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Director's Digest

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ECONOMICS OF "BY-PASS PROTEIN" FOR RUMINANTS: RE-EVALUATION OF A 20 YEAR OLD CONCEPT

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The absorption of indispensable amino acids from the digestive tract is necessary for maintenance, growth, reproduction and lactation of cattle. These amino acids are obtained from dietary protein that escapes rumen fermentation or from microbial protein synthesized in the rumen. Nitrogen metabolism is a complex, dynamic process in ruminants which makes it difficult to estimate absorption of protein or amino acids. The problems that arose with increased use of urea in certain types of ruminant diets indicated the need for improvement in feeding standards for expressing protein requirements of cattle. The first model to estimate absorbable protein was proposed by Burroughs et al. (1) and subsequently modified (2). During the past 20 years many different models have been proposed to estimate the postruminal supply of digestible protein for ruminants. These models have been reviewed and guidelines proposed for formulating diets for ruminants (3). The method has recently been adapted for use with dairy cattle (4).

Models describing the dynamics of nitrogen metabolism in ruminants have the potential of:

1. More adequately meeting the protein (amino acid) needs of ruminants for a given level of production and thereby preventing under or over feeding protein.
2. Formulate diets that are most economical for supplying protein needs of ruminants for a given level of production.

GROWING CATTLE

The protein requirement of growing cattle gaining 1.14 kg/d is illustrated in Figure 1. The requirement is expressed in terms of metabolizable protein, or protein digested and absorbed from the digestive tract. The requirement was estimated from the model outlined in Nutritional Requirements of Dairy Cattle (4). It can be seen for cattle gaining at a constant rate, the protein requirement is greater because of the increase in size and greater feed intake, but the requirement for gain is lower because of the change in body composition with less protein and more fat.

Also shown in Figure 1 are the quantities of metabolizable protein supplied by three different diets. These diets contained corn silage supplemented with urea, corn + corn silage (25:75) supplemented with urea or corn and alfalfa hay (40:60). For calves weighing 200 kg and expected to gain 1.14 kg/d, the metabolizable protein derived from microbial protein along with undegraded protein in corn silage or corn + corn silage would not be adequate to meet their protein requirements. The corn silage diet would not supply enough metabolizable protein until the cattle weighed 300 kg. The expected gain of cattle fed the corn silage diet supplemented with urea would be .54, .82 and 1.14 kg/d at 200, 250 and 300 kg, respectively. The diet would be adequate at 300 kg because feed consumption of cattle would increase to result in more protein being absorbed. The corn and alfalfa hay diet would be nearly adequate at 200 kg and would furnish more than enough metabolizable protein at 250 kg.

It is evident from Figure 1 that the proper supplemental protein would vary for each of the three diets and it would vary within diets as the cattle became heavier. Urea is not adequate supplement for 200 kg cattle fed corn silage or corn + corn silage, but is adequate for 300 kg cattle fed corn silage, or 250 kg cattle fed corn + corn silage. These diets could be adequately supplemented if a feed ingredient was added which provided additional undegraded protein. Three examples of potential supplemental proteins are given in Table 1. Expeller processed soybean meal (ESBM) and corn gluten meal (CGM) provide sufficient metabolizable protein at lower concentrations than solvent extracted soybean meal (SBM) because they are less extensively degraded. Urea should be added with ESBM and CGM in the corn + corn silage diet to provide sufficient available nitrogen in the rumen for synthesis of microbial protein. Each of these proteins would be expected to support gains of 1.14 kg/d.

Many growth trials have been conducted with growing cattle to show that the concepts presented above have validity. Results of two experiments (6,7) are presented in Tables 2 and 3. Urea was not a satisfactory supplement for either the high cob (Table 2) or high corn (Table 3) diets for 225 kg cattle if the objective was to optimize gains. After the cattle fed the cob diet weighed 370 kg or those fed corn weighed 290 kg, consumption of the diets supplemented with urea was great enough to support the growth anticipated based on energy in the diets. After the cattle fed urea reached this level of consumption there was some compensatory gain so performance over the entire feeding period resulted in little difference between urea and the protein supplements.

An important question for producers is whether the improvement in feed conversion with protein supplements when cattle are of lighter weights is enough to justify their use compared with urea. If supplemental protein is required to optimize growth, it is possible to substitute a less degradable protein and supply the same quantity of absorbed protein with less supplemental protein. Are the benefits of less degradable proteins sufficient to justify their use in growing diets for young cattle?

