Nutritional Evaluation of Poultry By-Product Meal as a Protein Source for Ruminants: Effects on Performance and Nutrient Flow and Disappearance in Steers

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Summary

This research shows that feeding poultry by-product meal to growing steers gives similar results as feeding soybean meal and that poultry by-product meal can replace soybean meal as a source of supplemental crude protein for steer calves consuming a corn silage-based diet. The decision to replace soybean meal with poultry by-product meal can be made on a cost per pound of crude protein basis. Soybean meal was included as a treatment in the current study because it is frequently used as a source of supplemental protein in growing ruminant diets. In order to feed poultry by-product meal to ruminants, the label must indicate that the product was processed by approved procedures.

Introduction

Ruminally undegraded intake protein (UIP), microbial protein, and endogenous proteins are the sources of protein that are digested and absorbed as amino acids in the small intestine of ruminants. Under most dietary conditions, microbial protein is a substantial portion of the protein entering the small intestine, where enzymatic digestion releases amino acids that are absorbed to meet the animals' requirements for maintenance, reproduction, growth, and lactation. The metabolizable protein requirement of low-producing ruminants can be met by microbial protein; however, as production increases (early rapid growth, high wool and/or milk production), it becomes more important to provide UIP.

Supplementing ruminant diets with UIP can increase the flow of nitrogen (N) and amino acids to the small intestine and result in improved growth and efficiency of N utilization. Poultry by-product meal (PBM) may be a protein source capable of supplying UIP. Feeding trials with growing-finishing steers has indicated that PBM can be effectively utilized as a source of supplemental N. The ruminal undegradability of PBM in steers has been reported to range from 32 to 40%; however, more in-depth information about PBM is needed to adequately balance diets. The identification of protein sources resistant to microbial degradation in the rumen and available for absorption in the small intestine is essential in formulating the diets of high-producing ruminants. Objectives of the current studies were to determine ruminal solubility and degradability of PBM N and to evaluate the influence of supplemental PBM on steer average daily gain (ADG); dry matter intake (DMI); gain efficiency (lb gain/lb feed); and efficiency of bacterial protein synthesis and nutrient flow within, and disappearance from, the gastrointestinal tract of beef steers.

Procedures

Growth Study

Ninety-six crossbred steers (predominantly Charolais; 503 ± 11 lb body weight) were obtained through public auctions in central Kentucky. A three-week receiving protocol for health and corn silage diet adaptation was used. Steers were monitored for temperature (>103.5°F) and respiratory problems and treated appropriately.

Prior to initiation of the 84-d study, steers were vaccinated with Clostri Shield 7 Way® and Vira Shield 5 + Somnus®, treated for internal and external parasites with Ivomec®, and implanted with Compudose®.

Experimental diets (Table 1) were formulated to contain 11.5% crude protein (CP) and consisted of 49% corn silage, 36% cottonseed hulls, and 15% supplement. The sources of supplemental N (% of total supplemental N; dry matter basis) were 100% soybean meal (SBM):0% urea (100% SBM), 0% PBM:100% Urea (0% PBM), 25% PBM:75% urea (25% PBM), 50% PBM:50% urea (50% PBM), 75% PBM:25% urea (75% PBM), and 100% PBM:0% urea (100% PBM). Supplements were formulated to contain 37% CP, with PBM providing 11, 22, 33, and 44% of the total dietary CP in the 25, 50, 75 and 100% PBM diets, respectively. Diets were formulated to provide adequate amounts of Ca, P, and vitamins A, D, and E. Steers were stratified by weight and allotted randomly to one of six treatments. They were then sorted by treatment and weight and allotted randomly to one of 24 pens (four steers/pen, four pens/treatment). Steers were weighed before the 0800 feeding on two consecutive days at the beginning and end of the trial. Intermediate weights were taken every 28 d. All steers were offered diets at a common percentage of BW (calculated from the pen of steers previously consuming the least daily DMI on a BW basis) for the final 5 d of the study in order to minimize the effects of intake on ruminal fill.

Feed bunks were checked daily and pen intake adjusted to allow for 10% refusals. Steers were fed 55% of the daily allotment of corn silage and cottonseed hulls at 0800 and 45% at 1600. The daily allotment of supplement was top-dressed at 0800 to ensure consumption. Fresh water was available at all times. Supplements, corn silage, cottonseed hulls, and orts were collected and analyzed weekly for DM. Feed samples were ground through a 1-mm screen and analyzed for N, acid detergent insoluble nitrogen (ADIN), and neutral detergent fiber (NDF). During the second week of the study, one steer developed bacterial pleuropneumonia and was removed from the trial. Intake of the steer was estimated and overall pen intake adjusted to account for its removal.

Digestion Study

ANIMALS AND DIETS: Six Angus steers (573 ± 9 lb initial BW) with ruminal, duodenal, and ileal cannulas were used in a 6 x 6 Latin square, with treatments and diets the same as described for the growth trial (Table 1). The CP content of all diets was greater than formulated because the cottonseed hulls contained more CP than anticipated (9.9 compared with 4.1%; 52% of the cottonseed hull N was ADIN). Chromic oxide was included at .2% of the diet as an indigestible marker of digesta flow. Steers were housed in individual pens (8.2 ft x 8.2 ft) in a temperature (73° F) and light (16 h light: 8 h dark) controlled room with water available at all times. Steers were weighed at the beginning of each period, and DMI was adjusted to 2.0% of BW. Daily feed allotments were divided into equal portions and fed every 2 h using automated feeders.

SAMPLE COLLECTION AND ANALYSIS: Each period was 14 d, with 10 d for adjustment followed by 4 d for collection of digesta and feces. Corn silage, cottonseed hulls, and supplement samples were collected on d 9 to 14 of each period and composited. On d 11 to 14, approximately 200 g of duodenal and ileal digesta and 100 g of fecal material were collected three times/d at 8-h intervals with a 6-h increment added between days to shift sampling times. This allowed a sample to be obtained at every even hour of the 24-h day. Fecal subsamples (50 g) were composited within steer and frozen. Digesta were homogenized and 100-g subsamples composited within steer and frozen. Feed and fecal samples were dried (50°C) for 48 and 96 h, respectively. Digesta samples were freeze-dried. Dried samples were ground through a 1-mm screen as described above.

On d 11, each steer was intraruminally pulse-dosed with 5 g of Co as Co-EDTA in a 200-mL aqueous solution. The Co marker was administered throughout the rumen by injecting through a stainless steel probe with a perforated tip. Ruminal fluid (100 mL) was collected at 2, 4, 6, 8, 10, 12, 16, and 24 h postdosing. Ruminal fluid pH was measured immediately after collection. Twenty milliliters of ruminal fluid were frozen for later analysis of Co concentration. Five milliliters of ruminal fluid were acidified and frozen for subsequent analysis of volatile fatty acids (VFA) and ammonia (NH_3) N.

Ruminal contents (6 to 8 lb) were obtained from all areas of the rumen on d 14 and ruminal bacteria isolated and frozen. Bacteria were freeze-dried, ground with a mortar and pestle, and composited within treatment.

Statistical Analysis

In the growth study dry matter intake, ADG and gain/feed were analyzed as a randomized complete block design. The protein efficiency of PBM was calculated as the slope of the line using ADG as the ordinate and N supplied by PBM as the abscissa for the 0, 25, 50, 75, and 100% PBM diets. The statistical model included treatment and weight block. Non-orthogonal contrasts used to separate treatment means were: 1) 100% PBM vs 100% SBM, 2) 0% PBM vs 100% SBM, 3) linear, 4) quadratic and 5) cubic effects of PBM.

For the digestion study, data were analyzed as a Latin square design. The statistical model included period, steer, and treatment. However, n was 5 for all variables in which ileal data were used because of cannula malfunction in one steer. Non-orthogonal contrasts were the same as described for the growth study. Ruminal VFA, NH_3 N, and pH data collected at fixed times throughout the sampling day were analyzed as repeated measures. No treatment x time interactions were observed ($P > .10$); therefore, measurements were averaged across time and treatment means compared as described above. Ruminal escape of PBM N was calculated as the slope of the line using duodenal non-NH_3, non-bacterial N as the ordinate, and N supplied by PBM as the abscissa for the 0, 25, 50, 75, and 100% PBM diets.

Results and Discussion

In the growth study, steer final weight, total gain, ADG, DMI, and gain/feed increased linearly ($P < .003$) as PBM increased (Table 2). There were no differences ($P > .48$) for these variables between 100% SBM and 100% PBM, whereas 100% SBM increased ($P < .003$) each compared with 0% PBM. Many studies have reported improved performance by growing ruminants when natural proteins, compared with urea, are used as sources of supplemental N. This can be accomplished by the supplemental protein source increasing the total flow of digestible protein (microbial, dietary, and endogenous) flowing to the small intestine and(or) providing digestible UIP that is complementary to any limiting amino acid in microbial CP. In the present study, the increased flow of protein to the small intestine, as a result of increased DMI, may have increased the quantity of protein absorbed from the small intestine. However, the concomitant increase ($P < .01$) in ADG and gain/feed can be interpreted to imply that even if DMI had not increased as PBM increased in the diet, there would still have been an increase in ADG.

In the digestion study, ruminal NH_3 N decreased linearly ($P < .001$) as PBM increased in the diet (Table 3). This corresponded with a reduction in DIP as PBM increased, which reduced protein available for microbial degradation and subsequent conversion to NH_3 N. The concentration of ruminal NH_3 N was greater ($P < .001$) for 100% SBM compared with 100% PBM but lower ($P < .001$) for 100% SBM compared with 0% PBM. The lowest ruminal NH_3 N in the present study was 5.90 mM (100% PBM diet). This concentration of NH_3 N is well above the level shown to stimulate maximal growth of rumen microbes, and NH_3 concentration was unrelated to microbial efficiency. Therefore, ruminally available N should not have been limiting. Ruminal fluid dilution rate was not influenced ($P > .70$) by PBM; however, it was greater ($P < .05$) for 100% SBM compared with the 0 and 100% PBM treatments. Supplemental N source had no effect ($P > .33$) on ruminal volume or pH.

Total ruminal VFA concentration was not affected ($P > .22$) by supplemental N source; however, the molar proportions of individual VFA were affected by treatment (Table 3). Acetate was lower ($P < .05$) for 100% SBM compared with both 0 and 100% PBM. As PBM increased in the diet, propionate decreased ($P < .07$) and isobutyrate increased ($P < .001$) linearly. Isobutyrate was also greater ($P < .001$) for 100% SBM compared with 0 and 100% PBM. Butyrate, isovalerate and valerate were not affected ($P > .10$) as PBM increased; however, 100% SBM increased butyrate ($P < .04$) and isovalerate ($P < .08$) compared with 100 and 0% PBM, respectively. Acetate:propionate

increased linearly (P < .06) as PBM increased and was greater (P < .07) for 100% PBM compared with 100% SBM.

Duodenal N flow increased linearly (P < .001) as PBM increased in the diet, while 100% SBM increased (P < .02) duodenal flow of N compared with 0% PBM and decreased (P < .001) N flow compared with 100% PBM (Table 4). Because bacterial N flow at the duodenum was not affected (P > .19) by treatment, changes in duodenal N flow are the result of non-bacterial N. Duodenal NH_3 N decreased (P < .04) and duodenal non-NH_3, non-bacterial N flow increased in a linear fashion (P < .001) as PBM increased. The 100% SBM treatment increased duodenal NH_3 N flow compared with 0 and 100% PBM (P < .003) and duodenal non-NH_3, non-bacterial N flow compared with 0% PBM (P < .03). The duodenal non-NH_3, non-bacterial N flow was greater (P < .001) for 100% PBM compared with 100% SBM.

Ruminal escape of PBM and SBM N was 40.6 (Figure 1) and 13.7%, respectively (ruminal escape of SBM N was estimated by subtracting 0% PBM duodenal non-NH_3, non-bacterial N flow from 100% SBM duodenal non-NH_3, non-bacterial N flow and dividing the remainder by SBM N intake).

Efficiency of bacterial CP synthesis (g bacterial N/kg of true or apparent OM disappearance from the stomach) was decreased

Table 1. Ingredient and chemical composition of diets fed to steers.

	Growth Study Source of Supplemental Nitrogen[a]						Digestion Study Source of Supplemental Nitrogen[a]					
Item[b]	0% PBM	25% PBM	50% PBM	75% PBM	100% PBM	SBM	0% PBM	25% PBM	50% PBM	75% PBM	100% PBM	SBM
Ingredient, % of DM												
Corn silage	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00	49.00
Cottonseed hulls	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
Ground corn	11.06	9.48	7.90	6.32	4.75	1.65	10.89	9.30	7.69	6.10	4.51	1.40
Poultry byproduct meal	-	1.97	3.95	5.92	7.89	-	-	1.98	3.97	5.95	7.93	-
Soybean meal	-	-	-	-	-	10.99	-	-	-	-	-	11.04
Urea	1.58	1.19	.79	.40	-	-	1.55	1.16	.78	.39	-	-
Choice white grease	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45	.45
Trace mineral salt[c]	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47	.47
Dicalcium phosphate	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53	.53
Limestone	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89	.89
Vitamin premix[d]	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
Chromic oxide	-	-	-	-	-	-	.20	.20	.20	.20	.20	.20
Chemical												
OM, % of DM	-	-	-	-	-	-	94.0	93.5	93.2	92.4	93.0	93.6
CP, % of DM	12.3	12.2	12.4	12.5	12.6	12.5	14.0	13.9	14.2	14.1	14.1	14.1
ADIN, % of CP	2.2	2.8	3.7	4.9	5.0	3.4	3.4	4.6	4.9	5.1	5.7	3.9

[a]0% PBM = 0% poultry by-product meal:100% urea; 25% PBM = 25% PBM:75% urea; 50% PBM = 50% PBM:50% urea; 75% PBM = 75% PBM: 25% urea; 100% PBM = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]DM = dry matter, OM = organic matter, CP = crude protein, ADIN = acid detergent insoluble nitrogen.

[c]98.5% NaCl, .35% Zn, .34% Fe, .20% Mn, 330 ppm Cu, 70 ppm I, 50 ppm Co, and 90 ppm Se.

[d]8,800 IU/g vitamin A, 1,760 IU/g vitamin D, and 1.1 IU/g vitamin E.

Table 2. Effects of supplemental nitrogen on the growth of steers that consumed a diet based on corn silage and cottonseed hulls.

	Source of Supplemental Nitrogen[a]							P-Value[c] (P<)		
Item[d]	0%PBM	25% PBM	50% PBM	75% PBM	100% PBM	SBM	SEM[b]	Linear	100 vs SBM	0 vs SBM
Initial wt, lb	502	495	504	502	502	504	2	.43	.82	.76
Final wt, lb	656	680	700	719	733	739	7	.001	.51	.001
Total gain, lb	154	185	196	217	231	235	7	.001	.49	.001
Days 0 to 84										
ADG, lb/d	1.83	2.20	2.33	2.60	2.75	2.82	.07	.001	.49	.001
DMI, lb/d	14.43	15.58	16.04	16.52	16.32	16.65	.40	.003	.59	.003
Gain/feed	.126	.141	.145	.157	.168	.170	.004	.001	.80	.001

[a]0% PBM = 0% poultry by-product meal:100% urea; 25% PBM = 25% PBM:75% urea; 50% PBM = 50% PBM:50% urea; 75% PBM = 75% PBM:25% urea; 100% PBM = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]Standard error of mean, n = 4.

[c]100 vs SBM = 100% PBM vs 100% SBM; 0% PBM vs 100% SBM.

[d]ADG = average daily gain, DMI = dry matter intake.

for 100% SBM compared with 0 (P < .04) and 100% (P < .02) PBM, while PBM did not affect (P > .35) bacterial CP synthesis. Bacterial N flow at the duodenum was not influenced (P > .19) by supplemental N source; therefore, the increased OM disappearance from the stomach for 100% SBM generated the observed decrease in efficiency of bacterial CP synthesis.

Small intestinal N disappearance (g/d) increased linearly (P < .05) as PBM increased in the diet, while 100% SBM did not affect N disappearance from the small intestine compared with 0 (P > .26) or 100% (P > .36) PBM. Nitrogen disappearance from the small intestine for the PBM diets paralleled duodenal N flow. Apparent N disappearance from the small intestine, as a percentage of duodenal N flow, was not affected (P > .18) by treatment. Thus, increased disappearance of PBM N in the small intestine appeared to be a function of duodenal N flow. Our finding that apparent N disappearance as a percentage of duodenal flow did not differ between PBM and SBM indicates that the intestinal availability of PBM and SBM N is similar or comparable.

Ileal N flow increased linearly (P < .001) as PBM increased. The 100% PBM treatment increased (P < .001) ileal N flow compared with 100% SBM; however, no difference (P > .77) was observed in ileal N flow for 100% SBM compared with 0% PBM. Total N disappearance from the hindgut (P < .007) and apparent N disappearance, expressed as a percentage of ileal N flow, increased (P < .03) in a linear manner as PBM increased. Nitrogen disappearance (g/d) from the hindgut was greater (P < .09) for 100% PBM compared with 100% SBM; however, 100% SBM increased (P < .03) hindgut N disappearance as a percentage of ileal N flow compared with 0% PBM. Nitrogen flowing past the ileum of ruminants can generally be considered of little value to the animal. Nitrogen disappearance from the hindgut in this study may be a result of increased bacterial fermentation of protein that escaped degradation in the foregut. Apparent total tract N disappearance, as a percentage of N intake, decreased linearly (P < .004) as PBM increased in the diet. Nitrogen disappearance was also greater for 100% SBM compared with 0 (P < .06) and 100% (P < .001) PBM.

