.74[a]	.69[b]	.65[c]	.67[bc]	.013
Total	3.74[a]	3.64[ab]	3.48[b]	3.63[ab]	.062
Requirement[2]	3.28[a]	3.16[b]	3.10[b]	3.16[b]	.027
% of requirement[2]	114	116	112	115	1.3
Calculated RUP intake, kg/day					
Total	1.36[a]	.97[c]	1.16[b]	1.20[b]	.016
Requirement[2]	1.16[a]	1.12[b]	1.10[b]	1.12[b]	.008
% of requirement[2]	117[a]	86[c]	106[b]	107[b]	1.2

[1]From McCullough (1981).

[2]From NRC (1988).

[abc]Means within a row with different superscripts differ, ($P<.05$).

Daily milk and 4% fat-corrected milk yields (FCM) were significantly higher for cows fed the corn ration than for cows fed the wheat-based rations (Table XI). Faldet et al. (1986a) also observed decreased milk yields when wheat increased in the concentrate mixture. Supplementation of wheat-based diets with corn gluten meal, blood meal, and protected lysine and methionine increased milk yield to that of a corn control (Nalsen et al., 1987b). Differences in milk yield among the three wheat-based rations in the present study were not significant (P>.05). Other researchers have reported increased milk production by supplementing corn-based diets with RUP sources (Sahlu et al., 1984; Kung and Huber, 1983; Schingoethe et al., 1988; Polan et al.,1985). Wheat protein is degraded more rapidly in the rumen than corn protein (Chalupa, 1982a). Therefore, ruminal undegradable protein may be more critical for wheat rations than corn rations. The lower feed intake reported with cows fed wheat rations, may have made energy rather than protein the most limiting nutrient.

Daily milk yield tended to be higher for cows fed RUP+AA than for cows fed RUP (32.26 vs 31.52 kg/day; P<.09). Because the calculated amount of RUP was similar between the two rations (5.7 vs. 5.6%), the tendency for increased milk production may be due to the protected lysine and methionine. Lysine and methionine have been suggested as first and second, or colimiting for milk and milk protein production (Broderick et al., 1974; Schwab et al.,1976;

TABLE XI

WEIGHT CHANGE, MILK PRODUCTION AND COMPOSITION OF COWS FED CORN OR WHEAT WITH RUMINAL UNDEGRADABLE PROTEIN WITH OR WITHOUT RUMINALLY PROTECTED LYSINE AND METHIONINE

	Ration				
Item	Corn Control	Wheat (Low RUP)	Wheat (High RUP)	Wheat (RUP+A.A.)	SE
Milk yield					
kg/day	34.3^{a}	32.3^{b}	31.5^{b}	32.3^{b}	.32
kg/kg feed DM	1.24^{c}	1.25^{cb}	1.30^{a}	1.28^{ab}	.013
Fat test, %	3.62	3.62	3.63	3.68	.082
FCM, kg/day	32.2^{a}	30.5^{b}	29.8^{b}	30.6^{b}	.43
Protein, %	3.15^{c}	3.23^{b}	3.26^{b}	3.32^{a}	.018
Body weight changes					
kg/4 wk period	6.2	12.6	9.3	8.4	4.30

^{abc}Means within a row with different superscripts differ ($P<.05$).

Rogers et al., 1987). Using corn-based concentrates, Schingoethe et al. (1988) reported that protected methionine supplementation increased milk yield when fed with soybean meal, however, there was no additional response when fed with heat-treated soybean products. Milk yields were similar between cows fed soybean meal plus protected methionine and heat-treated soybean meal (Schingoethe et al., 1988).

Because cows fed the corn ration produced more milk than cows fed wheat (Table XI), daily protein requirements (NRC, 1988) were higher for cows fed corn (Table X). Daily protein requirements did not differ among cows fed the wheat-based rations. Actual protein intakes exceeded NRC (1988) requirements for all treatments. Most of this was attributed to the higher than expected DM intakes (Table X). The RUP requirements (NRC, 1988) paralleled total protein requirements. Calculated RUP intakes exceeded requirements (NRC, 1988) for all treatments, except the Low RUP. Ruminal undegradable protein intake with cows fed the wheat rations did not appear to affect daily milk production since milk yields from cows fed the Low RUP ration were similar to cows fed wheat rations containing more ruminal degradable protein.

