ANIMAL PROTEIN BYPRODUCTS AND BYPRODUCT BLENDS FOR DAIRY CATTLE

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This subject or parts of it have been reviewed at this conference several times since the start of the Florida Ruminant Nutrition Symposium in 1990. For example, Van Horn and Powers (1992) reviewed the role of bypass protein in supplying amino acid needs, Van Horn and Harris (1993) reviewed the milk yield responses to supplements supplying rumen undegraded protein (RUP), and Hoover and Miller (1995) reviewed research which optimized carbohydrate fermentation in the rumen to produce greater amounts of bacterial crude protein (BCP) for digestion and absorption in the lower gut.

Summary of Feeding Trials

Previously, we concluded (Van Horn and Harris, 1993) that fish meal had given the most consistent milk yield response of all of the RUP supplements; the average response in 20 experimental comparisons in which fish meal was compared against diets supplemented with soybean meal was +2.2 lb milk per day. Adding 10 more comparisons (Carroll et al., 1994, Khorasani et al., 1994; Santos et al., 1995; Penno et al., 1995; two by Spain et al., 1995; and four by Broderick, 1995) did not change the overall average (30 comparisons) from +2.2 lb/day. There appear to be greater responses when fish meal is used to supplement diets based on alfalfa, especially alfalfa silage as compared with alfalfa hay (e.g., Broderick, 1995) and wetter alfalfa silages compared with drier silages (Broderick et al., 1993). Milk fat percentages were sometimes depressed with fish meal. Calsamiglia et al. (1995) concluded that reduction in milk fat percentage occurred whether administered ruminally or post-ruminally and without effecting a change in ratio of acetate plus butyrate to propionate. Results, therefore, indicated that those effects were likely due to alterations in metabolism post-ruminally caused by polyunsaturated oils contained in the meal, not the protein.

Responses to other animal byproduct protein supplements (e.g., meat and bone meal, meat meal, blood meal, and blends of these with feather meal) have been smaller and less consistent. For example, Van Horn and Harris (1993) reported an average milk yield response based on six comparisons of +.6 lb/day. Adding eight comparisons (Robinson and McQueen, 1994; Grummer et al., 1994; Wattiaux et al., 1994; Mansfield et al., 1994; Palmquist and Weiss, 1994; Broderick et al., 1993; Christensen et al., 1993a, 1993b) still gives an average increase for the 14 comparisons of +.6 lb/day. Milk fat percentages were sometimes increased with meat and feather-product blends.

Although not an animal source RUP supplement, Van Horn and Harris (1993) concluded that corn gluten meal was not an effective RUP supplement giving an average response, in 10 comparisons with soybean meal, of -.5 lb milk/day probably owing to amino acid imbalance, especially lysine. High quality distillers dried grains and brewers grains often gave slightly positive results.

Although there are some exceptions, especially with fish meal, the papers reviewed above indicate that the average response to RUP supplements such as

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animal byproduct blends compared with soybean meal is positive but small (less than 1 lb milk/day). Other reviews have reached similar conclusions but pooled the data differently so that comparisons are not exactly the same. Everett (1995) presented a graphic summary of 55 experiments utilizing RUP reviewed Purina Mills that showed only +.2 lb milk/day over all RUP supplements. Santos and Huber (1995) concluded from a review of 88 comparisons of RUP sources with SBM from 60 lactation trials published in Journal of Dairy Science from 1985 to 1994 that milk yield and milk protein percentages generally were not improved.

Rumen Undegraded Protein (RUP), Peptides, and Amino Acids

A conclusion that RUP supplements generally give relatively small benefits above more readily degradable protein supplements like soybean meal (SBM) should not lead us to conclude that RUP is unimportant. We know that cows cannot maintain high performance on degradable intake protein (DIP) alone. Long ago, it was demonstrated that cows could not produce milk up to their capability with too much dependence on degradable protein, at least non-amino acid nitrogen like urea (Virtanen, 1966; Randel et al. 1975).

Also, Burroughs et al. (1975), who was the early leader in developing the metabolizable (or absorbable) protein concept for ruminants, based protein requirements for cattle on making maximum use of microbial protein and established that RUP increased absorbable protein which correlated with animal gain response. Klopfenstein et al. (1980) developed an animal growth model to compare the incremental weight gain response in low-protein diets from RUP supplements and soybean meal above that obtained with an all-urea supplemented control diet. The ratios of growth response (above gain from the urea diet) from increments of supplemental RUP supplements to response from soybean meal were used to express relative protein efficiencies. For example, a response of 1.985 lb gain/additional lb protein fed from blood meal in a trial compared with .635 lb/additional lb protein from soybean meal gave a ratio of 1.985/.635 = 3.13 or 313% relative efficiency for blood meal compared with soybean meal. Using this evaluation method or modifications, such as including some degradable protein products in the urea-based control diets to further enhance microbial protein production, has given performance-based protein efficiency values for high RUP supplements. These methods have clearly shown that RUP supplements have value over soybean meal for weight gain in growing steers fed diets deficient in protein for optimum growth.