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Figure 1. Ruminal escape of poultry by-product meal (PBM). Escape nitrogen was calculated as the slope of the line utilizing duodenal non-ammonia, non-bacterial nitrogen flow (DNAMMNBN) as the ordinate and nitrogen supplied by PBM as the abscissa. The dotted line indicates the basal flow of DNAMMNBN without supplemental PBM nitrogen.

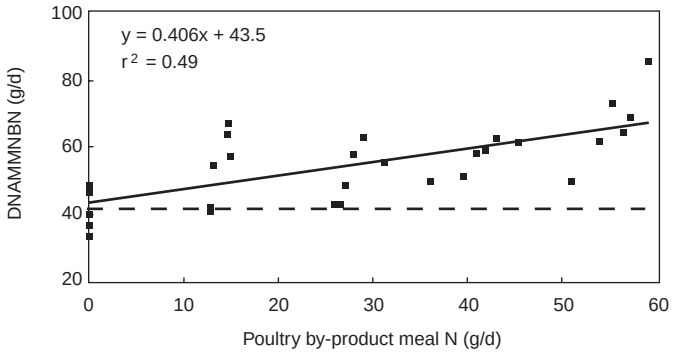

Table 3. Ruminal characteristics of steers fed diets with soybean meal or increasing poultry by-product meal as sources of supplemental nitrogen.

	Source of Supplemental Nitrogen[a]							P-Value[c] (P<)		
Item[d]	0% PBM	25% PBM	50% PBM	75% PBM	100% PBM	SBM	SEM[b]	Linear	100 vs SBM	0 vs SBM
Ammonia nitrogen, mM	12.02	10.05	8.49	7.48	5.90	8.85	.36	.001	.001	.001
Fluid dilution rate, %/h	10.7	11.2	10.7	10.7	10.7	12.2	.5	.71	.05	.05
Ruminal volume, L	36.2	35.4	37.8	36.0	37.4	36.5	1.7	.61	.72	.93
pH	6.57	6.52	6.55	6.54	6.56	6.54	.02	.96	.65	.34
Total VFA , mM	88.5	89.8	88.6	88.4	87.7	90.2	1.4	.50	.23	.42
VFA, mol/100 mol										
Acetate	67.1	66.3	67.6	67.1	67.8	65.3	.6	.21	.006	.05
Propionate	17.0	18.4	16.9	17.1	16.4	17.2	.4	.07	.21	.80
Isobutyrate	1.4	1.4	1.5	1.6	1.6	1.8	.04	.001	.001	.001
Butyrate	11.2	10.5	10.7	10.5	10.6	12.0	.4	.41	.04	.20
Isovalerate	2.0	2.0	2.0	2.3	2.2	2.4	.1	.11	.46	.08
Valerate	1.3	1.3	1.4	1.4	1.4	1.3	.04	.28	.80	.19
Acetate:propionate	4.0	3.6	4.0	4.0	4.2	3.8	.1	.06	.07	.50

[a]0% PBM = 0% poultry by-product meal:100% urea; 25% PBM = 25% PBM:75% urea; 50% PBM = 50% PBM:50% urea; 75% PBM = 75% PBM:25% urea; 100% PBM = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]Standard error of mean, n = 6.

[c]100 vs SBM = 100% PBM vs 100% SBM; 0% PBM vs 100% SBM.

[d]VFA = volatile fatty acid.

Table 4. Nitrogen digestion by steers fed diets with soybean meal or increasing poultry byproduct meal as sources of supplemental nitrogen.

	Source of Supplemental Nitrogen[a]							P-Value[c] (P<)		
Item[d]	0% PBM	25% PBM	50% PBM	75% PBM	100% PBM	SBM	SEM[b]	Linear	100 vs SBM	0 vs SBM
Nitrogen intake, g/d	124.0	124.3	125.6	123.2	124.8	125.6	1.3			
Total nitrogen flow at duodenum	126.7	141.1	138.8	146.0	153.6	135.2	2.1	.001	.001	.02
Bacterial nitrogen at duodenum, g/d	79.1	81.1	82.0	84.0	81.2	80.0	1.7	.20	.63	.70
Ammonia nitrogen at duodenum, g/d	5.1	5.6	4.8	4.7	4.9	6.0	.2	.04	.001	.003
Non-ammonia, non-bacterial N flow at duodenum, g/d	42.5	54.5	52.0	57.2	67.4	49.1	1.8	.001	.001	.03
Bacterial nitrogen, %	7.6	7.7	7.6	7.6	7.6	8.1				
Bacterial nitrogen:purine ratio	1.25	1.18	1.24	1.23	1.15	1.12				
Bacterial CP synthesis, g of nitrogen/lb of OMDA	45.0	45.8	47.0	50.3	46.8	35.0	2.9	.40	.02	.03
Bacterial CP synthesis, g of nitrogen/lb of OMDT	28.9	29.3	29.5	31.1	29.7	25.2	1.1	.36	.02	.04
Nitrogen disappearance from stomach, Apparent, g/d	-2.7	-16.8	-13.3	-22.8	-28.7	-9.6	2.4	.001	.001	.06
Nitrogen disappearance from stomach, True[e], g/d	76.4	64.2	68.7	61.2	52.5	70.4	2.4	.001	.001	.11
Nitrogen disappearance from small intestine, g/d	63.3	69.9	66.6	73.0	72.7	68.5	3.2	.05	.37	.27
Apparent N disappearance from small intestine,% of duodenal flow,g/d	49.7	49.5	47.6	49.8	47.5	51.0	1.8	.48	.19	.63
Ileal nitrogen flow, g/d	64.3	71.2	72.7	73.3	81.2	65.5	2.6	.001	.001	.78
Nitrogen disappearance from hindgut, g/d	11.8	16.4	18.2	16.4	22.4	16.8	2.1	.007	.09	.12
Apparent N disappearance from hindgut, % of ileal N flow	17.6	22.8	24.8	22.3	26.3	25.7	2.1	.03	.85	.03
Fecal nitrogen flow, g/d	52.3	55.4	54.3	56.2	59.0	48.8	1.5	.009	.001	.14
Apparent total tract nitrogen disappearance, %	57.8	55.3	56.7	54.2	52.6	61.0	1.1	.004	.001	.06

[a]0% PBM = 0% poultry by-product meal:100% urea; 25% PBM = 25% PBM:75% urea; 50% PBM = 50% PBM:50% urea; 75% PBM = 75% PBM:25% urea; 100% PBM = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]Standard error of mean, n = 6, except for nitrogen disappearance from small intestine, apparent nitrogen disappearance from small intestine, ileal nitrogen flow, nitrogen disappearance from hindgut, and apparent nitrogen disappearance from hindgut where n = 5.

[c]100 vs SBM = 100% PBM vs 100% SBM; 0% PBM vs 100% SBM.

[d]N = nitrogen, OMDA = apparent organic matter disappearance from stomach,OMDT = true organic matter disappearance from stomach.

[e]Corrected for nitrogen of bacterial origin.

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Summary

Lack of a treatment effect on disappearance of amino acids from the small intestine implies that intestinal flow of absorbable amino acids was not affected by supplemental N source. In this study, the undegraded intake protein amino acids from poultry by-product meal and soybean meal appeared limited in their intestinal availability. Based on the results of this study, supplementation with poultry by-product meal, urea, and soybean meal yielded similar flows of absorbable amino acids to the small intestine of steer calves consuming corn silage- and cottonseed hulls-based diets. Therefore, poultry by-product meal provides ruminant nutritionists with an alternative source of supplemental protein to consider when formulating diets.

Introduction

In ruminants, the duodenal flow of amino acids is supplied by microbial protein synthesized in the rumen, ruminally undegraded dietary protein, and endogenous sources. Supplementing ruminant diets with sources of undegradable intake protein (UIP) can increase the duodenal flow of amino acids. However, some sources of UIP have been shown to decrease microbial crude protein (CP) synthesis and flow of bacterial amino acids to the small intestine compared with more degradable protein sources. Consequently, a balance of undegradable and degradable intake protein is needed to maximize microbial CP production and duodenal flow of dietary amino acids.

Poultry by-product meal (PBM) is a by-product of the poultry industry consisting of the ground, dry-rendered parts of the carcass of slaughtered poultry such as heads, feet, undeveloped eggs, intestines, and insignificant amounts of feathers. Poultry by-product meal may provide sufficient degradable intake pro-

tein to maintain microbial CP synthesis while also providing UIP. Research has shown that supplemental PBM can improve steer dry matter intake (DMI), average daily gain (ADG), and gain:feed compared with urea, and ADG and gain:feed compared with soybean meal (SBM). However, we are unaware of any studies that have measured the effect of PBM on the flow and disappearance of amino acids (bacterial and non-bacterial) from the small intestine of ruminants. Knowledge of PBM amino acids that escape ruminal degradation and are absorbable in the small intestine will provide ruminant nutritionists with information necessary to balance diets for metabolizable amino acids. Therefore, this study was conducted to evaluate the effect of supplemental PBM on the duodenal flow and small intestinal disappearance of amino acids in steer calves consuming a corn silage- and cottonseed hulls-based diet.

Procedures

Six Angus steers (573 ± 9 lb body weight [BW]) with ruminal and double-L shaped duodenal and ileal cannulas were used in a 6 x 6 Latin square design. Diets (provided at 2.0% of BW) were formulated (dry matter [DM] basis) to contain 11.5% CP, 49% corn silage, 36% cottonseed hulls, and 15% supplement. Daily feed allotments were divided into equal portions and offered every 2 h using automated feeders. Treatments, based on supplemental nitrogen (N) source, were 100% SBM and 0, 25, 50, 75, and 100% PBM, with urea used to balance for N. Supplements were formulated to contain 37% CP, with PBM providing 11, 22, 33, and 44% of the total dietary CP in the 25, 50, 75, and 100% PBM diets, respectively. Soybean meal was formulated to provide 47% of the total dietary CP in the 100% SBM treatment.

AMINO ACID ANALYSIS: Approximately 150-mg samples (in duplicate) of SBM, PBM, ruminal bacteria, and duodenal and ileal digesta were hydrolyzed. Oxidation of amino acids and specifically sulfur amino acids was minimized. Amino acid composition of hydrolysates was determined by reverse phase HPLC using a Waters Pico•Tag Amino Acid Analysis System. Preliminary analysis of ruminal bacteria, PBM, SBM, and duodenal and ileal digesta indicated incomplete recovery of methionine in duodenal and ileal digesta. Therefore, methionine recovery was determined and average recovery was used to correct for methionine loss. Methionine recoveries (%; n = 11) were 75.6 ± .65 and 45.0 ± .59 for duodenal and ileal digesta, respectively. Asparagine and glutamine are not reported due to quantitative conversion during hydrolysis to aspartate and glutamate, respectively.

Table 1. Amino acid (AA) composition of ruminal bacteria, poultry by-product meal, and soybean meal[a].

	Bacterial AA Composition Source of Supplemental Nitrogen[b]						Supplement AA Composition[c]	
Item	0	25	50	75	100	SBM	SBM	PBM
Amino acid, g/100 g AA								
Histidine	1.55	1.45	1.44	1.46	1.48	1.62	2.62	2.16
Arginine	5.42	5.35	5.62	5.31	5.38	5.51	8.59	7.36
Threonine	5.84	5.52	5.56	5.80	5.85	5.53	4.27	4.13
Valine	4.36	4.56	4.41	4.25	4.17	5.02	3.83	4.37
Methionine	2.78	2.71	2.65	2.79	2.79	2.48	1.38	2.01
Isoleucine	4.29	4.16	3.99	4.18	4.07	4.25	3.28	2.89
Leucine	7.91	7.66	7.62	7.83	7.81	7.47	7.55	6.79
Phenylalanine	5.26	5.09	5.10	5.24	5.18	5.02	4.88	4.07
Lysine	7.58	7.33	7.23	7.73	7.57	6.87	6.07	5.31
Aspartate	13.52	13.68	13.96	13.67	13.69	13.48	12.40	8.18
Glutamate	14.46	14.40	14.36	14.23	14.10	14.08	20.32	13.68
Serine	6.03	5.68	5.79	5.97	5.96	5.73	6.12	6.21
Glycine	5.49	5.68	5.69	5.80	5.96	5.47	4.71	13.42
Alanine	6.49	7.50	7.36	6.60	6.80	6.73	4.34	7.19
Proline	4.19	4.36	4.41	4.34	4.37	4.36	6.02	9.08
Tyrosine	4.84	4.86	4.81	4.81	4.81	4.82	3.62	3.15
Essential AA[d], g/100 g AA	44.98	43.84	43.62	44.58	44.31	44.41	42.48	39.09
Nonessential AA[e], g/100 g AA	55.02	56.16	56.38	55.42	55.69	55.59	57.52	60.91
Total AA, g/kg DM	309.90	302.70	305.80	301.50	297.20	345.00	412.10	467.00
AA N, % of total N	54.50	52.60	54.00	53.10	52.40	57.01	73.20	65.90

[a]n = 2; < 5% experimental error ([difference/mean] * 100).

[b]0 = 0% poultry by-product meal:100% urea; 25 = 25% PBM:75% urea; 50 = 50% PBM:50% urea; 75 = 75% PBM:25% urea; 100 = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[c]PBM = poultry by-product meal; SBM = soybean meal.

[d]Essential amino acids = histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine.

[e]Nonessential amino acids = aspartate, glutamate, serine, glycine, alanine, proline, tyrosine.

Duodenal and ileal digesta DM flow were calculated using chromic oxide as a marker of digesta flow. Bacterial DM flow was calculated by dividing bacterial N flow (g/d) by bacterial N concentration (g/g DM). Bacterial amino acid flow was calculated by multiplying bacterial DM flow (g/d) by the amino acid concentration of isolated bacteria (g/g DM). Duodenal non-bacterial amino acid flow was calculated as total duodenal flow minus bacterial flow. In this study, mention of essential amino acids pertains to histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, and lysine, and non-essential amino acids pertains to aspartate, glutamate, serine, glycine, alanine, proline, and tyrosine.

STATISTICAL ANALYSIS: Data were analyzed as a 6 x 6 Latin square design. The statistical model included effects of period, steer, and treatment. Because of cannula malfunction in one steer, n = 5 for amino acid data in which ileal flow was used. Non-orthogonal contrasts used to separate treatment means were: 1) 100% PBM vs 100% SBM, 2) 0% PBM vs 100% SBM, 3) linear, 4) quadratic, and 5) cubic effects of PBM.

Results and Discussion

The amino acid composition (g/100 g amino acids) of isolated ruminal bacteria, SBM, and PBM are reported in Table 1. The duodenal flow of all amino acids increased linearly ($P < .07$) as PBM increased and except for histidine, were greater ($P < .09$) for 100% PBM compared with 100% SBM (Table 2). Soybean meal increased ($P < .05$) duodenal aspartate flow compared with 0% PBM; however, the remaining individual, essential, non-essential, and total amino acids were not different ($P > .13$) for 100% SBM compared with 0% PBM.

The increase in duodenal flow of amino acids with PBM agrees with other studies in which sources of UIP were compared with more ruminally degradable sources of supplemental protein. Undegradable intake protein was 40.6% for PBM and 13.7% for 100% SBM used in the present study (companion study, data not shown).

The duodenal flow of all non-bacterial amino acids increased linearly ($P < .05$) as PBM increased and was greater ($P < .05$) for 100% PBM compared with 100% SBM (Table 3). The duodenal flow of essential, non-essential, and total non-bacterial amino acids was not different ($P > .53$) for 0% PBM compared with 100% SBM; however, flow of valine, alanine, and proline were increased ($P < .04$) and lysine was decreased ($P < .09$) for 0% PBM. The similarity in duodenal amino acid flow for 100% SBM and 0% PBM was expected given the comparable flow of bacterial N and the large degree of ruminal degradation observed for SBM N.

Table 2. Effect of supplemental nitrogen source on duodenal flow of total (bacterial + nonbacterial) amino acids (AA) in steers consuming a cornsilage- and cottonseed hulls-based diet.