Total milk yields were decreased ($P<.05$) with the wheat-based diets compared to the corn (Table XI). Conversion of feed to milk, however, was more efficient ($P<.05$) for cows fed the wheat-based concentrate mixes containing High RUP and RUP+AA than for cows fed the corn ration. Cows fed the High RUP ration were also more efficient ($P<.05$), while cows fed the High RUP+AA tended to be more efficient at converting feed into milk than cows fed the Low RUP ration. Cows fed the corn ration and the Low RUP ration produced 1.24 and 1.25 kg milk/kg feed, respectively.

Milk fat percentages were not altered by treatment (Table XI). Sodium bicarbonate and magnesium oxide were included in all concentrate mixtures (Table IX), and may have prevented depressed fat test, even with the wheat-based diets. Also, the concentrate to forage DM intake ratio averaged 55:45 among the four treatments. Increasing the proportion of concentrate above 60% in the total ration can increase the incidence of low milk fat (Clark and Davis, 1980). This has generally been attributed to increased starch digestion in the rumen, which can decrease the ruminal acetate to propionate ratio (Clark and Davis, 1980; Olson, 1984). Milk protein content was increased ($P<.05$) when cows were fed the wheat-based diets compared to the corn diet. Increasing the amount of amino acids available for absorption in the small intestine, or improving the profile of amino acids in the small intestine can increase milk protein content (Thomas, 1983). In addition, cows fed the wheat ration with RUP+AA yielded significantly higher protein concentrations than cows fed other rations. This response may indicate that lysine and methionine are limiting amino acids for milk protein synthesis with wheat-based diets. These results agree with lysine and methionine supplementation studies of corn-based diets (Donken et al., 1987; Rogers et al., 1987). In contrast, Nalsen et al. (1987b) reported that amino acid supplementation of wheat-based diets had no effect on milk protein content. Cows fed the wheat rations with Low RUP and High RUP were intermediate in milk protein percentage.

Weight changes among treatments were highly variable, therefore, significant differences between treatments were not detected. There was a tendency, however, for cows fed wheat to gain more weight than cows fed corn.

Ruminal pH tended to decrease with the wheat rations (Table XII). Nalsen et al. (1987a) reported similar ruminal pH for cows fed 75% corn and 75% wheat concentrate mixtures. In contrast, Faldet et al (1986b) found ruminal pH decreased as wheat replaced up to 80% of the corn in the concentrate mix. Fat test also declined in association with the lower ruminal pH. This reportedly was due to lower than expected fiber content of the rations. Axe et al. (1987) also reported decreased ruminal pH for steers as wheat replaced sorghum grain in the diet, however, the forage component comprised only 10% of the total ration. Wheat feeding decreased ($P<.05$) the molar percentage of acetic acid in ruminal fluid compared to the corn ration. Though nonsignificant, molar percentages of propionic and butyric acid, and total ruminal VFA concentrations were numerically

TABLE XII

RUMINAL AND BLOOD PARAMETER RESPONSES OF LACTATING COWS FED CORN OR WHEAT WITH RUMINAL UNDEGRADABLE PROTEIN WITH OR WITHOUT RUMINALLY PROTECTED LYSINE AND METHIONINE