Economic analysis of the data for the corn silage and corn + corn silage diets shown in Figure 1 and Table 1 are given in Table 4. The greatest savings occurred when the need for additional undegraded feed protein was the highest, i.e. the 200 kg cattle fed corn silage. As the need for undegraded protein becomes less critical, such as with heavier cattle or cattle fed corn with silage, there was reduced economic return from the use of a less degradable protein. When protein supplements are relatively low in price there is not as much economic advantage to use more degradable proteins because additional corn silage or corn must be fed in place of the less degradable protein being replaced.

An economic analysis of the data from the experiment comparing SBM or ESBM with urea is given in Table 5. In all comparisons, replacing urea in the supplement with proteins increased cost of the feed. However during the first 43 days of the feeding period, performance of the cattle was improved enough by feeding sources of undegraded protein to result in somewhat lower feed costs per gain. After 70 days the advantage of feeding either SBM or ESBM at the higher concentrations was not adequate to justify the increased costs. There was some advantage for the lower level of ESBM at 70 days. If this was fed until the cattle were sold for slaughter, it would result in significantly greater feed costs per gain for all the cattle fed supplemental protein compared with urea. If urea had been substituted for the supplemental proteins after 70 days and assuming performance of the cattle would not have been affected, feed costs would have been reduced. However, there still was no economic advantage for using any of the sources of supplemental protein during the trial.

LACTATING CATTLE

The protein requirement of a cow during lactation is illustrated in Figure 2. The data were calculated from published milk production and feed intake curves (4). The diets containing low or high protein were those used by Claypool et al. (8). The diets were corn silage, chopped alfalfa hay and a concentrate mixture containing barley in a ratio of 29:17:54 on a dry matter basis. Protein was increased in the high protein diet by replacing barley with soybean meal. As shown, the low protein diet would not supply enough metabolizable protein during the first 16 weeks of lactation. The high protein diet would be adequate during the first 4 weeks and then supply too much protein thereafter. In the original experiment in which these diets were compared, cows fed the low and high protein diets produced 29.2 and 32.2 kg milk per day, respectively, for the first 90 days of lactation.

The data in Figure 2 suggest that dietary protein would be used most efficiently for supporting maximum milk production by feeding the high protein diet for 4 weeks followed by a diet containing an intermediate concentration of protein and then the low protein diet after 16 weeks.

The high protein diet contained 21.34% soybean meal on a dry basis. Substituting a less degraded protein would result in similar quantities of metabolizable protein with less supplemental protein. The high protein diet is compared with two reformulations containing ESBM or CGM instead of SBM in Table 6. Each of the diets would provide 126.7 g of metabolizable protein per kg of dry matter. Urea should be added with the less degradable proteins to provide enough nitrogen for rumen metabolism.

The diets shown in Table 6 provide more metabolizable protein than needed by 590 kg cows producing 32.2 kg milk per day observed in the Claypool experiment (8). Reformulating by increasing barley and reducing SBM to 17.04%, ESBM to 11.85% (urea increased to .46%) and CGM to 7.28% (urea increased to .57%) should provide enough metabolizable protein for cows consuming 18.7 kg dry matter and producing 32.2 kg milk per day.

Economic analysis of feeding the reformulated diets containing adequate metabolizable protein in comparison with the low protein diet (8) is given in Table 7. The assumptions are that cows produced 29.2 and 32.2 kg milk (3.5% fat) per day for 90 days and consumed 17.7 and 18.7 kg feed dry matter per day when fed the low protein diet or diets containing supplemental protein, respectively. As shown, adding protein increased the cost of the feed but the higher feed costs were offset by greater milk production which resulted in approximately $50 greater return over feed costs. Because the lactating cow does not compensate for low production during the early lactation, this economic advantage would be maintained. However as shown in Figure 2, the lower protein diet could support production during later stages of lactation and should be used to reduce feed costs. Substituting supplements with higher concentrations of undegraded protein did not result in improved economic returns with the feed prices used in this analysis.