	Sources of Supplemental Nitrogen[a]							P-Value[c]		
Item	0	25	50	75	100	SBM	SEM[b]	L	100 vs SBM	0 vs SBM
Amino acid, g/d										
Histidine	7.9	8.6	8.3	9.2	9.1	8.4	.5	.07	.33	.46
Arginine	24.1	26.9	25.9	27.7	31.3	23.6	1.0	.001	.001	.75
Threonine	21.0	23.8	23.6	25.2	25.9	22.5	.7	.001	.004	.17
Valine	18.7	20.4	19.7	21.6	22.1	18.7	.6	.001	.001	.96
Methionine	12.8	14.2	13.9	14.1	15.2	13.3	.4	.002	.003	.41
Isoleucine	15.2	16.6	16.4	17.3	17.4	15.6	.5	.008	.03	.60
Leucine	35.7	38.7	38.5	39.8	40.8	35.2	1.1	.004	.002	.76
Phenylalanine	18.9	21.1	20.8	22.0	22.5	20.0	.5	.001	.003	.17
Lysine	26.9	30.2	29.6	31.9	32.6	29.2	1.0	.001	.04	.14
Aspartate	52.1	57.2	55.8	58.5	59.9	56.3	1.4	.002	.09	.05
Glutamate	66.4	72.1	69.8	73.5	74.7	66.3	1.8	.007	.005	.97
Serine	26.8	29.8	30.0	32.1	33.4	27.5	.8	.001	.001	.54
Glycine	34.1	42.5	40.8	44.4	47.2	36.3	1.5	.001	.001	.33
Alanine	29.8	34.0	32.3	34.7	36.2	29.6	.8	.001	.001	.90
Proline	24.1	27.0	27.4	29.7	31.4	23.2	.6	.001	.001	.31
Tyrosine	17.8	19.6	19.2	20.2	20.3	18.5	.5	.005	.03	.37
Essential AA[d], g/d	181.2	200.5	196.7	208.8	216.9	186.5	5.6	.001	.002	.53
Nonessential AA[e], g/d	251.1	282.2	275.3	293.1	303.1	257.7	6.7	.001	.001	.50
Total AA, g/d	432.3	482.7	472.0	501.9	520.0	444.2	12.0	.001	. .001	.50

[a]0 = 0% poultry by-product meal:00% urea; 25 = 25% PBM:75% urea; 50 = 50% PBM:50% urea; 75 = 75% PBM:25% urea; 100 = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]n = 6.

[c]L = Linear effect of PBM; 100 vs SBM = 100% PBM vs SBM; 0 vs SBM = 0% PBM vs SBM.

[d]Essential amino acids = histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine.

[e]Nonessential amino acids = aspartate, glutamate, serine, glycine, alanine, proline, tyrosine.

The duodenal flow of bacterial amino acids was not affected by PBM (P > .13) except for linear increases (P < .04) in valine and glycine (Table 4). In contrast, 100% SBM increased duodenal flow of bacterial histidine, arginine, valine, isoleucine, phenylalanine, aspartate, glutamate, serine, alanine, proline, and tyrosine compared with 100% PBM (P < .07) and histidine, arginine, valine, isoleucine, aspartate, glycine, alanine, proline, and tyrosine compared with 0% PBM (P < .04). Consequently, 100% SBM increased (P < .02) essential, non-essential, and total bacterial amino acid flows compared with 100% PBM and nonessential and total amino acid flows compared with 0% PBM (P < .06). Bacterial amino acid flow increased despite a lack of change in duodenal bacterial N flow (data not shown), suggesting that bacterial amino acid composition was altered by feeding SBM. Numerical differences in the total amino acid content (g/kg DM) of ruminal bacteria for the SBM and PBM treatments also suggest a change in bacterial composition due to SBM (Table 1). Based on these data, it seems the chemical composition of mixed ruminal bacteria can be modified by diet. However, it should also be mentioned that ability to isolate a contamination-free bacterial sample, technique used to isolate ruminal bacteria, bacterial marker used, and type of bacteria isolated (fluid vs particulate associated) can also affect the chemical composition of ruminal bacteria.

Poultry by-product meal linearly increased (P < .09) small intestinal disappearance of lysine and proline, and disappearance of arginine, alanine, and proline was greater (P < .07) for 100% PBM compared with 100% SBM (Table 5). There were no differences (P > .16) in small intestinal disappearance of amino acids for 100% SBM compared with 0% PBM. Small intestinal disappearance (g/d) and digestibility (expressed as a percentage of duodenal flow; data not shown) of essential, nonessential, and total amino acids was not affected (P > .30) by treatment.

Because duodenal flow of bacterial amino acids was not affected by PBM (P > .96) and total amino acids increased linearly (P < .001) without an increase (P > .29) in small intestinal disappearance, the intestinal availability of PBM amino acids that escaped ruminal degradation was low (19%; calculated as [100% PBM intestinal disappearance of total amino acids - 0% PBM intestinal disappearance of total amino acids]/[100% PBM total amino acid flow - 0% PBM total amino acid flow]) compared with the National Research Council (1996) assumption that UIP is 80% digestible. Consequently, ileal flow of total amino acids

Table 3. Effect of supplemental nitrogen source on duodenal flow of non-bacterial[a] amino acids (AA) in steers consuming a corn silage and cottonseed hulls-based diet.

	Sources of Supplemental Nitrogen[b]							P-Value[d]		
Item	0	25	50	75	100	SBM	SEM[c]	L	100 vs SBM	0 vs SBM
Amino acid, g/d										
Histidine	2.9	4.0	3.5	4.4	4.4	2.8	.5	.05	.04	.85
Arginine	6.6	9.8	7.2	10.1	14.3	4.8	1.1	.001	.001	.26
Threonine	2.2	6.1	5.1	6.0	7.4	3.3	.8	.002	.004	.38
Valine	4.6	5.8	5.0	7.6	8.9	1.3	.6	.001	.001	.002
Methionine	3.9	5.6	5.1	4.9	6.3	4.6	.4	.003	.006	.16
Isoleucine	1.4	3.3	3.2	3.4	4.6	0.9	.5	.003	.001	.53
Leucine	10.2	14.1	13.2	13.9	16.2	9.3	1.1	.003	.001	.55
Phenylalanine	2.0	4.8	3.8	4.6	6.1	2.5	.6	.001	.001	.49
Lysine	2.4	6.8	5.6	6.3	8.6	5.3	1.1	.004	.05	.09
Aspartate	8.5	13.4	9.5	13.2	16.6	9.5	1.3	.002	.002	.62
Glutamate	19.8	26.0	22.1	26.3	30.1	17.4	1.7	.001	.001	.32
Serine	7.4	11.7	10.8	12.3	14.6	7.6	.8	.001	.001	.84
Glycine	16.4	24.3	21.9	25.2	28.4	17.3	1.6	.001	.001	.71
Alanine	8.8	10.1	7.8	12.8	14.8	6.2	.8	.001	.001	.04
Proline	10.6	13.0	12.8	15.4	17.6	8.1	.6	.001	.001	.02
Tyrosine	2.2	4.1	3.2	4.3	5.1	1.8	.6	.005	.001	.63
Essential AA[e], g/d	36.2	60.3	51.7	61.2	76.8	34.8	6.2	.001	.001	.88
Nonessential AA[f], g/d	73.7	102.6	88.1	109.5	127.2	67.9	6.6	.001	.001	.54
Total AA, g/d	109.9	162.9	139.8	170.7	204.0	102.7	12.5	.001	.001	.69

[a]Calculated as total amino acid flow–bacterial amino acid flow at the duodenum.

[b]0 = 0% poultry by-product meal:100% urea; 25 = 25% PBM:75% urea; 50 = 50% PBM:50% urea; 75 = 75% PBM:25% urea; 100 = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[c]n = 6.

[d]L = Linear effect of PBM; 100 vs SBM = 100% PBM vs 100% SBM; 0 vs SBM = 0% PBM vs 100% SBM.

[e]Essential amino acids = histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine.

[f]Nonessential amino acids = aspartate, glutamate, serine, glycine, alanine, proline, tyrosine.

increased linearly (P < .008) for PBM (data not shown). The low intestinal availability of UIP amino acids from PBM and SBM (17%; calculated the same as above but replacing 100% PBM with 100% SBM) may result from the manner in which non-bacterial amino acid availability was calculated (by difference).

Acknowledgment

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Table 4. Effect of supplemental nitrogen source on duodenal flow of bacterial amino acids (AA) in steers consuming a corn silage and cottonseed hulls-based diet.

	Sources of Supplemental Nitrogen[a]							P-Value[c]		
Item	0	25	50	75	100	SBM	SEM[b]	L	100 vs SBM	0 vs SBM
Amino acid, g/d										
Histidine	5.0	4.7	4.8	4.8	4.7	5.6	.1	.19	.001	.001
Arginine	17.5	17.1	18.7	17.6	17.0	18.8	.4	.71	.003	.02
Threonine	18.8	17.6	18.5	19.2	18.5	19.2	.4	.46	.22	.50
Valine	14.1	14.6	14.7	14.1	13.2	17.4	.3	.04	.001	.001
Methionine	9.0	8.7	8.8	9.2	8.8	8.6	.2	.59	.43	.22
Isoleucine	13.8	13.3	13.2	13.8	12.9	14.8	.3	.14	.001	.04
Leucine	25.5	24.5	25.3	25.9	24.7	25.9	.5	.91	.11	.55
Phenylalanine	17.0	16.3	16.9	17.4	16.4	17.4	.4	.96	.05	.36
Lysine	24.4	23.4	24.0	25.6	23.9	23.9	.5	.50	.93	.43
Aspartate	43.6	43.7	46.4	45.3	43.3	46.8	.9	.76	.02	.03
Glutamate	46.6	46.1	47.7	47.1	44.6	48.9	1.0	.34	.006	.11
Serine	19.4	18.2	19.2	19.8	18.8	19.9	.4	.79	.07	.44
Glycine	17.7	18.2	18.9	19.2	18.8	19.0	.4	.02	.74	.03
Alanine	20.9	24.0	24.4	21.9	21.5	23.4	.5	.53	.02	.003
Proline	13.5	13.9	14.7	14.4	13.8	15.2	.3	.28	.006	.002
Tyrosine	15.6	15.5	16.0	15.9	15.2	16.7	.3	.72	.005	.03
Essential AA[d], g/d	145.1	140.2	144.9	147.6	140.1	151.7	3.0	.81	.02	.14
Nonessential AA[e], g/d	177.3	179.6	187.3	183.6	176.0	189.9	3.8	.92	.02	.04
Total AA, g/d	322.4	319.8	332.2	331.2	316.1	341.7	6.8	.96	.02	.06

[a]0 = 0% poultry by-product meal:100% urea; 25 = 25% PBM:75% urea; 50 = 50% PBM:50% urea; 75 = 75% PBM:25% urea; 100 = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]n = 6.

[c]L = Linear effect of PBM; 100 vs SBM = 100% PBM vs 100% SBM; 0 vs SBM = 0% PBM vs 100% SBM.

[d]Essential amino acids = histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine.

[e]Nonessential amino acids = aspartate, glutamate, serine, glycine, alanine, proline, tyrosine.

Table 5. Effect of supplemental nitrogen source on net disappearance of amino acids (AA) from the small intestine of steers consuming a corn silage and cottonseed hulls-based diet.

	Sources of Supplemental Nitrogen[a]							P-Value[c]		
Item	0	25	50	75	100	SBM	SEM[b]	L	100 vs SBM	0 vs SBM
Amino acid, g/d										
Histidine	3.7	4.1	3.5	4.4	3.7	4.3	.3	.71	.18	.17
Arginine	15.9	15.6	15.0	16.3	18.1	13.6	1.2	.20	.02	.17
Threonine	11.3	12.2	11.9	13.3	12.4	11.9	.6	.13	.62	.52
Valine	8.2	8.5	7.7	10.0	8.2	8.1	1.0	.66	.96	.96
Methionine	6.2	6.9	6.4	6.3	6.0	6.3	.5	.53	.67	.88
Isoleucine	8.4	8.9	8.5	9.3	8.6	8.2	.6	.72	.65	.80
Leucine	20.3	21.4	20.5	21.9	20.4	19.5	1.1	.80	.54	.62
Phenylalanine	10.9	11.7	11.3	12.3	11.4	11.3	.5	.35	.99	.54
Lysine	16.6	18.8	17.6	20.2	18.9	18.5	1.0	.09	.82	.21
Aspartate	31.5	34.3	32.1	34.6	33.1	34.1	1.5	.48	.66	.25
Glutamate	36.2	37.9	35.2	38.9	36.0	35.6	2.0	.93	.89	.83
Serine	10.6	11.4	11.0	13.1	11.5	11.4	.9	.23	.94	.54
Glycine	23.4	28.0	25.2	28.5	28.1	23.5	2.0	.13	.12	.97
Alanine	16.1	17.4	16.1	17.9	17.4	15.0	.9	.27	.07	.39
Proline	10.0	10.7	10.3	12.1	11.5	9.4	.7	.07	.05	.53
Tyrosine	10.8	11.8	10.8	11.9	10.9	11.1	.5	.86	.81	.74
Essential AA[d], g/d	101.5	108.1	102.4	114.0	107.7	101.7	5.9	.35	.49	.99
Nonessential AA[e], g/d	138.6	151.5	140.7	157.0	148.5	140.1	7.6	.31	.45	.90
Total AA, g/d	240.1	259.6	243.1	271.0	256.2	241.8	13.2	.32	.46	.94

[a]0 = 0% poultry by-product meal:100% urea; 25 = 25% PBM:75% urea; 50 = 50% PBM:50% urea; 75 = 75% PBM:25% urea; 100 = 100% PBM:0% urea; SBM = 100% soybean meal. All ratios on a nitrogen basis.

[b]n = 5.

[c]L = Linear effect of PBM; 100 vs SBM = 100% PBM vs 100% SBM; 0 vs SBM = 0% PBM vs 100% SBM.

[d]Essential amino acids = histidine, arginine, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine.

[e]Nonessential amino acids = aspartate, glutamate, serine, glycine, alanine, proline, tyrosine.

Net Nutrient Flux by Visceral Tissues of Lambs Fed Diets Differing in Supplemental Nitrogen Source

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Summary

Supplemental poultry by-product meal and blood meal/corn gluten meal were used more efficiently by lambs as sources of supplemental nitrogen compared with urea and soybean meal. This most likely occurred as a result of decreased ammonia absorption and hepatic urea production, thereby increasing nitrogen retention and reducing urinary nitrogen loss. These results suggest that nitrogen retention and efficiency of nitrogen use by lambs can be improved when undegradable intake protein is 40 to 60% of total crude protein compared with 25 to 30%. In addition, use of undegradable intake protein can minimize the excretion of nitrogen into the environment, providing economic and environmental incentives. Therefore, ruminant nutritionists should consider sources of undegradable intake protein when formulating diets.

Introduction

The form of nitrogen (N) present in duodenal digesta (amino acids, nucleic acids, ammonia (NH_3) and other N-containing compounds) is affected by the rate and extent of protein degradation in the rumen. Studies have demonstrated that undegradable intake protein (UIP) can increase the duodenal flow and small intestinal disappearance of amino acids. However, data is limited concerning the net absorption of amino acids, urea, and NH_3 in response to protein sources differing in ruminal degradability. A comprehensive knowledge of ruminant N metabolism, in response to differing levels of UIP, will provide nutritionists with data necessary to formulate diets that optimize N utilization and provide benefits of economic and environmental significance. Therefore, the objective of the cur-

rent study was to evaluate the effects of supplemental N sources, varying in UIP, on N use in lambs, including plasma concentration and net flux of α-amino N (AAN), urea N, and NH_3 N.

Procedures

Animals and Diets

Eight Lincoln wethers (79 ± 2 lb body weight [BW]) were surgically fitted with permanent indwelling catheters in a hepatic vein, the hepatic portal vein, a mesenteric vein, and a mesenteric artery. The design was a replicated 4 × 4 Latin square. Experimental diets (Table 1) were formulated to contain 12% CP, with the supplemental N source providing 38.3% of total dietary CP (DM basis). Sources of supplemental N were urea, soybean meal (SBM), poultry by-product meal (PBM), and a 50:50 combination (N basis) of blood meal and corn gluten meal (BMCGM). Corn gluten meal and blood meal were fed in combination because they have complementary amino acid (AA) profiles relative to the proposed profile of AA required for optimum growth. The UIP contents (N basis) of urea, SBM, PBM, and BMCGM were assumed to be 0, 25, 55, and 93%, respectively. These values were based on in situ data from our lab. Calculated total diet UIP concentrations were 27, 30, 43, and 60% of CP for urea, SBM, PBM, and BMCGM, respectively. Diets were formulated to provide adequate amounts of Ca, P, and vitamins A, D, and E. Lambs were housed in individual metabolism crates in a temperature (73°F) and light (16 h light: 8 h dark) controlled room with water available at all times. Lambs were weighed at the beginning of each period and dry matter intake adjusted to 2.0% of BW. Daily feed allotments were divided into equal portions and fed every two hours using automated feeders.

Table 1. Ingredient composition of diets fed to lambs.

	Supplemental N Source[a]			
Ingredient, % of DM	**Urea**	**SBM**	**PBM**	**BMCGM**
Corn	33.88	15.11	19.30	22.64
Soy hulls	12.76	24.57	21.90	19.81
Molasses	7.50	7.50	7.50	7.50
Corncobs	42.00	42.00	42.00	42.00
Urea	1.60	-	-	-
Soybean meal	-	8.56	-	-
Poultry by-product meal	-	-	7.04	-
Corn gluten meal	-	-	-	3.34
Blood meal	-	-	-	2.45
Limestone	1.09	1.09	1.09	1.09
Trace mineralized salt [b]	.56	.56	.56	.56
Ammonium chloride	.56	.56	.56	.56
Vitamin premix[c]	.05	.05	.05	.05

[a]SBM = soybean meal; PBM = poultry by-product meal; BMCGM = blood meal:corn gluten meal (50:50; N Basis).

[b]98.5% NaCl, .35% Zn, .34% Fe, .20% Mn, 330ppm Cu, 70 ppm I, 50 ppm Co, and 90 ppm Se.

[c]8,800 IU/g vitamin A, 1,760 IU/g vitamin D, and 1.1IU/g vitamin E.