Item	RATION				
	Corn Control	Wheat (Low RUP)	Wheat (High RUP)	Wheat (RUP+A.A.)	SE
Ruminal fluid pH	6.32	6.19	6.15	6.16	.093
Ruminal volatile fatty acids					
Total conc., mm/l	158.7	173.3	194.9	179.4	14.32
Molar %					
Acetic	68.6[a]	60.1[b]	63.5[b]	61.4[b]	1.82
Propionic	18.1	24.3	22.2	22.0	1.84
Butyric	11.5	13.0	12.3	13.9	.83
Valeric	1.05[b]	1.87[a]	1.64[ab]	1.85[a]	.226
Isovaleric	.74	.80	.38	.81	.229
Acetic to propionic ratio	3.8[a]	2.6[b]	3.5[ab]	3.0[ab]	.37
Ruminal NH_3-N, mg/dl	6.0	4.7	5.5	5.1	.75
Blood urea-N, mg/dl	12.0	13.3	13.1	12.6	.44
Blood NEFA, uEq/l	120.3	130.3	98.9	115.5	11.34

[ab]Means within a row with different superscripts differ ($P<.05$).

higher with the wheat-based rations than the corn ration. These responses indicate increased wheat starch degradation in the rumen compared to corn starch. Increased molar percentage of propionate in ruminal fluid of wheat-fed cows may explain increased weight gain for these cows. Metabolism of propionate could decrease body fat mobilization, while promoting body fat synthesis (Van Soest, 1963). The increased percentage of propionate in the rumen with the wheat diets may also explain the increased milk protein percentage. Ruminal infusions of propionic acid have increased milk protein content, though reasons for this response are unclear (Thomas, 1983). Axe et al. (1987) observed decreased ruminal pH and molar percentage of acetate, while total ruminal VFA concentration and molar percentage of propionate increased when wheat replaced sorghum grain in the concentrate for Angus steers. Molar proportions of valeric acid were also increased ($P<.05$) with the wheat rations containing Low RUP and RUP+AA than with the corn ration.

At 3 to 4 h after ration feeding, ruminal NH_3-N concentrations tended to decrease and blood urea-N tended to increase when cows were fed the wheat rations (Table XII). Increased degradation of wheat protein in the rumen could increase ruminal NH_3-N concentrations, unless organic matter fermention was adequate for ammonia incorporation into microbial protein. Ruminal NH_3-N concentrations for cows fed the wheat ration containing Low RUP were lower than expected since less protein would have been expected to bypass ruminal degradation. Blood NEFA concentrations were lower than anticipated for cows in early lactation. During the time frame of this trial, however, cows tended to gain weight regardless of treatment, which would reduce the NEFA concentrations of venous blood plasma.

Based upon ten year average (1978 to 1987) feed ingredient prices, except for soybean hulls, dicalcium phosphate, sodium bicarbonate, magnesium oxide, and sorghum silage, in which current prices (September, 1988) were used, the return over feed cost was highest for the corn ration ($6.93/cow/day) and lowest for the wheat ration containing RUP+AA ($6.06/cow/day) (Table XIII). The differential between the price of corn and wheat ($4.67 vs $6.13/cwt) resulted in increased concentrate prices with the wheat rations. Because of the higher protein content of wheat, protein supplements accounted for less of the total cost of the concentrate mix when wheat rather than corn was used as the primary energy source. The protected amino acid product used in this study is not currently available for retail sale, however, a protected methionine product currently available to the producer was quoted at $2.00/lb. Using this price, the protected amino acid accounted for $.80 of the total cost of the wheat concentrate mixture containing RUP+AA. Due to lower intake, daily feed costs were lowest for cows fed the wheat ration containing High RUP ($2.71/cow/day). The value of the milk was highest with the

TABLE XIII

ECONOMICS OF FEEDING WHEAT WITH RUMINAL UNDEGRADABLE PROTEIN WITH OR WITHOUT RUMINALLY PROTECTED LYSINE AND METHIONINE

Item	RATION			
	Corn Control	Wheat (Low RUP)	Wheat (High RUP)	Wheat (RUP+A.A.)
Milk yield, lb/cow/day	75.52	71.07	69.34	70.97
Value of milk, \$/day[a]	9.80	9.22	9.02	9.28
Feed costs[b]				
Conc. mix., \$/cwt	5.44	6.14	6.00	7.13
Alfalfa, \$/cwt	3.96	3.96	3.96	3.96
Sorghum silage, \$/cwt	.80	.80	.80	.80
Ration consumed, \$/day	2.87	2.95	2.71	3.22
Return over feed costs/cow, \$	6.93	6.27	6.31	6.06

[a]Milk priced at \$12.79/cwt (ten year average; 1978 to 1987) for 3.5% test, with \$.16 differential.