OTHER CONSIDERATIONS FOR USING UNDEGRADABLE PROTEINS

Even though microbial proteins supply over 50% of the absorbed amino acids in growing cattle and over 60% in lactating cows, feeding certain proteins or mixtures of proteins with an undegraded fraction could augment or diminish concentrations of individual amino acids in the mixture being absorbed. Titgemeyer et al. (9) reported that replacing soybean meal with corn gluten meal decreased lysine and increased methionine flowing to the duodenum. Feeding blood meal increased lysine but decreased methionine in comparison with corn gluten meal. Whether there might be economic advantage to using specific proteins to alter flows of amino acids depends on the need for amino acid supplementation and the price of supplemental protein vs. price of protected amino acids. Feeding rumen-protected methionine or methionine + lysine has not been found to increase growth rate of cattle fed corn silage or corn grain diets supplemented with urea (10). Feeding rumen-protected methionine + lysine (11) or methionine (12) to lactating cows fed corn silage, alfalfa and corn supplemented with extruded soybeans did not significantly increase milk production. In another study (13), supplementing with methionine + lysine did not increase milk production but did increase concentrations of protein in milk. The amino acid requirement of ruminants is complex and there is no suitable model to formulate diets for amino acids. Knowledge of amino acid composition of undegraded fractions of feed proteins and proportional use of amino acids for maintenance and production is needed before the model used to calculate metabolizable protein could be effectively used to estimate amino acid requirements.

Another possible benefit of feeding proteins that more adequately meet dietary requirement is improvement in health. Most experimental animals have been allotted to treatments after a period of adjustment and immunizations, so effects of feeding protein on health are not critically evaluated. In one study completed at Iowa State University with calves started on experiment immediately upon arrival at the feedlot after an 800 mile haul, supplemental undegraded protein seemed to suppress the immune response to routine immunizations. In a study with first-calf dairy heifers (14), feeding higher concentrations of protein for 70 days prior to parturition did not influence colostrum production or concentrations of IgG1 or IgM in milk. More studies are needed to confirm these observations suggesting that improved protein nutrition does not enhance the immune system.

When cattle are fed less degradable proteins, they utilize dietary proteins more efficiently and therefore excrete less dietary nitrogen in the urine. At present there is not incentive to reduce nitrogen in livestock wastes, but in the future, feeding less degraded proteins to ruminants could be one approach to decrease loss of nitrogen from livestock systems.

CONCLUSIONS

Although it is generally accepted that lactating cows and young growing cattle have high protein requirements, discretion must be used in selecting protein supplements for these animals. To optimize economic returns, protein supplementation should be changed in relation to the requirements for metabolizable protein.

In many situations, three different protein supplements should be used for cows during lactation as well as for young calves (200 kg or less) fed to finished slaughter weights. It is important to reduce the amount of supplemental protein in the diet or replace it with urea when consumption of the diet is adequate to support optimum performance with less supplemental protein or with urea.

If diets are formulated for light weight cattle (200 kg or less) or high producing cows (30 kg or more milk per day), it is advisable to feed a source of undegradable supplemental protein. However there may not be economic advantage to use a supplement with a higher proportion of the protein undegraded even though it may be used more efficiently.

There is greater potential for increased economic returns from use of undegraded proteins when protein requirements are high or when the undegradable proteins can be purchased at a competitive price. With the prices used for the comparisons in this paper, the undegraded proteins were more expensive per unit of crude protein, but less expensive per unit of undegraded protein. Adding the additional silage or barley and urea along with the undegraded proteins canceled much of the advantage of their lower cost per unit of undegraded protein.

If light weight cattle are sold after a period of backgrounding and before they are placed in an environment where there can be compensatory gain, there are potential economic advantages for use of supplements with undegraded proteins. However if ownership of cattle is retained, compensatory gain after cattle reach heavier weights and consume more feed may nullify the positive benefits obtained during the growing period.

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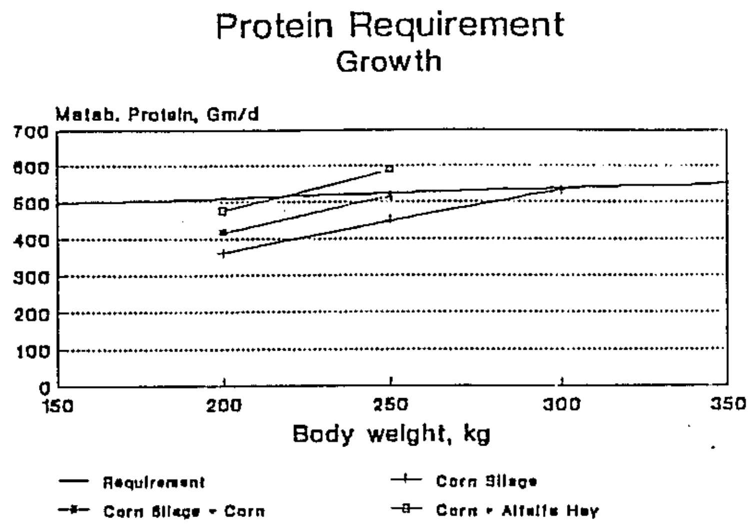