Sample Collection and Analysis

Each period was 10 d, with 6 d for adjustment followed by 4 d of feces and urine collection. Blood samples were collected on d 10. Diet samples were collected on d 5 to 8 of each period and composited. On d 7 to 10, total output of feces and urine was collected and composited daily by lamb (50 and 5% of total, respectively; weight basis) and refrigerated. On d 10, the final fecal composites were mixed well by hand and a 250-g subsample dried for calculation of fecal DM. The remaining fecal composite was frozen. Diet samples were dried for 48 h and ground through a 1-mm screen. Feed, fecal, and urine samples were analyzed for N.

On d 10, a 15 mL priming dose of 1.5% (wt/vol) p-amino hippurate (PAH, pH = 7.4) was administered through a .45-μm filter into the mesenteric vein catheter followed by continuous infusion of 1.5% PAH (.8 mL/min). Sixty minutes later, after blood PAH concentration had equilibrated, 5 mL of arterial, portal, and hepatic blood were collected into heparinized syringes, immediately transferred into 12 × 75 mm polypropylene tubes, placed on ice, and transported to the laboratory for analysis. This was repeated at hourly intervals for 6 h.

In the laboratory, blood was analyzed for packed cell volume and plasma prepared by centrifugation. Plasma was immediately analyzed for glucose, lactate, and urea N. Plasma was deproteinized, centrifuged, and the supernatant analyzed for AAN. An equal volume of plasma and H_2O were mixed and analyzed for PAH and NH_3 N.

Calculations

Plasma flows through the portal-drained viscera (PDV) and liver were calculated using the Fick principle: $PF = IR^{PAH}/(Cv^{PAH} - Ca^{PAH})$, where PF represents plasma flow rate through the tissue (mL/min), IR^{PAH} is PAH infusion rate (mg/min), and Cv^{PAH} and Ca^{PAH} are the PAH concentrations (mg/mL) in venous and arterial plasma, respectively. Portal and hepatic venous flow rates were measured directly; hepatic arterial plasma flow was calculated by difference between portal and hepatic venous flows. Net fluxes of nutrients across the PDV, hepatic, and total splanchnic (TS) vascular beds were calculated using the following equations: PDV flux = PPF × (C_p - C_a), TS flux = HPF × (C_h - C_a), and Hepatic flux = TS flux - PDV flux, where PPF and HPF represent portal and hepatic venous plasma flow (L/h), and C_a, C_p, and C_h are nutrient concentrations in arterial, portal, and hepatic plasma, respectively. A positive net flux indicates a net release or absorption of a nutrient, while a negative net flux indicates uptake or utilization. Hepatic metabolite ratios were calculated as (hepatic output/hepatic input) - 1, where hepatic output was hepatic venous concentration multiplied by hepatic plasma flow and hepatic input was portal concentration multiplied by portal plasma flow plus arterial concentration multiplied by hepatic arterial blood flow. A negative hepatic ratio represents the fractional hepatic extraction of the metabolite entering the liver and a positive hepatic ratio represents the fractional increase from that entering the liver.

Statistical Analysis

Data were analyzed as a replicated 4 × 4 Latin square. The data were analyzed with Latin square, period within Latin square,

lamb within Latin square, and N source included in the model. Number of observations were 8 for all variables except glucose and lactate where n = 7 because of sample loss. Orthogonal contrasts were: 1) urea vs SBM, PBM, and BMCGM, 2) SBM vs PBM and BMCGM, and 3) PBM vs BMCGM.

Results and Discussion

Digestibility

Apparent DM digestibility (%) did not differ (P > .42) for urea compared with SBM, PBM, and BMCGM or SBM compared with PBM and BMCGM (Table 2). However, apparent DM digestibility was lower (P < .002) for PBM compared with BMCGM.

Fecal N excretion tended to be lower (P < .09) for urea compared with SBM-, PBM-, and BMCGM-supplemented lambs Also, PBM increased fecal N (g/d) compared with BMCGM (P < .002). This agrees with previous work that showed increasing PBM linearly increased fecal N flow. Urinary N excretion was greater (P < .001) for lambs supplemented with urea compared with SBM, PBM, and BMCGM and for SBM compared with PBM and BMCGM. However, no difference (P > .99) in urinary N (g/d) was observed between PBM and BMCGM. Apparent N digestibility was lower (P < .006) for PBM compared with BMCGM. Nitrogen retention (g/d) and digested N retained (%) were lower (P < .001) for urea compared with SBM, PBM, and BMCGM and for SBM compared with PBM- and BMCGM-supplemented lambs. No differences (P > .33) in N retention or digested N retained were observed between PBM and BMCGM.

Metabolite Concentrations

Arterial plasma AAN concentration (mM) increased (P < .04) for PBM and BMCGM compared with SBM-supplemented lambs (Table 3). Portal - arterial (P - A) and hepatic - arterial (H - A) concentration differences for AAN were lower (P < .02) for urea compared with SBM, PBM, and BMCGM and greater (P < .01) for BMCGM compared with PBM.

Arterial NH_3 N (mM) was not affected (P >. 20) by supplemental N source. However, the P - A NH_3 N difference was greater (P < .001) for lambs supplemented with SBM compared with PBM and BMCGM. No differences were observed in H - A NH_3 N due to treatment.

Arterial urea N concentration was increased (P < .001) for urea compared with SBM, PBM, and BMCGM and for SBM compared with PBM- and BMCGM-supplemented lambs. Differences in P - A and H - A urea N were greater (or less negative) for SBM compared with PBM and BMCGM (P < .03).

Lambs supplemented with SBM had lower (P < .05) arterial glucose (mM) compared with PBM and BMCGM. However, supplemental N source did not affect P - A or H - A glucose. Similarly, arterial (mM) lactate and P - A and H - A differences were not influenced (P > .22) by treatment.

Plasma Flow and Metabolite Flux

Arterial, portal, and hepatic plasma flows (L/h) were greater (P < .09) for SBM compared with PBM and BMCGM (Table 4). Consequently, plasma flows were greatest for supplemental N sources with a lower proportion of UIP. Blood flow has been shown to be influenced by digestible energy intake, osmolality, CO_2 tension, VFA concentrations, and hormones. The precise mechanism(s) by which ruminal degradability of dietary protein affected plasma flow in the current study is not clear.

Net PDV flux of AAN was greater (P < .02) for BMCGM compared with PBM-supplemented lambs (Table 4). Despite increased PDV flux seen with BMCGM, net hepatic flux was not affected (P > .14) by supplemental N source. However, average hepatic removal of AAN ranged from 35 to 68% (68, 35, 65, and 43% for urea, SBM, PBM, and BMCGM, respectively) of AAN reaching the liver, indicating differences in liver uptake

Table 2. Effect of supplemental N source on apparent N digestibility and N retention.

	Supplemental N Source[a]					P-Value		
Item	Urea	SBM	PBM	BMCGM	SEM[b]	Urea vs Others	SBM vs PBM and BMCGM	PBM vs BMCGM
Initial wt, lb	83.4	81.8	81.6	81.8				
DMI, lb/d	1.67	1.64	1.63	1.64				
N intake, g/d	15.7	16.4	16.1	15.8				
Apparent DM								
Digestibility, %	74.3	74.8	73.2	75.6	.4	.57	.42	.002
N excretion, g/d								
Fecal	4.3	4.5	4.8	4.2	.1	.09	.76	.002
Urinary	9.3	8.6	7.2	7.2	.2	.001	.001	1.00
Apparent N								
Digestibility, %	72.9	72.8	70.3	73.5	.7	.39	.32	.006
N retention, g/d	2.2	3.3	4.1	4.4	.2	.001	.001	.33
Digested N retained[c], %	19.0	27.9	36.4	37.7	1.5	.001	.001	.56

[a]SBM = soybean meal; PBM = poultry by-product meal; BMCGM = blood meal:corn gluten meal (50:50; N basis).

[b]n = 8.

[c]Calculated as (N retention, g/d/N digested, g/d) * 100.

of AAN based on supplemental N source. Net TS flux was decreased (P < .02) for urea compared with SBM, PBM, and BMCGM and increased (P < .04) for SBM compared with PBM and BMCGM and for BMCGM compared with PBM. Net TS flux relates to the amount of a metabolite that is released into the circulation and is available for use by the peripheral tissues. Therefore, SBM and BMCGM should have provided more AAN for protein synthesis compared with urea and PBM. However, N retention (g/d) and digested N retained (%) were similar for PBM and BMCGM and greater for PBM and BMCGM compared with SBM (Table 2). Possible explanations for this apparent discrepancy include differences in the amino acids absorbed (in relation to lamb requirements) or quantity of amino acids absorbed as small peptides (the AAN procedure used would measure di- and tri-peptides as one alpha-amino group). The hepatic ratio for AAN was less negative (P < .02) for SBM compared with PBM and BMCGM, indicating a greater proportion of AAN was removed by the liver of PBM- and BMCGM-supplemented lambs.

Net PDV absorption and net hepatic removal of NH_3 N were greater (P < .001) for SBM compared with PBM and BMCGM. The increased absorption of NH_3 N for urea and SBM compared with PBM- and BMCGM-supplemented lambs (24.8 and 27.7 vs. 19.4 and 20.6 mmol/h, respectively) was expected based on differences in dietary UIP. Net absorption of NH_3 N was 115, 107, 95, and 77% of the net absorption of AAN for urea, SBM, PBM, and BMCGM, respectively. Supplemental N source did not affect (P > .53) NH_3 N hepatic ratio.

Net PDV uptake of urea N was greater (P < .07) for PBM and BMCGM compared with SBM. However, net hepatic and TS flux of urea N were increased (P < .01) for SBM compared with PBM and BMCGM. The increased hepatic urea N flux for SBM-supplemented lambs corresponded to the increased hepatic removal of NH_3 N which was mainly converted to urea via the urea cycle. Urea N transfer to the gut was 18, 10, 17, and 17% of N intake for urea, SBM, PBM, and BMCGM supplemented lambs, respectively. Increased TS flux of urea N results in a greater quantity of urea N released into the circulation and, consequently, excreted in the urine. This may explain the increase in urinary N (g/d) observed for urea and SBM compared with PBM and BMCGM. The urea N hepatic ratio was less (P < .04) for urea compared with SBM, PBM, and BMCGM and for PBM compared with BMCGM-supplemented lambs. The increased hepatic ratio for lambs supplemented with greater UIP may be because of decreased arterial urea (mM) and/or increased deamination of AA by the liver. Decreased arterial urea would reduce hepatic input of urea, while greater AA deamination would increase liver urea output. No differences (P > .09) were observed in net flux measurements for glucose or lactate (Table 4).

Table 3. Plasma arterial and venous-arterial metabolite concentrations.

	Supplemental N Source[a]					P-Value		
Item	Urea	SBM	PBM	BMCGM	SEM[b]	Urea vs Others	SBM vs PBM and BMCGM	PBM vs BMCGM
Alpha-amino N, mM								
Arterial	2.90	2.86	3.00	3.12	.07	.27	.04	.26
P - A[c]	.26	.31	.29	.38	.02	.02	.34	.01
H - A[d]	.08	.16	.08	.17	.02	.02	.14	.01
Ammonia N, Mm								
Arterial	.038	.035	.036	.036	.002	.20	.54	.70
P - A	.295	.330	.268	.287	.009	1.00	.001	.16
H - A	-.004	-.004	-.006	-.008	.002	.47	.17	.48
Urea N, mM								
Arterial	4.72	4.59	3.55	3.64	.16	.001	.001	.72
P - A	-.095	-.064	-.115	-.109	.015	.97	.03	.78
H - A	.13	.19	.09	.13	.02	.71	.003	.12
Glucose, mM								
Arterial	3.48	3.45	3.56	3.55	.04	.45	.05	.84
P - A	.03	.02[e]	.004[e]	.02[e]	.013	.41	.50	.41
H - A	.24	.26	.22	.26	.02	.92	.57	.19
Lactate, mM								
Arterial	.873	.893	.863	.844	.050	.92	.56	.81
P - A	.094	.104	.108	.100	.009	.30	.95	.53
H - A	.080	.068	.085	.084	.010	.97	.22	.92

[a]SBM = soybean meal; PBM = poultry by-product meal; BMCGM = blood meal:corn gluten meal (50:50; N basis).

[b]n = 8 except for glucose and lactate measurements where n = 7; therefore, the largest SEM is presented.

[c]Portal - arterial difference.

[d]Hepatic - arterial difference.

[e]Means not different (P > .05) from 0.

Table 4. Effect of supplemental N source on plasma flow, metabolite flux, and hepatic ratio in lambs.

	Supplemental N Source[a]					P-Value		
Item	Urea	SBM	PBM	BMCGM	SEM[b]	Urea vs Others	SBM vs PBM and BMCGM	PBM vs BMCGM
Plasma flow, L/h								
Arterial	17	21	16	17	2	.70	.09	.64
Portal	85	84	72	72	5	.10	.04	.94
Hepatic	102	105	87	88	5	.16	.02	.86
Alpha-amino N, mmol/h								
PDV[c]	21.6	25.9	20.5	26.6	1.6	.16	.24	.02
Hepatic	-14.7	-9.0	-13.3	-11.5	1.9	.14	.17	.52
TS[d]	6.9	16.9	7.2	15.1	2.0	.02	.04	.02
HR[e]	-.044	-.027	-.047	-.041	.005	.40	.02	.44
Ammonia N, mmol/h								
PDV	24.8	27.7	19.4	20.6	1.3	.16	.001	.53
Hepatic	-25.2	-28.1	-20.0	-21.4	1.3	.17	.001	.46
TS	-.4	-.4	-.6	-.7	.2	.54	.31	.54
HR	-.887	-.896	-.889	-.896	.009	.53	.76	.59
Urea N, mmol/h								
PDV	-8.2	-4.9	-8.3	-7.9	1.3	.46	.07	.84
Hepatic	21.6	25.9	16.5	20.0	1.9	.73	.01	.22
TS	13.3	21.0	8.2	12.1	2.6	.90	.01	.32
HR	.046	.055	.055	.064	.003	.01	.20	.04
Glucose, mmol/h								
PDV	2.10[f]	2.14[f]	.40[f]	1.05[f]	1.12	.46	.31	.68
Hepatic	22.57	23.29	18.89	21.83	1.83	.54	.20	.25
TS	24.66	25.43	19.30	22.88	2.16	.37	.12	.24
HR	.062	.068	.063	.069	.005	.43	.75	.32
Lactate, mmol/h								
PDV	7.67	8.34	7.80	7.08	.75	.94	.33	.49
Hepatic	-.04[f]	-1.39[f]	-.33[f]	.36[f]	.65	.56	.10	.45
TS	7.63	6.95	7.47	7.43	.83	.74	.66	.98
HR	.005[f]	-.016[f]	-.004[f]	.007[f]	.008	.27	.11	.32

[a]SBM = soybean meal; PBM = poultry by-product meal; BMCGM = blood meal:corn gluten meal (50:50; N basis).

[b]n = 8 except for glucose and lactate measurements where n = 7; therefore, the largest SEM is presented.

[c]Portal-drained visceral.

[d]Total splanchnic.

[e]Hepatic ratio; (hepatic output/hepatic input) - 1.

[f]Means not different (P > .05) from 0.

Effect of Poultry By-Product Meal on Growth, Carcass Traits, and Muscle Accretion of Finishing Lambs

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Summary

Fifteen crossbred wethers (initial BW 27 ± 1 kg) were allotted in a completely randomized design to evaluate the effect of poultry by-product meal (PBM) and soybean meal (SBM) supplementation fed on a limited intake, restricted crude protein basis. Variables measured included growth rate, carcass traits, and muscle accretion of finishing lambs. Lambs were randomly assigned to isonitrogenous, isocaloric diets (85% concentrate, 15% roughage) containing PBM or SBM as the protein source. Lambs were individually fed a diet formulated to meet NRC recommendations to provide energy for 136 g/d gain at 30 kg BW (moderate growth potential) and reformulated at 40 kg BW. Crude protein supply was limited to 160 g/d the entire trial. Intakes were adjusted weekly to 2.75% BW. All lambs

were fed to a similar final weight (49 ± 2 kg). Carcass traits included rib-eye area, back-fat thickness, quality grade, and the weights of major and minor cuts. In addition, the semimembranosus, semitendinosus, and adductor muscles were dissected and weighed. The right side of the carcass was analyzed for composition of lean and adipose tissue. Average daily gain for PBM and SBM was .12 and .14 kg (P > .10), respectively. Weights of semimembranosus, semitendinosus, and adductor were not different (P >.10) at 348.8 vs 347.8, 124.9 vs 122.7, and 143.0 vs 146.8, respectively. Lean tissue composition of feeding PBM and SBM was not different (P > .10) at 33.4 and 34.2%. There were no differences in rib-eye area, back-fat thickness, quality grade, and weights of major and minor cuts. Feeding PBM does not affect carcass traits or tissue composition of finishing lambs when dry matter intake is equalized and crude protein restricted.

Introduction

Protein available at the small intestine of ruminants is a combination of microbial protein and feed protein, which escapes digestion in the rumen. Microbial protein usually comprises a substantial part of the protein entering the small intestine. Although microbial protein alone may provide enough protein for an animal at maintenance, it may not be adequate to meet the metabolizable protein requirement of a growing animal. Therefore, diets are often supplemented with a source of escape protein. Poultry by-product meal is a rendered by-product that can be used as a source of escape protein for ruminants. PBM is a by-product made of ground, dry-rendered, clean parts of the carcass of slaughtered poultry such as heads, feet, undeveloped eggs, and intestines. Previous research with PBM has been inconclusive regarding production responses and carcass traits, and little information exists on the availability of the protein in PBM that escapes the rumen undegraded. Studies suggest that feeding an escape protein may result in a beneficial postruminal amino acid supply. More research is necessary to evaluate PBM as an escape protein. The objective of this experiment was to evaluate the effect of supplemental PBM and SBM on production traits and carcass characteristics of lambs fed a limited intake, restricted crude protein diet.