[b]Ten year average (1978 to 1987) ingredient prices when available: Hard red winter wheat @ \$6.13 and corn @ 4.67/cwt.

corn ration which nullified the advantage of the High RUP with lower daily feed cost. The difference between the corn ration and the wheat rations in return over feed costs was determined over a range of corn and wheat prices (Appendix, Table XXI). For example, if wheat was priced at $3.00/cwt and corn was priced at $3.00/cwt, the return over feed costs/cow/day would be $.28 greater with the corn ration than the Low RUP ration. The difference in return over feed costs/cow/day were similar when comparing the corn ration vs the Low RUP ration and the corn ration vs the High RUP ration. By altering the price of blood meal, corn gluten meal, and cottonseed meal, similar comparisons were made between the High RUP vs the Low RUP ration, and the RUP+AA vs the Low RUP ration (Appendix, Table XXII).

This study, as other studies, (Cunningham, 1970; Faldet et al., 1986b; Nalsen et al., 1987a) suggests that feeding wheat to lactating cows reduces milk yield. Increased ruminal undegradable protein for wheat rations did not appear to affect daily milk yields. Cows fed the wheat rations containing ruminal undegradable protein, however, were more efficient at converting feed into milk. Because of the lower feed intake with cows fed the wheat-based rations, energy intake may have further limited milk production. Lysine and methionine appear to be limiting amino acids for milk protein synthesis with wheat-based rations.

CHAPTER V

SUMMARY AND CONCLUSIONS

Current recommendations (NRC, 1988) suggest feeding a protein supplement that is relatively undegradable in the rumen to cows in early lactation. Wheat protein is degraded more rapidly in the rumen than corn protein (Chalupa, 1982a), therefore, the reduced milk yields of cows fed wheat-based rations (Faldet et al., 1986a; Faldet et al, 1986b) may be due to decreased amino acid flow to the small intestine.

A blend of corn gluten meal and blood meal fed with 60% wheat concentrate mixtures increased daily milk production when alfalfa hay was the only forage. Thus, protein or specific amino acids may limit milk production with wheat-based diets. Daily milk yield was not affected, however, when high bypass protein wheat concentrate mixtures were fed with sorghum silage in a complete ration. The supply of amino acids to the small intestine may be different with wheat/alfalfa compared to wheat/silage diets. Whether the concentrate and forage are fed separately or in a complete ration may also affect the protein-energy interrelationships in the rumen.

Nutrients other than protein may limit productivity when wheat-based diets are fed to lactating cows. Feed intake usually declined when wheat was fed to cows, therefore, energy intake may limit productivity of wheat diets compared to corn diets. Increased energy content of wheat rations with whole cottonseed appeared to increase daily milk production, similar to results obtained with increased bypass protein of wheat rations. In addition, increased dietary fat may increase milk fat content, but may also decrease milk protein.

Although wheat rations tended to decrease daily milk yields compared to corn rations, cows appear to convert wheat into milk (as efficiently or) more efficiently than cows fed corn rations, especially when the wheat ration contains supplemental energy or high bypass protein. If wheat concentrate mixtures with high bypass protein or supplemental fat could be formulated at the same cost as a corn ration, there may be an economical advantage to feeding wheat.

Lysine and methionine may be limiting amino acids with wheat-based rations. Daily milk yield tended to be higher when protected lysine and methionine was fed with a high bypass protein wheat ration, than when a high bypass protein wheat ration alone was fed. The major effect of lysine and methionine appeared to be increased milk protein. Because milk yield and fat did not change when wheat-based diets were supplemented with an amino acid product, an economical advantage was not apparent. In states where a premium is paid for milk protein, there may be a economic advantage to feeding a protected lysine and methionine product. In most cases, milk protein content was higher when wheat was fed than when corn was fed, possibly due to increased ruminal propionate concentrations (Thomas, 1983).