Figure 1. Metabolizable protein requirement of cattle gaining 1.14 kg per day at different body weights. Also shown are the quantities of metabolizable protein supplied by a corn silage or corn + corn silage diets supplemented with urea.

Table 1. Quantities of solvent extracted soybean meal (SBM), expeller processed soybean meal (ESBM) or corn gluten meal (CGM) needed to adequately supplement different diets fed to growing cattle[1].

Weight kg	Diet	Supplemental protein SBM	ESBM	CGM
		kg/head per day		
200	Corn silage	1.08	.79	.51
	Corn + corn silage	.68	.50	.32
	Corn + Alfalfa	.24	.17	.11
250	Corn silage	.54	.39	.25

[1]Values for undegraded proteins in all feeds except ESBM were taken from (4). The value for ESBM was taken from (5).

Table 2. Performance of cattle fed urea, SBM, CGM or corn stillage as sources of supplemental protein[1].

4 pens per diet 5 cattle per pen	Urea	SBM	CGM	Stillage
Starting wt, kg	221	224	223	224
Period 1 (0 - 168 days)				
Ending wt, kg	330	373	373	370
Daily gain, kg	.65	.89	.89	.87
Daily feed DM, k	6.1	7.4	6.7	6.4
Feed/Gain	9.51	8.26	7.49	7.48
Period 2 (169 - 336)				
Ending wt, kg	503	535	534	534
Daily gain, kg	1.03	.96	.96	.99
Daily feed DM, kg	9.8	10.3	10.0	9.2
Feed/Gain	9.56	10.69	10.43	9.28
Total period (0 - 336 days)				
Daily gain, kg	.84	.93	.93	.92
Daily feed DM, kg	8.0	8.8	8.3	7.8
Feed/Gain	9.49	9.50	9.01	9.45

[1]Urea diet during the first period contained 63.0% ground cobs, 20.84% cracked corn, 12.0% molasses and 4.16% urea, minerals and vitamins. Soybean meal (15.0%), corn gluten meal (5.2%) and stillage (15.33%) replaced corn and urea. During the second period the urea diet contained 53.0% ground cobs, 34.61% cracked corn, 10.0% molasses and 2.39% urea, minerals and vitamins. Soybean meal (9.5%), corn gluten meal (4.0%) and stillage (10.0%) replaced corn and urea.

Table 3. Performance of cattle fed urea, SBM or ESBM as sources of supplemental protein[1].

4 pens per diet 6 cattle per pen	Urea	SBM 8%	ESBM 4%	ESBM 8%
Starting wt, kg	225	227	226	224
0 - 43 days				
Daily gain, kg	.68	.83	.86	.95
Daily feed DM, kg	5.7	5.9	6.1	6.4
Feed/Gain	8.44	7.12	7.12	6.75
43 - 70 days				
Daily gain, kg	1.33	1.46	1.51	1.30
Daily feed DM, kg	7.9	8.5	8.6	8.8
Feed/Gain	5.95	5.82	5.67	6.81
70 - 140 days				
Daily gain, kg	1.15	1.12	1.09	1.21
Daily feed DM, kg	8.0	8.4	8.4	8.6
Feed/Gain	6.98	7.56	7.74	7.11
Beyond 140 days				
Days	281	278	278	273
Daily gain, kg	1.08	1.15	1.10	1.08
Daily feed DM, kg	9.5	9.9	9.8	9.8
Feed/Gain	8.82	8.63	8.84	9.12
Total period				
Daily gain, kg	1.06	1.12	1.10	1.11
Daily feed DM, kg	8.4	8.8	8.8	8.9
Feed/Gain	7.93	7.83	7.92	8.01

[1]Urea supplemented diet contained, 55.0% cracked corn, 33.0% ground corn cobs, 8.0% molasses and 4.0% urea, minerals and vitamins. Soybean meal replaced corn and urea.