Briceno et al. (1988) determined milk yield responses to estimated metabolizable protein (RUP + BCP) with a pooled data set from 20 experiments at the University of Florida designed to measure responses to added protein. An obvious first conclusion was that intake of protein (lb/day) had a much greater effect on milk yield than did protein percent of diet dry matter regardless of the measure of dietary protein used. Although no animal-byproduct RUP supplements were compared in those experiments, expressing protein on an estimated metabolizable protein basis accounted for more variation in milk yield than crude protein or RUP alone. The responses for the high- and low-producing cows are shown in Figure 1. Even though these responses were curvilinear, diminishing at highest levels of intake, the diminishing curvatures were not as great as responses to crude protein or RUP intakes and the differences between actual yields and yield curves adjusted to equal dry matter intake were much less. The dry matter intake-adjusted curves in Figure 1 should be more indicative of the true response to metabolizable protein than actual curves because these responses are more independent from correlated responses to increases in energy intake.

It appears, however, there are complementary factors that should cause us to explore what else is going on in the rumen, lower gastrointestinal tract and at the mammary gland that make milk yield responses to increases in dietary protein smaller than expected in many cases.

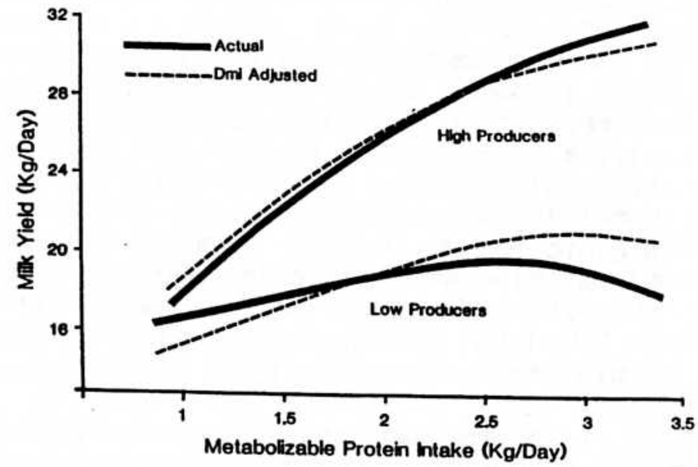

Figure 1. Milk yield response to metabolizable protein intake (estimated from equations of Burroughs et al., 1975) adjusted and unadjusted for dry matter intake by cows in the high- and low-producing halves of the data set. From Briceno et al. (1988).

A relatively new finding that could significantly alter how we evaluate RUP supplements is the finding in sheep and young ruminants that ruminants apparently absorb peptides from the rumen and omasum (Webb et al. 1992, 1993; Koeln et al., 1993, Matthews and Webb, 1995). In fact, they conclude that, quantitatively, peptides absorbed from stomach compartments, duodenum, and spleen may be a more important form of amino acid absorption than free amino acids and that ruminal microorganisms may play an important role in determining the composition of peptides available for absorption. Thus, basing our estimates of absorbable protein on what is digested and absorbed from the small intestine could be missing significant quantities of peptides and free amino acids that may have been absorbed from stomach compartments. This would not change the current emphasis on trying to maximize microbial protein synthesis in the rumen. However, it could explain how a high quality but highly degradable supplement like soybean meal often maintains performance equal to that obtained from less degradable animal byproducts and animal byproduct blends. The soybean meal, presumably, provided equal absorbable protein but some of it was absorbed as degradation peptides from the rumen or as peptides produced or altered by rumen microorganisms and then absorbed previous to the small intestine.

Clark et al. (1992) presented an excellent review, including many excellent studies from their laboratory, that showed that nonammonia nonmicrobial nitrogen (a measure of RUP) increased linearly as RUP supplements were substituted in place of soybean meal but microbial nitrogen (BCP) decreased so that the net gain in total protein delivered to the small intestine was rather small when RUP supplements were fed. It would be interesting to know what the comparison of total absorbed protein would have been in those experiments if peptide absorption from stomach compartments could have been determined as well. Also, Hoover and Miller (1995), Aldrich et al. (1993), and others have found that passage of bacterial N to the duodenum was highest when rumen availabilities of both nonstructural carbohydrate and protein were high. Using continuous fermenters, Calsamiglia et al. (1995) showed that supplementation of diets with RUP supplements increased flows of nonammonia N, RUP, total and essential amino acids, and modified the amino acid profile flowing out of the fermenters. In this experiment, use of RUP supplements did not reduce BCP production. Thus, RUP supplements contributed positively to increased amino acid flows.