Ruminal pH and acetate to propionate ratio generally declined with wheat feeding suggesting increased ruminal starch degradation with the wheat diets. Thus, milk fat content should decrease with wheat rations. Although milk fat tended to decline with wheat rations, the depression was not significant for any wheat ration. Sodium bicarbonate and magnesium oxide were added to all of the rations which may have prevented significant milk fat depression. Concentrate intake did not exceed 55% on a dry matter basis, which may have also prevented milk fat depression. In the first study, ruminal ammonia concentrations tended to increase, whereas in the second study, ruminal ammonia concentrations tended to decrease with wheat feeding. Cows fed the wheat rations in the first trial consumed more protein than cows fed the corn ration, whereas in the second trial, daily protein intake was similar between rations. The difference in crude protein intake may have caused the difference in ammonia levels between the two trials. Because wheat protein is degraded more rapidly than corn protein in the rumen, ammonia from wheat protein may have been absorbed through the ruminal epithelium or assimilated into microbial protein prior to ruminal sampling in the second trial. In either case, blood urea levels tended to increase with wheat feeding, suggesting that ruminal microbes could not adequately assimilate ammonia from the rapidly degraded wheat protein into microbial protein. Protein source did not appear to affect ruminal ammonia or blood urea levels. The reason for this response is unclear, since protein available for ruminal degradation should have been lower with the ruminal undegradable protein rations.

Future research with wheat feeding to lactating dairy cows needs to include methods by which feed intake can be maintained when feeding wheat. A combination of whole cottonseed and high bypass protein with wheat-based concentrates may be one method by which both energy and amino acid requirements of the cow can be met.

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APPENDIX

TABLE XIV

TREATMENT SEQUENCE CODES - TRIAL 1 AND 2

Treatment Sequence[a]	Code Number
1-2-1	1
2-3-2	2
3-4-3	3
4-1-4	4
1-3-1	5
2-4-2	6
3-1-3	7
4-2-4	8
1-4-1	9
2-1-2	10
3-2-3	11
4-3-4	12

[a]Trial 1:Corn = 1; CSM = 2; WCS = 3; High RUP = 4.

[a]Trial 2:Corn = 1; Low RUP = 2; High RUP = 3; RUP+AA = 4.

TABLE XV

LACTATION, CALVING DATE, TREATMENT SEQUENCE, POSTPARTUM DAYS WHEN STARTED, AND MILK PRODUCTION PER PERIOD FOR EACH COW

TRIAL 1

Cow No.	Lact. No.	Calving date, 86	Trt. code.	Postpartum days	Avg. milk yield (kg/day) Per. 1	Per. 2	Per. 3
503	3	8/21	1	48	26.0	23.1	24.4
524	3	8/30	2	47	26.4	22.8	23.2
419	4	9/01	3	46	****	****	****
615	2	9/03	5	51	27.9	26.5	27.1
338	5	9/04	6	50	33.5	33.7	30.0
629	2	9/05	7	49	28.7	29.0	24.8
625	2	9/06	4	48	26.1	26.6	24.1
523	3	9/07	9	47	27.3	24.9	24.6
529	3	9/08	10	46	29.6	32.0	****
340	5	9/08	11	46	28.5	23.3	23.6
673	2	9/08	12	46	22.8	19.8	18.0
294	5	9/11	1	50	40.2	34.3	32.9
521	3	9/13	2	48	30.8	31.0	26.5
096	6	9/15	3	46	31.6	30.0	****
522	3	9/18	4	43	29.5	31.9	27.3
653	2	9/18	5	50	34.5	****	29.3
404	4	9/18	8	50	30.0	29.8	****
506	3	9/20	6	48	31.6	29.5	23.1
520	3	9/20	7	48	32.5	34.1	28.2
571	2	9/21	8	47	30.4	30.2	30.2
617	2	9/21	9	47	40.3	35.8	32.8
618	2	9/21	10	47	27.6	30.0	****
455	4	9/21	11	47	34.5	27.7	28.0
337	5	9/25	12	43	33.4	31.2	28.4