Procedure

Fifteen crossbred wethers (initial BW 27 ± 1 kg) were allotted to a completely randomized design with treatments of SBM or PBM as supplemental protein sources providing at least 40% of the total protein in the corn/cottonseed hull diet (Table 1). To evaluate the effect of PBM and SBM on protein availability, intake of the lambs was restricted to 2.75% body weight and the diets were formulated to be isonitrogenous and isocaloric. The individually fed diets (85% concentrate, 15% roughage) were formulated so that the crude protein of the treatments was below the NRC requirements (200 g/d) at 160 g/d to ensure that crude protein was the limiting nutrient and treatment differences occurred because of an improved amino acid profile. Intake was adjusted weekly. Diets were designed to provide energy for 136 g/d gain at 30 kg body weight (moderate growth potential) and were reformulated when the lambs reached 40 kg for the same

Table 1. Composition of soybean meal (SBM) and poultry by-product meal (PBM) diets.

Ingredient (Dry-matter basis)	SBM 30kg	PBM 30kg	SBM 40kg	PBM 40kg
Soybean meal	16.5	0	9.0	0
Poultry by-product meal	0	14.0	0	7.7
Corn	57.9	56.4	63.5	63.5
Cottonseed hulls	15.0	15.0	10.0	10.0
Cobs	0	3.9	7.0	8.3
Molasses	5.0	5.0	5.0	5.0
Fat	1.0	2.0	1.0	2.0
Limestone	2.2	1.8	2.2	1.8
Urea	.5	.5	.5	.5
Biophosphate	.6	0	.6	0
Ammonium Chloride	.5	.5	.5	.5
Vitamins A, D, and E premix[a]	.2	.2	.2	.2
Trace mineral salt + Se[b]	.5	.5	.5	.5
Sulfur	trace	trace	trace	trace

[a]Vitamin A, D, and E premix composition: 1,818,181.8 IU/kg of vitamin A, 363,636.4 IU/kg of vitamin D_3, and 227.3 IU/kg of vitamin E.

[b]Trace mineralized salt composition: > 95% NaCl, .35% Zn, .34 % Fe, .20% Mn, .033% Cu, .007% I, .005% Co, and 90 ppm Se.

Table 2. Effects of poultry by-product meal (PBM) and soybean meal (SBM) on lamb performance.

Observation	SBM	PBM	SEM
Initial wt, kg	27	27	.90
Average daily gain, kg	.14	.12	.01
Kg feed per kg gain	7.56	7.70	.57

Table 3. Effects of poultry by-product meal (PBM) and soybean meal (SBM) on carcass characteristics.

Observation	SBM	PBM	SEM
Number of lambs	8	7	
Slaughter wt, kg	49.4	48.9	.55
Hot carcass wt, kg	22.3	21.7	.64
Dressing percentage	46.29	45.48	1.06
Back-fat thickness, cm	.08	.08	.01
Length of longissimus, cm	6.14	6.36	.17
Width of longissimus, cm	2.67	2.95	.13
Longissimus area, cm^2	13.66	13.39	.35
Quality Grade	Choice	Choice	

Table 4. Effect of soybean meal (SBM) and poultry by-product meal (PBM) on chemical compositions of carcasses.

Observation	SBM	PBM	SEM
Moisture	52.48	54.01	1.01
Protein	17.95	18.05	.20
Fat	23.13	20.90	.58
Ash	5.89	6.09	.19

amount of gain. All lambs were fed to a similar final weight (49 ± 2 kg) and were slaughtered at the University of Kentucky Meat Laboratory. Carcass traits were measured and included: rib-eye area, back-fat thickness, quality grade, and the weights of the major and minor cuts. In addition, the semimembranosus, semitendinosus, and adductor muscles were dissected and weighed. Carcasses were analyzed for composition of lean and adipose tissue.

Results and Discussion

The level of performance of the lambs in this trial reflect the limits placed on intake of nutrients (Table 2) and there were no differences between treatments for any of the measured traits. Average daily gains were similar to the expected value of 136 g/d at 140 and 120 g/d for the SBM and PBM treatments, respectively. Kilogram of feed per kilogram of gain was also similar at 7.56 and 7.70 for SBM and PBM treatments, respectively.

There were no treatment effects upon carcass characteristics (Table 3), carcass chemical composition (Table 4), or weights of wholesale cuts (Table 5). Both treatments had a quality grade of Choice-. Dressing percentages were low at 49.4 and 48.9% for SBM and PBM treatments, respectively. Weights of selected hind limb muscles (Table 6) were also not significantly different (P >.05).

Chemical composition of the carcasses were not different (P >.05) between treatments. Percent of carcass moisture, protein, fat, and ash was 52.5, 18, 23, and 6 % for the SBM treatment vs 54, 18, 21, and 6% for the PBM treatment. Results from this trial indicate that the amino acid profile of the PBM supplement vs the SBM supplement was similar enough in quality to negate significant effects in the measured parameters. The next step in this research will be to supplement SBM and PBM at protein levels above the NRC requirement.

Table 5. Effect of soybean meal (SBM) and poultry by-product meal (PBM) on weights of wholesale cuts.

Observation	SBM	PBM	SEM
Number of lambs	8	7	
Wholesale cut, kg			
Leg	3.72	3.67	.09
Loin	1.00	.94	.05
Rack	.68	.71	.04
Shoulder	2.72	2.64	.14
Shank	.48	.48	.03
Breast	.42	.37	.05
Flank	.99	.92	.04
Neck	.60	.62	.05

Table 4. Effect of soybean meal (SBM) and poultry by-product meal (PBM) on selected hind limb muscles.

Observation	SBM	PBM	SEM
Muscle wt, g			
Semimembranosus	348.8	347.8	11.4
Semitendinosus	122.7	124.9	3.7
Adductor	143.1	146.8	3.4

Evaluation of Bakery Waste Meal and Caged Layer Waste Pellets as Supplements for Steer Calves Consuming a Corn Silage-Based Diet

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Summary

A minimum of 15% bakery waste, when combined with adequate degradable intake protein in the form of urea, will enhance the performance and efficiency of growing beef steers fed a corn silage diet. The performance of growing steers fed either layer waste or urea as the supplemental nitrogen source is similar. Future research goals include: 1) determine the optimum level of bakery waste to include in the diet of growing steers and 2) evaluate the rumen parameters in fistulated steers for the diet(s) that give the best performance and efficiency results from the "optimum level of bakery waste" feeding trial.

Introduction

By-products of many types are produced in large quantities and have become a national disposal problem. Ruminants, such as beef cattle, are ideally suited to reduce by-product waste volume and can thrive upon the nutrients supplied by the by-products. The meat which is produced by beef cattle consuming these by-products is a safe, palatable, and nutritious human food.

Bakery waste is composed of discarded bread, pasta, bagels, cereal, potato chips, pancakes, waffles, biscuits, dough, tortillas, muffins, and crackers. These products are dried, ground, and blended in standardized proportions to yield a consistent product. The major benefits of bakery waste to beef cattle include excellent palatability characteristics and a source of highly fermentable energy.

Caged layer waste is egg-producing chicken manure, which is free of bedding and, when marketed as a livestock feed ingredient, is sanitized by heat or ammoniation. This by-product is an excellent source of non-protein nitrogen. The beef animal's rumen microbes use nitrogen to reproduce themselves, providing "microbial" protein to the small intestine. Layer waste is also a good source of minerals such as calcium, phosphorus, potassium, iron, and zinc. Although layer waste can be used as a fertilizer, its relative value as a ruminant nutrient source has been estimated to be worth four times more than as a source of nutrients to a growing crop.

The rumen microbes need a highly available source of energy to efficiently use non-protein nitrogen to reproduce themselves and supply the ruminant with microbial protein.Therefore, the blending of bakery and layer waste appears to make good nutritional sense.The objective of this research was to determine the best ratio of layer waste pellets and bakery waste meal that would optimize dry matter intake, average daily gain, and efficiency of growing beef steers fed a corn silage-based diet.

Procedures

Ninety-six crossbred steer calves (519 lb, average initial weight) were used in an 84-day growth trial. Steers were adapted to a corn silage-based diet for three weeks, sorted and stratified by weight, and randomly allotted to treatment and pens (four steers/pen). Steers were observed for temperature and respiratory problems and treated when temperatures exceeded 103.5° F. Before the trial began, steers were vaccinated with Clostri-Shield® 7-Way and Vira-Shield® 5+Somnus (Grand Laboratories, Larchwood, Iowa), treated for internal and external parasites with Synanthic®, and implanted with Synovex-S® (Fort Dodge/Syntex, Fort Dodge, Iowa).

The diet was offered ad libitum and consisted of (dry matter basis) 76.5% corn silage, 15% supplement treatment, and 8.5% supplement premix (Table 1). Treatment supplements consisted of a control (cracked corn and urea) and combinations of layer waste pellets and bakery waste meal in the following ratios (DM basis): 0:100, 25:75, 50:50, 75:25, and 100:0. The treatment supplements were incorporated as a supplement top-dress to the diet. The supplement premix was specifically mixed for each dietary treatment and was also fed as a top-dress. The supplement premix added .5% soybean meal to the total diet and additional urea to balance each treatment supplement for degradable intake protein (DIP). Furthermore, the supplement premix supplied adequate levels of vitamins and minerals, using ground corncobs as a carrier. The nitrogen:sulfur ratio was formulated to be 10:1. The chemical analyses of feedstuffs are displayed in Table 2.

Feed bunks were checked daily, and pen intake was adjusted to allow for 10% refusals. Steers were offered 55% of the daily allotment of corn silage at 0800 and 45% at 1600. The daily allotment of the treatment and premix supplements were top-dressed at 0800 to ensure consumption. Fresh water was available at all times. Supplements and corn silage were collected and analyzed weekly for DM. Feed samples were ground through a 1-mm screen and analyzed for DM and crude protein.

The steers were weighed on two consecutive days at the beginning and end of the trial to minimize weighing variation. The potential effects of ruminal fill due to intake differences at the end of the trial were minimized by limiting intake to a constant percentage of body weight for two consecutive days.

The variables which were analyzed included initial and final weights, gain, dry matter intake (DMI), average daily gain (ADG), and efficiencies of gain (gain efficiencies) and feed (feed efficiencies). The effects of various levels of bakery and layer waste were analyzed for linear and quadratic effects. Contrasts were made between the following treatments: "control" vs "100% layer waste" and /or "100% bakery waste;" and "100% layer waste" vs "100% bakery waste."

Results and Discussion

Dry matter intake was not affected ($P > .05$) by treatment (Table 3). We had originally projected that DMI may be depressed by the higher levels of the layer waste; however, this intake depression did not occur.

Increasing the diet level of bakery waste increased ($P < .05$) ADG, gain, and final weight and improved ($P < .001$) gain efficiency and feed efficiency. We had originally proposed that the increased supply of ruminally available nitrogen and readily fermentable carbohydrate in the diet of steer calves would enhance performance with the combination diets and that ruminal nitrogen may be limiting with the higher levels of bakery waste. However, it appears that the fermentable carbohydrate of bakery waste combined with the rumen-available nitrogen supply (urea) promoted a high degree of rumen efficiency. This probably occurred due to an increased production of protein and volatile fatty acids by the ruminal microflora.

Table 1. Composition of experimental diets, percentage of DM basis.

	Bakery Waste:Layer Waste (Treatment Number)					
Item	**Control (1)**	**100:0 (2)**	**75:25 (3)**	**50:50 (4)**	**25:75 (5)**	**0:100 (6)**
Corn silage	76.500	76.500	76.500	76.500	76.500	76.500
Corn grain, cracked	15.000	0.000	0.000	0.000	0.000	0.000
Bakery waste	0.000	15.000	11.250	7.500	3.750	0.000
Layer waste	0.000	0.000	3.750	7.500	11.250	15.000
Corncobs, ground[a]	5.082	5.263	6.345	6.585	6.835	7.075
Urea	1.160	1.110	0.880	0.640	0.390	0.150
Limestone	0.700	0.650	0.000	0.000	0.000	0.000
Soybean meal	0.500	0.500	0.500	0.500	0.500	0.500
Trace mineral salt + selenium[b]	0.800	0.700	0.500	0.500	0.500	0.500
Tallow	0.175	0.175	0.175	0.175	0.175	0.175
Calcium sulfate	0.060	0.080	0.080	0.080	0.080	0.080
Vitamin A, D, E premix[c]	0.020	0.020	0.020	0.020	0.020	0.020
Zinc oxide	0.002	0.002	0.000	0.000	0.000	0.000
Copper sulfate	0.001	0.000	0.000	0.000	0.000	0.000

[a]Carrier for all supplement/premix items listed subsequently.

[b]NaCl—95%, Zn—.35%, Fe—.34%, Mn—.20%, Cu—330 ppm, I—70 ppm, Co—50 ppm, Se—90 ppm.

[c]8,800 IU/g vitamin A; 1,760 IU/g vitamin D; and 1.1 IU/g vitamin E.

The steers fed the 100:0 (bakery waste:layer waste) treatment performed better (P < .05) than either the control diet (corn and urea) or the 0:100 treatment in all measured criteria. Steers fed the 0:100 treatment performed similarly (P > .05) to the control diet in all determinations.

These data may indicate that the fermentable carbohydrate (energy supply) was limiting in the control and 0:100 treatments. Including 15% (DM basis) bakery waste in the diet of growing steers was the optimum treatment when evaluating all performance and efficiency criteria.

Table 2. Chemical analyses of primary feedstuffs.

Item	Dry matter, %	Crude Protein, % of DM
Corn silage	35	7.6
Corn grain	88	8.9
Bakery waste[a]	91	9.0
Layer waste[b]	89	29.2
Corncobs	90	2.8
Soybean meal	89	54.2

[a] "Cookie Meal" Plus® compliments of Griffin Industries, Cold Spring, Ky. Crude fat—9%.

[b] Pelleted caged layer waste compliments of Rose Acres Farms, Seymour, Ind. Calcium—13.2%; phosphorus—2.7%; potassium—3.2%; iron—2,336 ppm; zinc—481 ppm (dry-matter basis).

Table 3. Evaluation of bakery and layer waste as supplements for steer calves consuming a corn silage-based diet.

	Bakery Waste:Layer Waste (Treatment Number)							P-Value[a]					
Item[b]	Control (1)	100:0 (2)	75:25 (3)	50:50 (4)	25:75 (5)	0:100 (6)	SEM[c]	L	Q	1 vs 2	1 vs 6	2 vs 6	1 vs 2 & 6
Initial, lb	520	520	517	521	518	517	2	.283	.572	.851	.269	.200	.589
Final, lb	676	710	680	676	669	676	9	.017	.059	.022	.971	.020	.166
DMI, lb/d	13.77	14.06	13.50	13.96	14.64	14.16	.43	.337	.815	.652	.533	.862	.536
Gain, lb	157	190	162	155	151	159	9	.021	.040	.019	.847	.028	.123
ADG, lb	1.86	2.26	1.93	1.84	1.80	1.88	.11	.020	.045	.019	.901	.024	.132
Gain/feed	.136	.161	.142	.132	.124	.134	.005	.001	.004	.002	.740	.001	.069
Feed/gain	7.39	6.24	7.05	7.69	8.20	7.57	.28	.001	.019	.012	.651	.005	.188

[a] L—linear, Q—quadratic and treatment contrasts identified by treatment number.

[b] DMI = dry matter intake, ADG = average daily gain, gain/feed and feed/gain = efficiency.

[c] Standard error of mean, n = 6.

Efficacy of Chromium Yeast Supplementation for Growing Beef Steers

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Summary

This experiment was conducted to determine the efficacy of feeding chromium yeast to growing beef steers. Animal growth, gain efficiency, and blood glucose kinetics were determined in 24 beef steers (253 kg ± 4 kg body weight) fed a corn silage-based diet supplemented with 0 (control), 100, 200, or 400 μg chromium/kg of diet dry matter. The data indicate that steers receiving increased levels of chromium yeast may clear glucose faster during intravenous glucose tolerance and insulin challenge tests. However, chromium yeast supplementation had no effect on ADG and gain efficiency, suggesting that chromium yeast supplementation to unstressed growing calves may not be beneficial or cost-effective.

Introduction

Chromium has been implicated as an essential nutrient for humans, lab animals, and domestic livestock. It is thought that chromium increases glucose tolerance by potentiating the action of insulin in clearing postprandial glucose from the blood. This could lead to improved glucose utilization. However, inorganic forms of chromium are relatively unavailable for absorption. Organic forms of chromium, such as chromium yeast, are thought to be more available for absorption. Research on ruminants has suggested that organic chromium supplementation may have the greatest influence on stressed animals. Research regarding the biological effects of chromium yeast supplementation on non-stressed ruminants is limited, and results have been variable. Therefore, our objectives were to examine the influence of chromium yeast supplementation to non-stressed beef steers on 1) growth and gain efficiency and 2) blood glucose

kinetics during intravenous glucose tolerance and intravenous insulin challenge tests.