Because efficiency of energy utilization is so highly correlated with BCP (e.g., Hoover and Miller, 1995), milk yields seem to have been more highly correlated with diets that optimized BCP than RUP. Thus, we can conclude that paying a premium to include RUP supplements (versus SBM) should be done only after all efforts have been made to optimize BCP. Hoover and Miller (1995) conclude that to optimize BCP at 3.0 to 4.0 lb protein/day, about 25 lb of organic matter must be digested in the rumen. They estimated that BCP was maximized when nonstructural carbohydrates were 30 to 40% of diet dry matter and that 11 to 12% of the diet dry matter must be DIP. With total diet protein at 16 to 18% of DM, DIP should contribute more than 65% of total dietary protein needs, a bit higher than NRC (1989) suggests.

An important set of experiments focusing on rumen carbohydrate digestion done at the University of Arizona relates to optimizing BCP by increasing rumen-fermentable starch. Oliveira et al. (1993) showed that steam-flaking sorghum improved apparent total-tract starch digestibility from 70 to 92%, milk yield 1.6 kg/day with only slight depression in milk fat percentage and significantly increased milk protein percentage from 2.95 to 3.10%. Mitzner et al. (1994) showed that much of the same benefit occurred when sorghum was finely ground and that finely ground sorghum was equal to finely ground corn.

Subsequent Arizona experiments (Chen et al., 1994; Poore et al., 1993b; Simas et al., 1995) showed even greater benefit from steam-flaking sorghum on protein yields and modest benefit from steam-flaking corn. Starch in diets with steam-flaked grain had higher ruminal digestibilities (approximately 80 versus 55%) and higher total-tract starch digestibility (98 versus 84%) and greater duodenal flows of nonammonia nitrogen and bacterial nitrogen (Poore et al., 1993a; Oliveira et al., 1995). Substitution of steamed-flaked sorghum for a mixture of grain and byproducts typical of many dairy diets increased yields of milk and milk protein and milk protein percentage linearly. The optimum level of steam-flaked sorghum appeared to be 30 to 40% of a moderately processed flake (360 g/liter).

The net effect of an absorbable protein model, which perhaps now needs to include absorbed peptides from stomach compartments as well as intestinal absorption of RUP and BCP amino acids, must be judged on how the formulated diet meets absorbed amino acid needs. Schwab (1995), in his review, indicates that lysine and methionine are generally the two most limiting amino acids for growing ruminants and lactating cows without protein supplementation and that most protein supplements further accentuate these deficiencies because they have less of these two amino acids than bacterial protein. Further, the contribution of lysine in the RUP fraction of feed proteins often is slightly lower than in the same feeds before exposure to ruminal fermentation and lysine and cysteine, which can be synthesized from methionine, are more susceptible to heat processing and may have lower intestinal digestibilities than other essential amino acids in RUP. Hence, the current emphasis on supplemental amino acids for lactating cows has focused on lysine and methionine. Lysine appears to be first limiting when corn or and corn byproduct feeds provide most of the RUP whereas methionine probably is first limiting when smaller amounts of corn grain are fed and most of the RUP is provided by oilseed or animal-derived proteins.

Schwab (1995) points out that milk protein percentages and yields are more responsive to supplementation of rumen-protected lysine and methionine (RPLM) than milk yield. For example, Chapoutot et al. (1992), in an experiment designed to determine individual cow responses, observed that 37 of 42 cows responded with higher content of milk protein, 31 with higher protein yield, and only 16 with more milk. The ration was corn silage, alfalfa hay, corn grain, wheat middlings, wheat bran, wheat, soybean meal, and corn gluten meal. Schwab (1995) indicates that research shows that milk protein content responses are immediate, are similar or become greater after peak lactation, are independent of levels of milk yield or genetic potential for milk protein content, and that casein is the milk protein fraction most affected (not whey or NPN fractions). He also concludes that response to RPLM is greater when levels of either lysine or methionine or both in RUP are low rather than high and often greater when intake of crude protein is high rather than low (perhaps indicative of proportional deficiency). Increasing duodenal concentrations of lysine and methionine often increase content of milk protein more than would be expected by increasing ration crude protein. Improved ruminal utilization of carbohydrates (e.g., steam-flaking of sorghum) apparently reduces depression of milk protein percentage associated with supplemental fat (Simas et al., 1995) similar to the correction observed with supplemental RMLM (Christensen et al., 1994). Karunanandaa et al. (1994), however, did not find that RMLM corrected the depression in milk protein percentage associated with feeding supplemental fat to Jersey cows.