****All data excluded.

TABLE XVI

LACTATION, CALVING DATE, TREATMENT SEQUENCE, POSTPARTUM DAYS WHEN STARTED, AND MILK PRODUCTION PER PERIOD FOR EACH COW

TRIAL 2

Cow No.	Lact. No.	Calving date, 87	Trt. Seq.	Postpartum days	Avg. milk yield (kg/day) Per. 1	Per. 2	Per. 3
331	4	8/25	1	45	36.9	37.2	38.2
455	5	8/25	2	45	33.3	31.1	****
718	2	8/30	3	40	31.2	30.3	27.2
149	7	8/30	4	40	31.9	31.0	29.3
746	2	8/30	5	40	34.9	32.1	32.8
686	2	8/30	6	40	31.9	30.8	30.5
724	2	8/31	7	39	30.4	31.2	25.4
729	2	8/31	8	39	****	****	****
325	5	9/04	9	42	35.6	33.5	****
761	2	9/05	10	41	29.9	31.9	26.5
416	4	9/06	11	40	34.1	35.0	32.7
522	4	9/06	12	40	33.5	32.0	29.8
625	3	9/07	1	39	37.4	34.9	33.4
524	3	9/08	2	38	****	****	****
360	6	9/09	3	37	36.4	36.4	32.3
696	2	9/09	4	37	29.6	32.7	29.3
673	3	9/10	5	36	40.0	32.3	31.6
506	4	9/10	6	36	30.4	31.8	30.1
316	6	9/10	7	36	39.9	39.5	32.6
688	2	9/10	8	36	31.3	30.9	28.2
571	3	9/14	9	39	37.0	34.2	35.0
770	2	9/14	10	39	31.3	35.2	29.5
727	2	9/16	11	37	32.8	31.8	26.2
337	6	9/17	12	36	36.4	34.6	31.1

****All data excluded.

TABLE XVII

ACTUAL ANALYSIS OF FORAGES, % DRY BASIS

TRIAL 1 AND 2

Item	Sorghum Silage	Alfalfa Hay	
	Trial 2	Trial 1	Trial 2
Dry matter	37.20	88.36	88.35
Crude Protein	5.96	21.34	18.41

TABLE XVIII

EFFECT OF CORN AND WHEAT PRICE ON DIFFERENCE IN RETURN OVER FEED COSTS WHEN WHEAT IS SUBSTITUTED FOR CORN ON A WEIGHT BASIS - TRIAL 1

	Price of Wheat[1]								
	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
Price of Corn[1]	Corn ration vs CSM ration								
3.00	.83[2]	.92	1.00	1.08	1.17	1.25	1.33	1.42	1.50
3.50	.74	.83	.91	.99	1.08	1.16	1.24	1.32	1.41
4.00	.65	.73	.82	.90	.98	1.07	1.15	1.23	1.32
4.50	.56	.64	.73	.81	.89	.97	1.06	1.14	1.22
5.00	.47	.55	.63	.72	.80	.88	.97	1.05	1.13
5.50	.38	.46	.54	.63	.71	.79	.87	.96	1.04
6.00	.28	.37	.45	.53	.62	.70	.78	.87	.95
	Corn ration vs WCS ration								
3.00	.59[3]	.67	.75	.84	.92	1.00	1.09	1.17	1.25
3.50	.49	.58	.66	.74	.83	.91	.99	1.08	1.16
4.00	.40	.49	.57	.65	.74	.82	.90	.99	1.07
4.50	.31	.39	.48	.56	.64	.73	.81	.89	.98
5.00	.22	.30	.39	.47	.55	.64	.72	.80	.89
5.50	.13	.21	.29	.38	.46	.54	.63	.71	.79
6.00	.04	.12	.20	.29	.37	.45	.54	.62	.70
	Corn ration vs High RUP ration								
3.00	.57[4]	.64	.74	.83	.91	1.00	1.09	1.17	1.26
3.50	.48	.56	.65	.74	.82	.91	.99	1.08	1.17
4.00	.38	.47	.56	.64	.73	.82	.90	.99	1.08
4.50	.29	.38	.47	.55	.64	.72	.81	.90	.98
5.00	.20	.29	.37	.46	.55	.63	.72	.81	.89
5.50	.11	.20	.28	.37	.45	.54	.63	.71	.80
6.00	.02	.10	.19	.28	.36	.45	.54	.62	.71