Procedures

Twenty-four cross-bred steers (253 ± 4 kg body weight) were individually fed twice daily a diet containing 90% corn silage and 10% soybean meal-based supplement (dry matter basis; Table 1) at 2.2% body weight/day. Steers were supplemented with 0 (control), 100, 200, or 400 µg Cr/kg of diet DM. Body weights were taken prior to the experiment and at three and six weeks of chromium yeast supplementation. Average daily gain and gain efficiency were calculated for each steer. Intravenous glucose tolerance tests (IVGTT) and intravenous insulin challenge tests (IVICT) were conducted at three and six weeks of chromium yeast supplementation at 0800 and 1300, respectively. Prior to IVGTT and IVICT, steers were fitted with indwelling jugular catheters. The IVGTT and IVICT were initiated after an overnight fast by intravenously dosing each steer via jugular catheter with glucose (.5 g/kg BW) or insulin (.1 unit/kg), respectively. Blood samples were collected at -10, 0, 5, 10, 15, 20, 25, 30, 45, 90, 120, 150, and 180 min relative to dosing. Plasma was harvested, frozen, and analyzed for glucose concentrations. Blood glucose clearance rate (k) and half-life ($T_{1/2}$) were calculated using the following equations: k (%/min) = {(ln [glucose time1] - ln [glucose time2]) / (time2 - time1)} * 100 and $T_{1/2}$ (min) = (.693 / k) *100.

The IVGTT and IVICT data were analyzed as a repeated measures design, and growth data were analyzed as a completely randomized design using GLM procedures of SAS. Contrast statements were used to compare treatments for linear, quadratic, and cubic effects due to chromium yeast supplementation.

Results and Discussion

There were no effects (P > .10) of chromium supplementation on ADG or gain efficiency (Table 2). However, some minor differences in blood glucose kinetics were observed. Glucose clearance rate from 5 to 45 min after glucose dosing increased linearly (P = .09) and glucose half-life decreased linearly (P = .06) with increasing chromium supplementation. However, this may have occurred because plasma glucose concentrations 5 min after glucose dosing were increased (P = .03) with increasing chromium supplementation (Figure 1; Table 3). There was a

Table 1. Components and composition of basal diet[a].

Diet Components	
Ingredient	**% of diet dry matter**
Corn Silage	90.0
Soybean meal	7.61
Fine ground corn	.57
Urea	.23
Choice white grease	.11
Vitamin A, D, & E premix	.02
Trace mineral salt with Se	.27
Dicalcium phosphate	.47
Limestone	.72
Diet Composition	
Item	**% of diet dry matter**
Ash	6.0
Crude Protein	12.5
NDF	42.3
ADF	21.4

[a]Diet contained 0 (control), 100, 200, or 400 µg Cr/kg diet dry matter from chromium yeast.

Figure 1. Plasma glucose concentration during an intravenous glucose tolerance test.

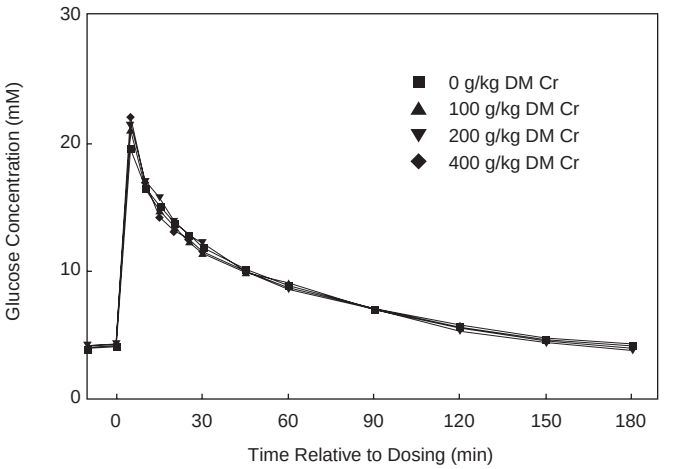

Table 2. Influence of chromium yeast supplementation on body weight (BW), average daily gain (ADG), and gain efficiency.

	Treatment							
		Chromium Yeast Supplied				Contrast P-Value[b]		
Item	**Control**	**100 µg/kg DM**	**200 µg/kg DM**	**400 µg/kg DM**	**SE[a]**	**Lin**	**Quad**	**Cub**
Initial BW (kg)	250	252	255	255	8.34	.65	.85	.92
Week 3 BW (kg)	271	272	273	277	9.39	.60	.94	.99
Week 6 BW (kg)	293	294	295	299	9.81	.64	.95	.98
ADG (kg/d)	1.04	1.03	.98	1.07	.06	.77	.37	.66
Gain:feed	.19	.19	.18	.20	.01	.74	.25	.67

[a]Standard error of the mean.

[b]Contrast P-values for linear (Lin), quadratic (Quad), and cubic (Cub) effects of chromium yeast supplementation.

treatment by sampling period interaction because the plasma glucose concentrations were increased to a greater extent in the 400 μg/kg treatment in Week 3 as compared to Week 6 (data not shown). Glucose clearance rate from 10 to 30 min after insulin dosing tended to increase linearly (P = .16) and half-life tended to decrease linearly (P = .14) with increasing chromium supplementation (Figure 2; Table 4).

Changes in glucose clearance rates and half-lives indicate that growing steers receiving chromium yeast may have a greater ability to clear glucose from the circulation. This in turn could lead to improved glucose utilization, resulting in improvements in ADG and gain efficiency. However, since ADG and gain efficiency were not influenced, the use of chromium yeast in diets for non-stressed growing steers fed a corn silage-based diet may not be beneficial or cost-effective.

Figure 2. Plasma glucose concentrations during an intravenous insulin challenge test.

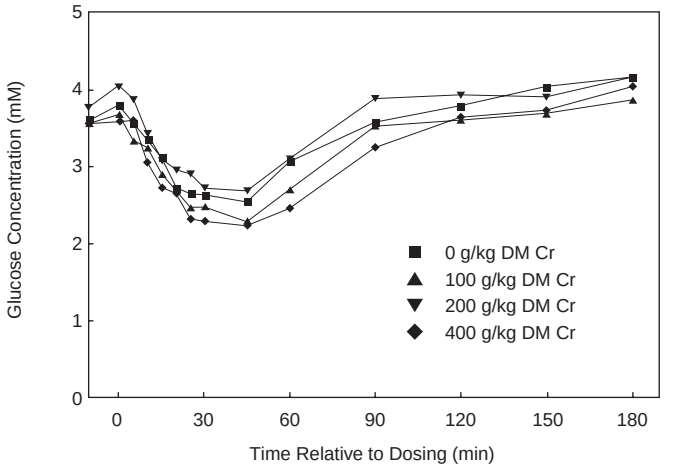

Table 3. Influence of chromium yeast supplementation on plasma glucose kinetics during an intravenous glucose tolerance test (combined data from both blood collection periods).

	Treatment							
		Chromium Yeast Supplied				Contrast P-Value[b]		
Item	Control	100 μg/kg DM	200 μg/kg DM	400 μg/kg DM	SE[a]	Lin	Quad	Cub
Basal glucose concentration (mM; Time 0 min)	4.21	4.13	4.33	4.13	.21	.88	.63	.50
Glucose concentration (mM; Time 5 min)[c]	19.76	21.27	21.53	22.19	.78	.03	.38	.63
Glucose concentration (mM; Time 45 min)	10.15	9.94	10.15	9.94	.52	.74	.96	.66
Clearance rate (k; %/min)[c]	1.65	1.96	1.91	2.02	.20	.09	.48	.46
Half-life ($T_{1/2}$; min)[c]	42.9	37.7	36.4	35.9	4.2	.06	.10	.38

[a]Standard error of the mean.

[b]Contrast P-values for linear (Lin), quadratic (Quad), and cubic (Cub) effects of chromium yeast supplementation.

[c]Blood collection period × treatment interaction (P < .10).

Table 4. Influence of chromium yeast supplementation on plasma glucose kinetics during an intravenous insulin challenge test (combined data from both blood collection periods).

	Treatment							
		Chromium Yeast Supplied				Contrast P-Value[b]		
Item	Control	100 μg/kg DM	200 μg/kg DM	400 μg/kg DM	SE[a]	Lin	Quad	Cub
Basal glucose concentration (mM; Time 0 min)	3.81	3.69	4.06	3.59	.26	.65	.42	.27
Glucose concentration (mM; Time 10 min)	3.36	3.25	3.44	3.06	.19	.28	.45	.39
Glucose concentration (mM; Time 30 min)	2.63	2.48	2.72	2.29	.20	.23	.43	.27
Clearance rate (k; %/min)	1.21	1.34	1.37	1.48	.15	.16	.80	.78
Half-life ($T_{1/2}$; min)	64.6	54.9	56.6	50.5	6.7	.14	.67	.49

[a]Standard error of the mean.

[b]Contrast P-values for linear (Lin), quadratic (Quad), and cubic (Cub) effects of chromium yeast supplementation.

Backgrounding Calves on Broiler Litter with Varying Levels of Corn and Soyhulls

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Summary

One hundred four crossbred steers were used in an experiment to evaluate 1) the economics of feeding broiler litter diets to backgrounding steers and 2) varying levels of corn and soyhulls in a feed containing 50% broiler litter. Calves were grazed on accumulated fescue from October 21, 1997, until February 16, 1998, and had free access to self-feeders containing a broiler litter diet. Calves were placed in 5-acre fescue paddocks and received one of the following dietary treatments: 50 % broiler litter with 1) 50% corn; 2) 37.5% corn, 12.5% soyhulls; 3) 25% corn, 25% soyhulls; or 4) 12.5% corn, 37.5% soyhulls.

Calves gained more ($P < .05$) when they received the 37.5% level of soyhulls. Feed intake increased as the level of soyhulls increased, although feed efficiency remained the same. The overall rate of gain was very favorable on this feeding regime until the last time period (January 17 to February 16), when gain for all treatments decreased as accumulated fescue was depleted.

Introduction

Deep-stacked broiler litter (a heat-processed mixture of bedding, manure, feathers, and spilled feed) is sometimes used as a feed ingredient in diets for backgrounding feeder calves. Expansion of the poultry industry in western Kentucky has made broiler litter available to producers in this area. However, economic advantages of feeding broiler litter may need to be contrasted against aesthetics and how the perception of this practice by the meat-consuming public might affect consumer demand. The objectives of this trial were to determine 1) if backgrounding operations utilizing broiler litter and corn could be feasible in Kentucky and 2) if the addition of soyhulls would improve animal performance.

Procedures

One hundred four crossbred steers were purchased from four area stockyards in the fall of 1997. After a 20-day conditioning period, calves averaged 509 lb and were randomly assigned to one of four dietary treatments. Twenty-six calves were placed in each of four 5-acre paddocks which had accumulated fescue present. Steers were permitted ad libitum intake of one of the following diets: 50% broiler litter with 1) 50% corn; 2) 37.5% corn, 12.5% soyhulls; 3) 25% corn, 25% soyhulls; 4) 12.5% corn, 37.5% soyhulls. Broiler litter was deep-stacked for three weeks prior to using. Litter was mixed with the whole-shelled corn, pelleted soyhulls, and 2 ounces/hd/day of white salt, which contained 40 ppm selenium, 800 mg/lb Rumensin and 200,000 IU/lb of vitamin A in a silage feeding/mixer wagon and delivered into self-feeders with an elevator. One self-feeder was placed on geotextile fabric and gravel pads in each paddock. Each self-feeder provided 24 ft of feeder space, allowing 11 inches of feeder space per head. Water was provided by automatic frost-free waterers in each pasture.

The experimental period began on October 21, 1997, and concluded February 16, 1998. Nitrogen was applied to the pastures the preceding August and fescue was allowed to accumulate. Near the end of the period, when pastures were grazed off, large round bales of fescue hay were placed in each paddock. Whole-shelled corn and fescue pasture was used in this trial to simulate low input feeding (minimum of feed preparation and harvesting equipment).

Results and Discussion

Overall performance of steers in this trial is shown in Table 1. Steers receiving the diet with 37.5% soyhulls gained significantly ($P < .05$) more than those that received no soyhulls. These calves consumed more feed, but feed efficiency was not different. Feed cost per lb of gain was not improved by adding soyhulls

Table 1. Performance of steers fed broiler litter-based diets with varying levels of corn and soyhulls (Oct 21, 1997, to Feb 16, 1998).

	50% Broiler Litter with			
Corn:	50%	37.5%	25%	12.5%
Item / Soyhulls:	0	12.5%	25%	37.5%
Steers, number	26	25	26	26
Average initial wt, lb	526	511	491	510
Average final wt, lb	742	753	750	768
Average daily gain, lb	1.83[a]	2.09[a,b]	2.06[a,b]	2.19[b]
Average daily feed intake, lb	19.65	23.46	23.56	25.10
Feed/gain, lb	10.75	11.21	11.46	11.46
Feed cost $/lb gain[c]	29.56	30.83	31.52	31.52

[a,b]Means on the same line with different superscripts differ ($P < .05$).

[c]Based on ration cost of $55/ton (corn @ $2.50 bu, litter @ $15 ton, soyhulls @ $90 ton).

Table 2. Average daily gain of steers fed broiler litter diets by time period (Oct 21, 1997, to Feb 16, 1998).

	Corn:	50%	37.5%	25%	12.5%
Period	Soyhulls:	0	12.5%	25%	37.5%
10/21 to 11/20		1.37	2.04	1.79	2.05
11/21 to 12/18		1.73	2.14	2.05	2.47
12/19 to 1/16		2.46	2.88	3.53	3.01
1/17 to 2/16		1.77	1.37	0.93	1.30

($90/ton); however, non-feed costs would be decreased because of the higher rate of gain on this diet and less time required in the backgrounding period.

Average daily gains by periods are shown in Table 2. Gains were very favorable during the winter grazing period except for the final period (January 17 to February 16). This indicates that grazing of stockpiled tall fescue likely should have been concluded earlier than mid-February.

Feed cost per pound of gain was very favorable for all treatments (ranging from 29.56 to 31.52 cents). When soyhulls replaced whole-shelled corn, feed intake of the broiler litter mixture was increased.

Blood serum levels of copper and selenium were determined on 10% of the calves on all treatments to assess the copper and selenium status of steers in this trial. Copper averaged 0.65 ppm (normal 0.6 to 1.5), and selenium averaged 42.1 ppb (normal 70 to 300). This indicated that the level of copper in these 50% broiler litter diets was not a problem and tended to be low-normal. Selenium levels were low despite being fed 2 oz/hd/day of a mineral supplement containing 40 ppm of selenium.

Influence of Abomasal Infusion of Glucose or Starch Hydrolysate on Pancreatic Exocrine Secretion in Beef Steers

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Summary

Understanding the regulation of pancreatic exocrine secretion may lead to the development of feeding systems that enhance pancreatic exocrine secretion of digestive enzymes and improve the efficiency of digestion and animal production. This experiment was conducted to determine the influence of post-ruminal carbohydrate source and level on pancreatic exocrine secretion in beef steers. Five crossbred steers (348 ± 12 kg body weight) were used in a 5 × 5 Latin square. Abomasal infusion treatments (250 ml infused/h) were water (control), 20 g/h glucose, 40 g/h glucose, 20 g/h starch hydrolysate (SH), and 40 g/h SH. The results indicate that abomasal infusion of glucose or SH increases total secretion of pancreatic juice and decreases secretion of α-amylase activity but has little influence on secretion of trypsin and chymotrypsin. The negative response of α-amylase due to increased small intestinal carbohydrate may limit small intestinal starch digestion of high concentrate diets. Further research regarding regulatory mechanisms of pancreatic α-amylase production in ruminants seems warranted.

Introduction

Feed grains, which contain high levels of starch, are a major energy source for ruminant production systems. Although the majority of starch is digested by the rumen microflora when high concentrate diets are fed, significant amounts of dietary starch reach the small intestine. Data has suggested that there are limits to small intestinal starch digestion. Pancreatic α-amylase and small intestinal disaccharidases are responsible for the breakdown of starch to glucose, which is absorbed by the small intestinal mucosa. Data has indicated that increases in post-ruminal starch supply decrease pancreatic α-amylase activity in pancreatic tissue and secretions, yet have little influence on small intestinal disaccharidase and glucose transport activity. This suggests that secretion of pancreatic α-amylase activity may limit small intestinal starch digestion. However, some data suggests that post-ruminal infusion of glucose increases secreted α-amylase activity and glucose transport activity. In addition, data comparing different levels of post-ruminal carbohydrate supply on pancreatic exocrine secretion is limited. Therefore, our objectives were to: 1) determine the influence of abomasal infusion of glucose or starch hydrolysate on pancreatic exocrine secretion and 2) determine the influence of level of carbohydrate infusion on pancreatic exocrine secretion.

Procedures

Five crossbred beef steers (348 ± 12 kg body weight) fitted with pancreatic pouch-duodenal re-entrant and abomasal infusion cannulas were fed a fescue hay-based diet (Table 1) at 1.5 × NE_m, supplemented to meet ruminally digestible intake protein and metabolizable protein requirements for a steer gaining .83 kg/d. Steers were randomly allotted to abomasal infusion treatment within period in a 5 × 5 Latin square design. Abomasal infusion treatments (250 ml infused/h) were water (control), 20 g/h glucose, 40 g/h glucose, 20 g/h starch hydrolysate (SH) and 40 g/h SH. Starch hydrolysate is raw cornstarch that has been partially hydrolyzed by a heat-stable α-amylase and was used because its digestion characteristics are similar to native starch passing through the small intestine. Abomasal infusion periods were 8 d with 3 or 4 d rest between periods. On d 8 of infusion, pancreatic juice was collected under continuous vacuum over 30-min intervals for 6 h.