One especially interesting experiment utilized to test RPLM was that of Armentano et al. (1993). Response was determined in 60 multiparous Holstein cows fed diets containing 85 or 100% of NRC (1989)-recommended amounts of rumen degradable intake protein (DIP). Those amounts averaged 8.6% and 10.2% of diet dry matter, the higher amount achieved with added urea. Diets were corn silage, corn, corn gluten meal, and soybean meal with or without .6% added urea. Addition of RPLM increased milk protein concentration by .11% and yield by 58 g/day in early lactation and .15% and 73 g/day in mid-lactation in cows fed 10.2% DIP. Increases were much less in cows fed 8.6% DIP. Milk yield increased by .9 and 1.2 kg/day in early and mid-lactation when DIP was 10.2% but decreased .5 and 1.7 kg/day when DIP was only 8.6%. An inference is that lack of DIP limited BCP production which diminished the milk yield response to RPLM even though milk protein percentage was affected positively.

Since increases in milk protein percentage with improved ruminal carbohydrate utilization have been similar to RPLM supplementation, future experiments need to determine if these effects are additive.

Ration Evaluation and Formulation

As we and others have pointed out previously, the milk yield responses to added protein are small and the return diminishes with each increment (e.g., Van Horn et al., 1979). I repeat a quote from King et al. (1991) in their paper evaluating lysine utilization:

> "the most sobering aspect of this research is the observation of a low incremental production response (low efficiency) to limiting AA supplementation in lactating cows. This observation is in stark contrast to the immediate, sizeable growth response noted in AA supplementation studies with rapidly growing laboratory rodents, suggesting either the classical explanation that there may be other essential AAs either colimiting or first limiting or that the net efficiency of absorbed AA use for productive purposes in animals fed high protein diets is lower."

The growth response model used by Klopfenstein (1980) also depends on much more linear responses to added protein than those observed with lactation. Lactation responses to energy, however, are usually linear (e.g., Briceno et al., 1987). And additional energy intake increases BCP (e.g., Hoover and Miller, 1995) which increases absorption of essential amino acids in close to the same ratios found in milk. However, the low net efficiency of transferring absorbed amino acids into milk (e.g., King et al., 1991) also infers that protein needs are secondary to energy needs, especially carbohydrate sources of energy. Response to fat supplementation to increase energy often is less than from carbohydrate (e.g., Tomlinson et al., 1994).

Another factor that probably contributes to the lack of response in the field to RUP supplements is that diets are often formulated to contain more protein than needed. For example, dairymen commonly feed diets containing 19% or more crude protein on a dry matter basis when formulations could be designed, if RUP is considered, to meet requirements with less dietary crude protein.

The Cornell Net Carbohydrate and Protein System (CNCPS) is a model developed to evaluate carbohydrate and protein balances in cattle rations (Barry et al., 1994). It and other models are useful tools to evaluate rations, probably to supplement regularly used ration formulation software. An experiment done at the University of Florida that did not show benefit to increasing RUP with blood meal to replace of soybean meal is referenced in Table 1. Diet formulas, dry matter intakes, and milk yield responses are shown first followed by several outputs from the CNCPS analyses of these diets. The CNCPS model estimated that effective NDF was supplied above requirements and predicted ruminal pH from all diets to be approximately 6.36 (not shown). The CNCPS output in Table 1 suggests that neither protein nor energy should have limited production to the lower actual level achieved in the experiment. Thus, the model prompts exploration of other factors that may have limited milk yield, e.g., milking management, prepartum management, genetic ability of cows, etc., etc. However, even mid-lactation cows would have given more milk if they could have been induced to eat more (e.g., Briceno et al., 1987) but they likely would not have partitioned all of the extra intake into milk and would have gained more weight.

If additional absorbed protein had been needed (Table 1), the CNCPS suggests that adding some other source of peptides to the 15% crude protein blood meal diet, but not so much as to add a urea synthesis energy cost to dispose of surplus N, would have been one way to do that. Another would be to increase NSC at the expense of some of the corn silage dry matter to increase BCP.