[1]$/cwt.

[2]Corn ration return over feed costs - CSM ration return over feed costs.

[3]Corn ration return over feed costs - WCS ration return over feed costs.

[4]Corn ration return over feed costs - High RUP ration return over feed costs.

TABLE XIX

EFFECT OF WHOLE COTTONSEED AND COTTONSEED MEAL PRICE ON DIFFERENCE IN RETURN OVER FEED COSTS - TRIAL 1

	Price of Whole Cottonseed[1]								
	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
Price of Cottonseed Meal[1]	WCS ration vs CSM ration								
4.00	.41	.35	.29	.24	.18	.13	.07	.02	-.04
5.00	.43	.38	.32	.27	.21	.16	.10	.04	-.01
6.00	.46	.41	.35	.29	.24	.18	.13	.07	.02
7.00	.49	.43	.38	.32	.27	.21	.16	.10	.04
8.00	.52	.46	.41	.35	.29	.24	.18	.13	.07
9.00	.54	.49	.43	.38	.32	.27	.21	.15	.10
10.00	.57	.52	.46	.41	.35	.29	.24	.18	.13
11.00	.60	.54	.49	.43	.38	.32	.27	.21	.15
12.00	.63	.57	.52	.46	.40	.35	.29	.24	.18

[1]$/cwt.

[2]WCS ration return over feed costs - CSM ration return over feed costs.

TABLE XX

EFFECT OF BLOOD MEAL, CORN GLUTEN MEAL, WHOLE COTTONSEED, AND COTTONSEED MEAL PRICE ON DIFFERENCE IN RETURN OVER FEED COSTS - TRIAL 1

Price of Blood Meal[1] / Corn Gluten Meal[1]	10.00 / 8.00	14.00 / 10.00	18.00 / 12.00	22.00 / 14.00
Price of Whole Cottonseed[1]	High RUP ration vs WCS ration			
4.00	-.18[2]	-.22	-.27	-.32
5.00	-.12	-.17	-.21	-.26
6.00	-.07	-.11	-.16	-.21
7.00	-.01	-.06	-.10	-.15
8.00	.04	.00	-.05	-.09
9.00	.10	.05	.01	-.04
10.00	.16	.11	.06	.02
11.00	.21	.17	.12	.07
12.00	.27	.22	.17	.13
Price of Cottonseed Meal[1]	High RUP ration vs CSM ration			
4.00	.23	.18	.14	.09
5.00	.26	.21	.16	.12
6.00	.28	.24	.19	.14
7.00	.31	.26	.22	.17
8.00	.34	.29	.25	.20
9.00	.37	.32	.27	.23
10.00	.39	.35	.30	.26
11.00	.42	.38	.33	.28
12.00	.45	.40	.36	.31

[1]$/cwt.

[2]High RUP ration return over feed costs - WCS ration return over feed costs.

[3]High RUP ration return over feed costs - CSM ration return over feed costs.