Table 1. Diet composition[a].

Feedstuff	% of DM
Fescue hay	96.05
Ground corn	1.54
Corn gluten meal	.85
Blood meal	.85
Molasses	.17
Trace mineral premix	.53
Vitamin A, D, & E premix	.03

[a]Diet contained 10% ash, 15.8% crude protein, 59.2% neutral detergent fiber, and 28.6% acid detergent fiber (dry-matter basis).

Weight and pH of 30-min samples were recorded and a 10% subsample composited and frozen until analysis. The remaining sample was returned to the duodenum via the re-entrant cannula. Composited pancreatic juice samples were analyzed for total protein and α-amylase, trypsin, and chymotrypsin activity. One unit (U) of enzyme activity is defined as 1 μmole product released/min. Data were analyzed as a 5 × 5 Latin square. Contrast statements to compare treatment means were control vs carbohydrate (glucose and SH), glucose vs SH, linear effect of glucose, and linear effect of SH.

Table 2. Influence of abomasal carbohydrate infusion on pancreatic secretion in steers.

	Abomasal Infusion Treatment					
		Glucose		Starch Hydrolysate		
Item	Control	20 g/h	40 g/h	20 g/h	40 g/h	SEM[a]
Total secretion (g/h)[b,c,d]	189	191	226	211	233	10.2
PH of secretion[e]	8.08	8.12	8.05	8.01	8.04	.029
Protein secretion (g/h)	2.97	2.93	2.92	2.93	2.83	.11
α-Amylase secretion (U/h)[b,c,d]	54,402	37,683	40,583	39,808	31,560	5,065
Trypsin secretion (U/h)	365	354	402	360	403	32.2
Chymotrypsin secretion (U/h)	110	107	110	93	91	11.4

[a]Standard error of the mean.
[b]Control vs carbohydrate (P < .10).
[c]Linear starch hydrolysate (P < .10).
[d]Linear glucose (P < .10).
[e]Glucose vs starch hydrolysate (P < .10).

Results and Discussion

Abomasal infusion of carbohydrate increased (P = .04) total secretion of pancreatic juice from 189 to 215 g/h (Table 2). Total juice secretion also increased linearly (P < .03) from 189 to 226 and 189 to 233 g/h due to abomasal infusion of glucose and SH, respectively. The pH of pancreatic juice was not influenced (P > .10) when comparing control vs carbohydrate treatments. However, pH decreased (P = .07) from 8.09 to 8.03 when comparing glucose vs SH treatments. Secretion of total protein (mg/h) was not influenced (P > .10) by abomasal infusion treatment. Secretion of α-amylase activity decreased (P = .01) from 54,402 to 37,409 units/h when comparing control vs carbohydrate. Secretion of α-amylase activity decreased linearly (P < .09) from 54,402 to 37,683 and to 31,560 units/h due to abomasal infusion of glucose and SH, respectively. Secretion of trypsin and chymotrypsin activity was not influenced (P > .10) by abomasal carbohydrate infusion.

Mechanisms responsible for decreased α-amylase secretion due to increased small intestinal carbohydrate are unclear. However, it does appear to be a specific effect on α-amylase secretion since trypsin, chymotrypsin, and total protein secretion were unaffected (P > .10) by abomasal carbohydrate infusion. Similar results were observed due to abomasal infusion of glucose or SH, indicating that absorbed glucose may be mediating dietary adaptation to increased small intestinal carbohydrate. However, absorbed glucose may mediate its effects through the stimulation of humoral secretions such as insulin, pancreatic polypeptide, or peptide YY.

Since increased small intestinal carbohydrate decreases α-amylase secretion and therefore likely decreases the efficiency of starch digestion, dietary regimens designed to enhance α-amylase secretion could result in improvements in small intestinal starch digestion of high concentrate diets. Therefore, specific regulatory mechanisms of dietary adaptation of α-amylase secretion need to be determined so that such dietary regimens can be designed.

Influence of Dietary Carbohydrate Source and Energy Intake on Pancreatic α-Amylase Expression in Lambs

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Summary

In high concentrate diets, a significant amount of starch passes through the small intestine. Pancreatic α-amylase is a primary enzyme responsible for the digestion of starch in the small intestine. Increasing the production of pancreatic α-amylase could increase the efficiency of small intestinal starch digestion. However, research has suggested that pancreatic α-amylase secretion is decreased with increasing levels of small intestinal starch flow. The long-term goal of this research is to better understand the mechanisms responsible for the regulation of pancreatic α-amylase expression so that feeding strategies can be developed that enhance pancreatic α-amylase production and small intestinal starch digestion. The objective of this experiment was to examine the molecular mechanisms regulating dietary starch and energy effects on pancreatic α-amylase expression. Twenty-four wether lambs (28 ± .51 kg body weight) were fed diets low or high in starch at 1.2 or 1.8 × net energy of maintenance for at least 28 days. The results indicate that increasing dietary starch levels increase pancreatic α-amylase protein and activity when intake of metabolizable protein is similar. However, decreases in α-amylase mRNA suggest that dietary regulation of pancreatic α-amylase expression in ruminants is complex and prob-

ably regulated by transcriptional and post-transcriptional events. Increases in rumen total VFA concentrations and the molar proportions of propionate and butyrate may be important for the regulation of pancreatic α-amylase expression. More research on specific mediators regulating pancreatic α-amylase expression seems warranted.

Introduction

Feed grains, which contain high levels of starch, are a major energy source for ruminant production systems. In diets which do not contain high levels of starch, the majority of starch is digested by the rumen microflora. However, in high concentrate diets, significant amounts of dietary starch reach the small intestine. In the small intestine, pancreatic α-amylase and small intestinal disaccharidases are responsible for the breakdown of starch to glucose, which is absorbed by the small intestinal mucosa. Data have indicated that increases in post-ruminal starch supply decrease pancreatic α-amylase activity in pancreatic tissue and secretions, yet have little influence on small intestinal disaccharidase and glucose transport activity. This would suggest that secretion of pancreatic α-amylase activity may limit small intestinal starch digestion. Previous research also has suggested that dietary energy intake may be an important positive regulator of pancreatic α-amylase secretion. However, in these studies dietary protein intake often increases with increasing energy intake. This makes it difficult to determine whether the response is because of energy or protein because increases in small intestinal protein supply enhance secretion of pancreatic α-amylase activity and small intestinal starch digestion.

Regulatory mechanisms involved in changes in α-amylase production and secretions are largely unknown, especially in ruminants. In monogastric species, the regulation of pancreatic α-amylase production due to dietary adaptation primarily occurs at the transcriptional level. Increases in α-amylase production in the developing calf are also primarily under transcriptional control. However, very little is known as to how diet influences the expression of α-amylase in ruminants. Therefore, the objectives of this experiment were to: 1) determine the influence of dietary carbohydrate source and energy intake on steady-state levels of pancreatic α-amylase mRNA, protein, and activity, 2) characterize the molecular mechanisms of α-amylase synthesis, and 3) compare total tract digestion, blood glucose, and ruminal VFA measurements with observed α-amylase expression results.

Table 1. Components of diets and dry matter (DM) intake of lambs.

	Dietary Treatment			
	1.2 × NE_m		1.8 × NE_m	
Item	Low Starch	High Starch	Low Starch	High Starch
DM intake (% of BW)	1.87	1.43	2.82	2.03
Average DM intake (g)	524	400	790	568
Ingredient	% of DM			
Fescue/alfalfa hay	70	10	70	10
Solka floc	2.96	0	14.71	0
Cracked corn	0	50.96	0	64.96
Soybean meal	6	9.5	0	10
Soypass	7	10	3.5	1
Blood meal	3.5	5	1.75	.5
Urea	0	1.5	0	1.5
Molasses	3	3	3	3
Corn oil	5	5	5	5
Ammonium chloride	.5	.5	.5	.5
Limestone	0	2	0	2
Dicalcium phoshate	.5	2	0	1
Sodium phosphate (monobasic)	1	0	1	0
Trace mineralized salt	.5	.5	.5	.5
Vitamin A, D, and E premix	.04	.04	.04	.04

Table 2. Composition of diets.

	Dietary Treatment			
	1.2 × NE_m		1.8 × NE_m	
Item	Low Starch	High Starch	Low Starch	High Starch
Ash (%)	10.8	7.6	9.5	7.0
Starch (%)	5.4	35.3	6.4	43.8
Gross energy (kcal/g)	4.63	4.64	4.58	4.59
Digestible energy (kcal/g)	3.98	4.36	3.83	4.26
Crude protein (%)	21.8	26.3	15.6	18.8
NDF (%)	49.5	27.1	57.9	26.7
ADF (%)	26.0	7.2	33.9	6.4
Starch intake (g)	28	141	51	249
Digestible energy intake (Mcal)	2.09	1.74	3.03	2.42
Crude protein intake (g)	114	105	123	107
NDF intake (g)	259	108	457	152
ADF intake (g)	136	29	268	36

Procedures

Twenty-four wether lambs (28 ± .51 kg body weight) were randomly assigned to dietary treatment. Lambs were fed diets (Tables 1 and 2) low or high in starch (approximately 5 and 40%, respectively) at 1.2 or 1.8 × net energy of maintenance for at least 28 days (average 36 days). Dietary energy intake was adjusted according to body weight every 14 days. In low-starch diets, the majority of the carbohydrate was supplied by the fiber portion of the diet. Diets were formulated so that all lambs would receive the same amount of metabolizable protein per day, since changes in small intestinal protein supply alter pancreatic α-amylase secretion. Lambs were housed in metabolism crates for the final two weeks. Feed and fecal samples were collected the final five days, composited within animal across sampling day, dried in a 55°C oven, and ground to pass a 2-mm screen. Diet and fecal samples were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), starch, and gross energy, and corresponding total tract digestibilities were calculated. Blood samples were collected

via jugular venipuncture 3 hours after feeding on the day prior to tissue collection, and plasma was harvested by centrifugation and analyzed for glucose concentration. At the conclusion of the feeding period, lambs were anesthetized with sodium pentobarbital and the caudal portion of the pancreas was removed and subsampled for subsequent analyses. Steady-state levels of pancreatic α-amylase activity, protein, and mRNA were determined using potato amylopectin degradation, immunoblot, and Northern analysis, respectively. The remainder of the pancreas also was removed and total pancreas weight was determined. In addition, mucosa from 1 meter of jejunum (middle of the proximal region) was collected using a glass slide and maltase activity measured using maltose as the substrate.

Samples of whole ruminal contents were taken after death. Contents were strained through four layers of cheesecloth, and the pH of the fluid portion was determined. The fluid portion then was acidified with 25% meta-phosphoric acid (1 ml to 5 ml of rumen fluid) and frozen until analyzed for volatile fatty acid (VFA) concentrations using gas chromatography.

Data were analyzed as a completely randomized design with a 2 × 2 factorial arrangement of treatments. However, it was observed that the high energy-high starch treatment had consistently different pancreatic α-amylase values than the other treatments. Because this dietary treatment may have resulted in the only animals with significant starch flow to the small intestine, comparisons were made between the high energy-high starch treatment and the mean of the other treatments using a contrast statement. Data from VFA analysis were also analyzed in this manner, since the high energy-high starch treatment had consistently different values than the other treatments.

Results and Discussion

Pancreas weight (g) increased ($P < .10$) because of increased energy intake but was unaffected ($P > .10$) by energy intake when expressed as g/kg body weight (Table 3). This suggests that pancreatic weight change was a function of body weight differences. The molecular weight and size of the sheep α-amylase protein and mRNA were estimated to be 55 kD and 1.6 kb, respectively (Figures 1 and 2). These values are similar to those observed in monogastric species. Steady-state levels of pancreatic α-amylase activity, protein, and mRNA were not influenced ($P > .10$) by energy intake or carbohydrate source when analyzed as a factorial design (Table 3). However, when comparing the high energy-high starch treatment to other treatments, differences were observed. Concentration of pancreatic α-amylase activity (U/g) was greater ($P < .10$) for the high starch-high energy treatment than other treatments, as was total α-amylase activity (U/pancreas) and total α-amylase activity per kg body weight (U/pancreas/kg). Steady-state levels of α-amylase protein were greater ($P < .10$) for the high starch-high energy treatment than other treatments (Figure 1), but steady-state levels of α-amylase mRNA tended to decrease ($P = .18$) by 50% (Figure 2). These data indicate that high levels of dietary starch at high energy intake causes increases in pancreatic α-amylase content, but gene transcription may be inhibited and/or mRNA stability reduced. Thus, dietary regulation of pancreatic α-amylase expression in ruminants appears to occur by post-transcriptional events.

Figure 1. Immunoblot of lamb pancreatic α-amylase protein. Data represent a typical set of four animals (1/treatment). L = low; H = high; E = energy; S = starch.

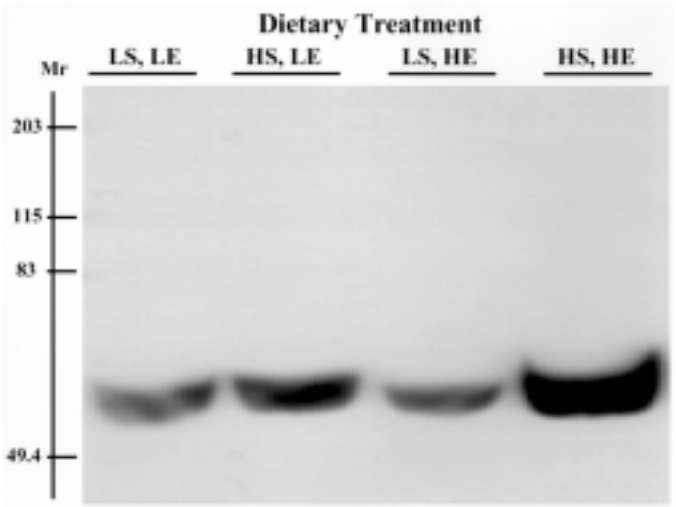
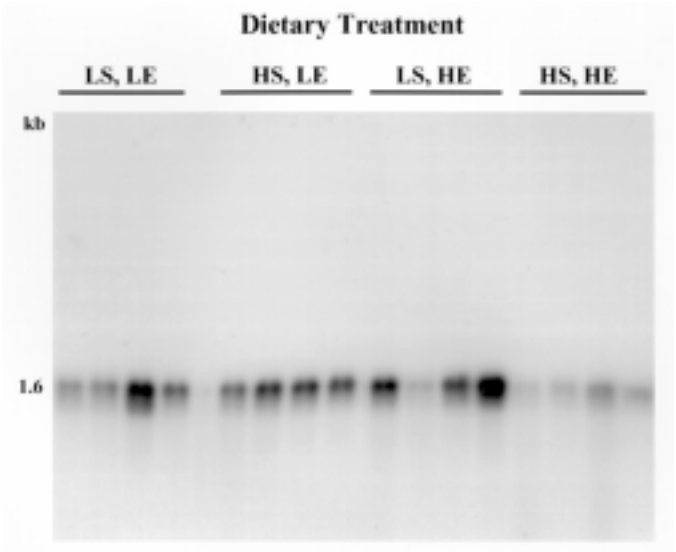


Figure 2. Northern blot of lamb pancreatic α-amylase mRNA. Data represent a typical blot using 16 representative animals (4/treatment). L = low; H = high; E = energy; S = starch.



Previous research has shown that high levels of dietary starch (or post-ruminal infusion of starch) result in the depression of α-amylase activity in the pancreas or pancreatic secretions of ruminants. It is unclear why the high energy-high starch diet increased pancreatic α-amylase activity and protein in this experiment. It is possible that, in prior experiments, metabolizable protein was not supplied at high enough levels to maintain and/or stimulate pancreatic secretion or content.

Jejunal maltase activity was not influenced ($P > .10$) by dietary treatment. These data agree with previous research suggesting that small intestinal disaccharidase activity is unaffected by dietary treatment in ruminants and suggest that pancreatic

α-amylase may be the primary enzyme involved in dietary adaptation to small intestinal starch digestion.

Final body weight increased (P < .10) with increasing energy intake but was not influenced by carbohydrate source (Table 4). Fecal starch concentrations were less than 1% (DM basis) for the high-energy, high-starch treatment. Therefore, it was assumed that total tract starch digestion was 100% for all treatments. Digestibility of DM, OM, and CP decreased (P < .10) with increased energy intake but increased (P < .10) when comparing the high-starch to the low-starch treatments. Energy by starch interactions were observed (P < .10), since digestibility was not depressed as greatly due to increased energy intake when high-starch diets were fed. Digestibility of energy and NDF decreased (P < .10) with increased energy intake and increased (P < .10) when comparing the high-starch to the low-starch treatments. Digestibility of ADF increased (P < .10) in high-starch diets.

Plasma glucose concentration was increased (P < .10) with increased energy intake and high starch (Table 4). Previous research has suggested that increases in blood glucose concentration may decrease pancreatic α-amylase production, since intravenous infusion of glucose inhibits α-amylase secretion in sheep. Our data would suggest that glucose is not a negative regulator, since increases in plasma glucose did not result in a depression of pancreatic α-amylase protein and activity.