Russell et al. (1992) described the ruminal fermentation assumptions used in the CNCPS. Microorganisms that ferment cellulose and hemicellulose (structural carbohydrates, SC) grow slowly and utilize ammonia as a N source for microbial protein synthesis whereas microorganisms that ferment starch, pectin, and sugars (nonstructural carbohydrates, NSC) utilize either ammonia or amino acids as a N source and some use peptides. The yield of NSC bacteria is increased as much as 18.7% as the ratio of peptides to NSC plus peptides in ruminal fluid increases from 0 to 14%. Carbohydrate has little effect on the rate of protein degradation by extracellular proteinases, but it can greatly affect the end product of amino acid metabolism. In the CNCPS, NSC microorganisms take up peptides at a rate of .07 g of peptide per gram of microorganism per hour and this N is used for microbial protein synthesis or ammonia. When carbohydrate permits growth, 66% of NSC microbial protein comes from peptides and 34% from ammonia.

Table 1. Comparison of blood meal additions with soybean meal as the only supplement in corn silage based diets.[1]

Category	Soybean meal diets		Blood meal diets	
	15% CP	18% CP	15% CP	18% CP
Diet ingredients (% of diet dry matter):				
Corn silage (40% grain), %	50.00	50.00	50.00	50.00
Corn meal, %	27.00	20.40	30.90	25.20
Whole cottonseed, %	8.00	8.00	8.00	8.00
Megalac, %	1.00	1.00	1.00	1.00
Blood meal, %			2.30	4.70
Soybean meal (49%), %	10.92	18.30	4.20	8.20
Urea, %			.50	.35
Minerals, %	3.08	2.30	3.10	2.55
Experimental data				
Crude protein, % of diet dry matter	14.9	18.3	15.0	18.5
RUP, % of diet dry matter	4.8	5.5	5.8	8.0
Dry matter intake, lb/day	46.4	47.2	45.6	47.3
Milk yield, lb/day	60.5	60.6	58.9	61.2
Cornell model estimates				
Metabolizable protein from bacteria, grams/day	1451	1412	1440	1421
Metabolizable protein from RUP, grams/day	764	1015	819	1282
Rumen N balance, grams/day	36	118	32	89
Peptide balance, grams/day	-4	74	-45	23
Urea cost, Mcal/day	0	.60	0	.57
Metabolizable energy-allowable milk, lb/day	85.7	87.3	84.4	88.7
Metabolizable protein-allowable milk, lb/day	66.0	75.3	68.6	87.7
Amino acid-allowable milk, lb/day	78.2	80.5	80.3	87.0

[1]Diets and response data from Tomlinson et al. (1994), Cornell model estimates calculated from diet composition and actual dry matter intakes.

The CNCPS, perhaps, is more important in evaluating if rumen protein and N components are optimum for carbohydrate utilization than vice versa since energy responses translate much more directly to more milk than do increases in protein flow from the rumen. Thus, the response to extra BCP is supportive to increases in milk yield and the BCP corrects marginal deficiencies that were reflected in lower milk protein percentages and yields

Summary

The first priority for protein nutrition of high-producing lactating cows is to optimize energy intake and utilization which optimizes BCP production in the rumen. This depends on supplying enough nonprotein N and peptides for rapid growth of the microorganisms utilizing nonstructural carbohydrates while supplying enough structural carbohydrates with large enough particle size to maintain adequate rumination and avoid excessive drops in rumen pH. The rumen microbes usually supply 55 to 65% of the absorbable protein utilized for lactation and the total amount is directly related to energy derived from carbohydrates. Degradable protein should be 10 to 12% of diet dry matter and some must be from high quality protein sources (soybean meal, etc.) to supply the peptides needed by microorganisms degrading NSC.

The amount of RUP needed is secondary to rumen protein needs but some is definitely needed. How much to rely on RUP supplements, such as animal byproducts, is uncertain but making diet calculations is important and nutritionists should attempt to formulate diets that will meet total protein needs without feeding excessive crude protein. There is an energy cost to the cow to convert excessive N to urea in the liver and a nutrient management cost to some dairymen if they have insufficient crop production to utilize all manure N for fertilizer and must export some manure off-farm. Often, some RUP supplements can be utilized cost effectively to spare total dietary protein supplementation, especially when oil-seed meals are high-priced. In cases where RUP supplements are economical, caution should be exercised to make certain that adequate DIP is supplied (10 to 12% of diet dry matter).

Thus, my recommendation is to consider RUP when formulating diets but make cost the deciding factor. If one can formulate cheaper diets with less crude protein using RUP supplements, do it. If not, use more degradable supplements to increase RUP. Animal byproducts and byproduct blends are effective RUP supplements that usually give better performance than corn-based RUP supplements.

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