TABLE XXI

EFFECT OF CORN AND WHEAT PRICE ON DIFFERENCE IN RETURN OVER FEED COSTS WHEN WHEAT IS SUBSTITUTED FOR CORN ON A EQUAL PROTEIN BASIS - TRIAL 2

	Price of Wheat[1]								
	3.00	3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.00
Price of Corn[1]	Corn ration vs Low RUP ration								
3.00	.28[2]	.38	.49	.60	.70	.81	.92	1.02	1.13
3.50	.19	.30	.40	.51	.62	.72	.83	.94	1.05
4.00	.10	.21	.32	.43	.53	.64	.75	.85	.96
4.50	.02	.13	.23	.34	.45	.55	.66	.77	.87
5.00	-.07	.04	.15	.25	.36	.47	.57	.68	.79
5.50	-.15	-.04	.06	.17	.28	.38	.49	.60	.70
6.00	-.24	-.13	-.02	.08	.19	.30	.40	.51	.62
	Corn ration vs High RUP ration								
3.00	.28[3]	.38	.48	.58	.68	.78	.88	.98	1.08
3.50	.20	.30	.40	.50	.60	.70	.80	.90	1.00
4.00	.11	.21	.31	.41	.51	.61	.71	.81	.91
4.50	.03	.13	.23	.33	.42	.52	.62	.72	.82
5.00	-.06	.04	.14	.24	.34	.44	.54	.64	.74
5.50	-.15	-.05	.05	.15	.25	.35	.45	.55	.65
6.00	-.23	-.13	-.03	.07	.17	.27	.37	.47	.57
	Corn ration vs RUP+AA ration								
3.00	.50[4]	.61	.71	.82	.92	1.03	1.13	1.24	1.34
3.50	.42	.52	.63	.73	.84	.94	1.05	1.15	1.25
4.00	.33	.44	.54	.65	.75	.86	.96	1.06	1.17
4.50	.25	.35	.46	.56	.67	.77	.87	.98	1.08
5.00	.16	.27	.37	.48	.58	.68	.79	.89	1.00
5.50	.08	.18	.29	.39	.49	.60	.70	.81	.91
6.00	-.01	.10	.20	.30	.41	.51	.62	.72	.83

[1]$/cwt.

[2]Corn ration return over feed costs - Low RUP ration return over feed costs.

[3]Corn ration return over feed costs - High RUP ration return over feed costs.

[4]Corn ration return over feed costs - RUP+AA ration return over feed costs.

TABLE XXII

EFFECT OF BLOOD MEAL, CORN GLUTEN MEAL, AND COTTONSEED MEAL PRICE ON DIFFERENCE IN RETURN OVER FEED COSTS - TRIAL 2

Price of Blood meal[1] / Corn Gluten Meal[1]	10.00 / 8.00	14.00 / 10.00	18.00 / 12.00	22.00 / 14.00
Price of Cottonseed meal[1]	High RUP ration vs Low RUP ration			
4.00	-.01	-.08	-.14	-.20
5.00	.03	-.03	-.10	-.16
6.00	.07	.01	-.05	-.12
7.00	.12	.06	-.01	-.07
8.00	.16	.10	.04	-.03
9.00	.21	.15	.08	.02
10.00	.25	.19	.13	.06
11.00	.30	.23	.17	.11
12.00	.34	.28	.22	.15
Price of Cottonseed meal[1]	RUP+AA ration vs Low RUP ration			
4.00	-.27	-.33	-.39	-.45
5.00	-.22	-.28	-.35	-.41
6.00	-.18	-.24	-.30	-.37
7.00	-.13	-.20	-.26	-.32
8.00	-.08	-.15	-.21	-.28
9.00	-.04	-.11	-.17	-.23
10.00	.00	-.06	-.12	-.19
11.00	.05	-.02	-.08	-.14
12.00	.09	.03	-.04	-.10

[1]$/cwt.

[2]High RUP ration return over feed costs - Low RUP ration return over feed costs.

[3]RUP+AA ration return over feed costs - Low RUP ration return over feed costs.

VITA

Court Gene Campbell

Candidate for the Degree of

Master of Science

Thesis: SUPPLEMENTAL PROTEIN, PROTECTED AMINO ACIDS OR ENERGY FOR LACTATING DAIRY COWS FED WHEAT-BASED CONCENTRATE MIXTURES IN EARLY LACTATION

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