Table 4. Feed costs for cattle fed corn silage or corn + corn silage and supplemented with SBM, ESBM or CGM[1].

Diet	Supplement		
Weight range	SBM	ESBM	CGM
Corn Silage	Total feed costs, $/head		
200 - 250	25.74	24.60	24.12
250 - 300	24.54	23.90	23.80
Corn + corn silage			
200 - 250	24.51	23.94	23.70

[1]Feed prices used were: corn silage $25/ton, corn $2.40/bu, soybean meal $200/ton, expeller soybean meal $225/ton, corn gluten meal $300/ton, urea $150/ton and minerals $200/ton. experiment the proteins continued to be

Table 5. Feed costs for cattle fed a high roughage diet supplemented with urea, solvent soybean meal or expeller processed soybean meal[1].

	Urea	SBM 8%	ESBM 4%	ESBM 8%
0 - 43 days				
Total feed cost, $/head	23.06	26.49	26.37	29.52
Feed cost/100 lb gain, $	36.03	33.96	32.16	32.80
0 - 70 days				
Total feed cost, $/head	43.05	50.42	49.67	54.93
Feed cost/100 lb gain, $	30.10	30.56	28.88	32.89
Total period				
Total feed cost, $/head	221.27	254.62	244.06	258.48
Feed cost/100 lb gain, $	33.78	37.12	36.10	38.75
If urea had been used in all diets after 70 days				
Total feed cost, $/head	221.27	234.21	231.50	233.89
Feed cost/100 lb gain, $	33.78	34.14	34.25	35.07

[1]Feed prices were those shown in Table 4 along with cobs $50/ton and molasses $60/ton.

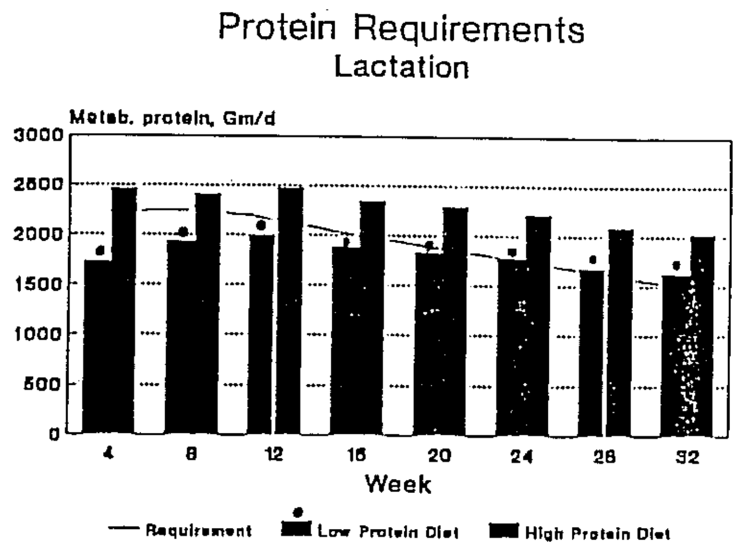

Figure 2. Metabolizable protein requirement for a cow during lactation. Also shown are quantities of metabolizable protein supplied by a low protein diet and the diet supplemented with soybean meal.

Table 6. Lactation diets containing supplemental proteins with different degradation.

Ingredient	SBM	ESBM	CGM
		% dry matter	
Corn silage	29.40	29.40	29.40
Alfalfa hay	16.84	16.84	16.84
Barley	29.56	35.87	41.43
Soybean meal	21.34	14.80	9.11
Molasses	1.43	1.43	1.43
Urea		.23	.36
Other	1.43	1.43	1.43

Table 7. Economic returns from feeding protein or supplements with more undegraded protein to lactating dairy cows[1].

	Diet			
	Low protein	SBM	ESBM	CGM
Feed cost, $/100 kg	12.17	13.89	13.77	13.87
Feed cost, $/90 days	193.87	233.81	231.78	233.43
Value of milk, $/90 days	867.24	956.34	956.34	956.34
Return over feed, $	673.37	722.53	724.56	723.01

[1]Feed prices were those used in Tables 4 and 5 along with barley $6.00/cwt and alfalfa hay $100/ton.