Table 3. Influence of dietary carbohydrate source and energy intake on pancreas weight; steady state levels of pancreatic α-amylase activity, protein, and mRNA; and jejunal maltase activity.

	Treatment					P-Value		
	1.2 x NE_m		1.8 x NE_m					
Item	Low Starch	High Starch	Low Starch	High Starch	SE[a]	Energy	Starch	Energy x Starch
Pancreas wt								
grams	35.7	37.0	44.5	41.3	3.48	.05	.80	.49
g/kg BW	1.30	1.43	1.43	1.37	.13	.81	.80	.49
Pancreatic protein concentration								
mg/g pancreas	129	136	138	140	12.3	.58	.71	.85
Pancreatic α-amylase activity								
U/g pancreas[b]	443	471	389	643	94.0	.59	.12	.21
U/mg protein[c]	3.50	3.47	2.85	4.23	.53	.92	.19	.17
kU/pancreas[b]	16.3	17.8	17.6	29.8	4.0	.12	.12	.22
U/pancreas/kg/BW[b]	586	682	550	927	161	.47	.11	.33
Pancreatic α-amylase protein								
Arbitrary Units[b]	5.11	5.19	3.99	11.88	3.39	.39	.22	.23
Pancreatic α-amylase mRNA								
Arbitrary units[d]	2.03	1.95	1.95	.97	.63	.38	.38	.45
Jejunal maltase activity								
U/g mucosa	1.55	2.03	1.92	1.85	.30	.76	.51	.38

[a]Standard error of the mean for energy x starch interaction.

[b]High energy-high starch vs others (P < .10).

[c]High energy-high starch vs others (P = .13).

[d]High energy-high starch vs others (P = .18).

Table 4. Influence of dietary carbohydrate source and energy intake on BW, total tract digestibility, and plasma glucose concentration.

	Treatment					P-Value		
	1.2 × NE_m		1.8 × NE_m					
Item	Low Starch	High Starch	Low Starch	High Starch	SE[a]	Energy	Starch	Energy × Starch
Final BW (kg)	27.5	26.2	31.8	29.6	1.50	.02	.25	.78
Digestibility (%)								
DM	69.7	86.8	66.1	86.5	.87	.03	.01	.07
OM	86.6	95.0	84.2	94.6	.44	.01	.01	.05
CP	88.7	94.7	82.8	91.9	.54	.01	.01	.01
Starch	100	100	100	100	-	-	-	-
NDF	84.5	93.1	83.0	91.2	.89	.07	.01	.81
ADF	81.4	85.6	81.4	83.0	.90	.18	.01	.17
Energy	85.9	93.8	83.6	93.0	.49	.01	.01	.14
Plasma glucose (mg/dl)	59.1	62.6	64.4	68.8	2.11	.01	.07	.83

[a]Standard error of the mean for energy × starch interaction.

Rumen fluid pH was decreased (P < .10) with the high-starch diets (Table 5). However, an energy-by-starch interaction occurred (P < .10) because the energy response differed between low- and high-starch diets. There also was an energy-by-starch interaction (P < .10) for total VFA concentration. When comparing the high-energy, high-starch treatment to other treatments, total VFA concentration was increased (P < .10). The molar proportions of propionate and butyrate were increased (P < .10) and acetate decreased (P < .10) due to high-starch diets. Also, the molar proportion of propionate and butyrate were increased (P < .10) and acetate decreased (P < .10) when comparing the high-energy, high starch treatment to others. Whether rumen total VFA concentration and molar proportions of propionate and butyrate are correlated to pancreatic α-amylase production is unclear but may warrant further investigation. Isovalerate and valerate molar proportions were increased (P < .10) with high starch and decreased (P < .10) due to increased energy intake. Increases in these branched-chain VFA due to decreased energy intake may be related to the high concentration of crude protein in these diets and the possibility of the microbes using protein as an energy source. The acetate to propionate ratio decreased (P < .10) with the high-starch diets.

The relationship between pancreatic α-amylase production and rumen fermentation, blood glucose, and diet digestibility is largely unknown. The results of this experiment would suggest that increased total VFA concentration in the rumen may be related to increased α-amylase production. The mechanisms involved may be associated with blood VFA concentration, since intravenous infusion of VFA causes increased α-amylase secretion in sheep.

Table 5. Influence of dietary carbohydrate source and energy intake on rumen fermentation parameters taken at death.

	Treatment					P-Value		
	1.2 × NE_m		1.8 × NE_m					
Item	Low Starch	High Starch	Low Starch	High Starch	SE[a]	Energy	Starch	Energy × Starch
pH[b]	6.53	6.39	6.59	5.98	.09	.07	.01	.02
Total VFA (mM)[b]	66.2	60.9	65.8	79.2	7.89	.07	.90	.07
VFA (moles/100 moles)								
Acetate[b]	63.2	57.5	66.4	56.0	2.72	.74	.01	.37
Propionate[b]	18.5	20.9	17.0	23.4	.94	.62	.01	.03
Isobutyrate	4.54	3.94	4.51	2.91	.81	.50	.16	.52
Butyrate[b]	8.73	11.96	9.28	13.05	1.44	.55	.02	.84
Isovalerate	4.00	4.29	2.39	3.71	.46	.02	.08	.25
Valerate	1.01	1.41	.46	.94	.26	.04	.09	.86
Acetate:propionate[b]	3.57	2.76	3.94	2.41	.25	.84	.01	.14

[a]Standard error of the mean for energy × starch interaction.

[b]High energy-high starch vs others (P < .10).

Ruminant Serum Response to Coconut Oil-Protected Vitamin A

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Summary

Yearling wethers consuming a fescue hay diet were orally administered a single 35,000 IU dose of vitamin A as retinyl acetate (approximately 19 times the daily requirement). The vitamin A dose was either suspended in 35 g of coconut oil and given orally or given without oil. Blood was drawn via mesenteric arterial catheters at 0, 16, 20, 24, 28, 32, and 36 h relative to vitamin A treatment. These samples were measured for changes in serum vitamin A concentration relative to the initial (time 0) concentrations. When vitamin A was suspended in 35 g of coconut oil, the levels of vitamin A in serum began rising by hour 16 and continued increasing until levels peaked at hour 28. The concentrations of serum vitamin A, when delivered in coconut oil, were significantly higher than time-zero concentrations and control levels at each sample between 16 and 28 h (P <.05). The final (36 h) blood vitamin A levels remained above pre-dosing levels (P < .10). These results indicate that the delivery of vitamin A to the blood via an orally dosed suspension in coconut oil improved blood vitamin A levels for ruminants of normal vitamin A status.

Introduction

Vitamin A given orally to ruminants undergoes extensive pre-intestinal degradation. Results of previous experiments with sheep indicate that more vitamin A reaches the abomasum when it is suspended in coconut oil prior to oral administration. The recovery of orally dosed vitamin A in abomasal digesta increased when coconut carrier oil was increased from 11.7 to 35.0 g. Reduction in pre-intestinal destruction should increase the availability of the vitamin A for absorption into the blood. This is a report of the determination of the serum response to coconut oil-protected vitamin A orally dosed to sheep.

Methods

Eight yearling sheep, average weight of 38 kg, were fed daily 900 g of ground fescue hay in two equal portions. Mesenteric arterial catheters were used for blood collections. Each sheep received 35,000 IU of vitamin A, equivalent to about 19 times the daily requirement (NRC, 1985). The vitamin A was retinyl acetate in the form of commercially available, dry beadlets combined in a premix with calcium carbonate and rice hulls. It was placed in gelatin capsules either with or without 35 g of coconut oil and bolused into sheep, 1 h post feeding (four animals per treatment). Blood samples (15 mL) were drawn before dosing, 0 h, and at 16, 20, 24, 28, 32, and 36 h after dosing.

The blood samples were immediately centrifuged at 10,000 x g for 20 min. The serum layer was pipetted into plastic test tubes with seal caps and refrigerated overnight for next-day analysis. Serum vitamin A was analyzed in duplicate for each sample using a trifluoroacetic acid procedure. A t-test was used to compare vitamin A concentrations of serum at each sample period with time zero serum vitamin A concentrations and to compare treatments at each sampling time.

Results and Discussion

The results in Table 1 demonstrate that the oral dosing of vitamin A (19 times daily requirement) without coconut oil failed to significantly change serum vitamin A concentration at any sampling time. In contrast, blood vitamin A concentrations rose above baseline for sample times 16 through 28 h (P <.05) when

vitamin A was suspended in 35 g of coconut oil. In this case, vitamin A concentrations rose from 40.8 μg/dL to a peak of 59.3 μg/dL at 28 h after dosing. A return to baseline levels had not occurred by the 36 h sample period (P <.10). Blood vitamin A levels were higher for the carrier-oil group compared to the no-oil treatment group at 16, 20, 24, 28, and 36 h (P <.10). Ruminants with adequate levels of vitamin A in storage are not detectably responsive to oral intake of dosing vitamin A at levels below 20x requirement. When dosing vitamin A below this level (i.e. 19x daily requirement) pre-suspension of the dose in 35 g of coconut oil appears to detectably increase blood vitamin A concentration at 16-36 hours after dosing. This supports earlier findings that intra-gastric recoveries of vitamin A are higher when the oral dose is pre-suspended in coconut oil and indicates that suspension in oil does not prevent absorption of vitamin A.

Table 1. Concentration of vitamin A in blood of sheep after oral dosing of vitamin A suspended in coconut oil.

	Vitamin A Concentration in Sheep Serum (μg/dL)	
Sample hour	35,000 IU Vitamin A No Coconut Oil	35, 000 IU Vitamin A+ 35 g Coconut Oil
0	44.57 ± 0.76	40.82 ± 3.50
16	45.60 ± 0.42[c]	51.20 ± 1.17[ac]
20	47.52 ± 2.20[d]	53.49 ± 2.86[ad]
24	48.66 ± 2.96[c]	57.87 ± 3.31[ac]
28	45.96 ± 1.12[c]	59.26 ± 2.67[ac]
32	43.55 ± 2.44	50.12 ± 4.44
36	45.96 ± 1.76[d]	54.61 ± 4.90[bd]

[a]Within treatment means different significantly from 0 sampling time, P <.05.

[b]Within treatment means differ significantly from 0 sampling time, P <.10.

[c]Between treatment means differ significantly, P < .05.

[d]Between treatment means differ significantly, P < .10.

Efficacy of Laidlomycin Propionate in Low-Protein Diets Fed to Growing Beef Steers: Effects on Steer Performance and Ruminal Nitrogen Metabolism

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Summary

We conducted two trials to evaluate the effect of laidlomycin propionate on steer growth and ruminal nitrogen metabolism. Laidlomycin propionate increases ruminal NH_3 N concentration compared with monensin even though both ionophores decrease the capacity of ruminal bacteria to degrade peptides and amino acids without affecting proteolysis. However, with the dosages used in the current study, monensin appears to be a more potent inhibitor of amino acid deamination by mixed ruminal bacteria (20 and 34% for net ammonia nitrogen production and alpha-amino nitrogen degradation, respectively). Laidlomycin propionate does not appear to elicit the protein-sparing effect observed with monensin. However, laidlomycin propionate does improve steer average daily gain and gain/feed compared with non-laidlomycin propionate-supplemented controls.

Introduction

Ionophores, such as monensin, have been shown to decrease ruminal ammonia (NH_3) nitrogen (N) concentration and elicit a protein-sparing effect. This protein-sparing effect was proposed following studies that showed monensin supplementation increased the abomasal flow of dietary protein and improved the gain efficiency of steers on lower protein diets (10.5% CP, DM basis) to a greater extent than steers consuming higher protein diets (12.5% CP, DM basis). A number of in vivo and in vitro studies have supported the protein-sparing hypothesis, demonstrating that monensin decreases ruminal NH_3 N concentration by decreasing proteolysis, degradation of peptides, deamination of amino acids, and the number of amino acid-fermenting ruminal bacteria.

Evidence suggests that laidlomycin propionate (LP) may not affect N metabolism in the same manner as monensin. Laidlomycin propionate has maintained or increased ruminal NH_3 N concentration in steers consuming concentrate diets. In addition, duodenal flow of NH_3 N has been increased in steers supplemented with LP, suggesting an increased ruminal NH_3 N concentration. Therefore, we conducted two trials to evaluate the effect of LP on steer growth and ruminal N metabolism. In Trial 1, the growth and ruminal characteristics of steer calves consuming LP were evaluated. Trial 2 was designed to compare ruminal fermentation and protein degradation in steers adapted to LP and monensin. In addition, the in vitro deamination of amino acids by adapted ruminal bacteria was assessed.

Procedures

Growth Trial

Ninety-six steers (562 ± 7 lb body weight) were obtained through public auctions in central Kentucky. A three-week receiving protocol for health and corn silage diet adaptation was used. Steers were monitored for temperature (>103.5°F) and respiratory problems and treated appropriately. Prior to initiation of the 91-d study, steers were vaccinated with 7 Way Clostri Shield® and Vira Shield 5 + Somnus®, treated for internal and external parasites with Ivomec®, and implanted with Ralgro®.

Experimental diets (Table 1) consisted of 90% corn silage and 10% supplement (dry matter (DM) basis) and were offered

free choice. The experimental design was a randomized complete block with a 2 × 2 factorial arrangement of treatments consisting of two levels of dietary CP (formulated to 10.5 and 12.5% of DM), with and without LP (11 mg/kg diet DM). Diets were formulated to provide adequate amounts of calcium, phosphorus, and vitamins A, D, and E. Steers were stratified by weight and allotted randomly to one of four treatments. They were then sorted by treatment and weight and allotted randomly to one of 24 pens (four steers/pen, six pens/treatment). Steers were weighed before the 0800 feeding on two consecutive days at the beginning and end of the trial. Intermediate weights were taken every 28 d. All steers were offered diets at a common percentage of BW for the final 5 d of the study in order to minimize the effects of intake on ruminal fill.

Ruminal fluid was collected via stomach tube on d 91 from one steer randomly selected from each pen 4 h after feeding and used for determination of pH, volatile fatty acids, and NH_3. Feed bunks were checked daily and pen intake adjusted to allow for 10% refusals. Steers were offered 55% of the daily allotment of corn silage at 0800 and 45% at 1600. The daily allotment of supplement was top-dressed at 0800 to ensure consumption. Fresh water was available at all times. Supplements and corn silage were collected and analyzed weekly for DM. Feed samples were ground through a 1-mm screen and analyzed for DM and N.

Ruminal Metabolism Trial

ANIMALS AND DIETS: Six ruminally cannulated Angus steers (578 ± 13 lb body weight) were used in a replicated 3 × 3 Latin square design. The steers were offered a 90% corn silage and 10% supplement diet (Table 1) at 2.0% of BW in two equal portions daily (0700 and 1900). The diet was formulated to contain 12.5% CP. Soybean meal (SBM) and urea were used as sources of supplemental N. Dietary treatments consisted of a control (no ionophore) and two ionophore treatments (LP and monensin). Laidlomycin propionate and monensin were individually weighed and mixed into the supplement at each feeding to provide 11 and 33 mg/kg of diet DM, respectively (monensin was provided at 16.5 mg/kg d 1 through d 7 then at 33 mg/kg d 8 through d 28 to allow adaptation and avoid intake depression often associated with monensin).

SAMPLE COLLECTION: Experimental periods were 28 d. Steers were dosed at 0700 on d 25 with 300 mL of Cr-EDTA. Ruminal samples (. 100 mL) were obtained at 0, 1, 3, 5, 7, 9, and 12 h post dosing and immediately analyzed for pH. Five milliliters was acidified with 1 mL of 25% metaphosphoric acid and frozen for analysis of NH_3 N and volatile fatty acids. Fifteen milliliters was frozen for Cr analysis to determine rumen fluid dilution rate and rumen volume.

In situ evaluation of protein degradation was conducted on d 27. In situ bags (5 × 10 cm; Ankom Company, Fairport, New York) containing 1 g of SBM were prepared in triplicate and analyzed for initial N content. Three empty bags (blanks) were analyzed to account for any N present in the bags themselves. Duplicate bags (containing 1 g of SBM) were sealed with a heat sealer and placed in a weighted polyester mesh bag within the rumen of each steer (0, 2, 4, 6, 8, 12, 16, and 24 h incubation) in reverse order, allowing all bags to be removed from the rumen simultaneously. Upon removal, in situ bags were rinsed under warm tap water until the effluent was clear. The bags were allowed to drip dry for 24 h, dried at 130°F for 24 h, and weighed. The entire bag and contents was analyzed for N. The in situ degradation of SBM is expressed as a percentage of the original N. Variables determined in the in situ study are percentage N degradation/h (calculated as the slope of the regression utilizing the natural log of the percentage N remaining vs time) and percentage of ruminal escape N.

MIXED CULTURE IN VITRO INCUBATION AND SAMPLING: Whole ruminal contents obtained from all areas of the rumen were collected at 0900 (2 h after feeding) on d 28. Contents were squeezed through eight layers of cheese cloth and fluid collected in 1-L Erlenmeyer flasks. The flasks were immediately transported to the lab and allowed to incubate anaerobically at 102° F for 30 min to buoy feed particles to the top of the flask and to sediment protozoa to the bottom. Mixed ruminal bacteria were then harvested from the center of the flask for use in preparation of inoculum. The inoculum consisted of a 50:50 combination of ruminal fluid and an anaerobic dilution solution.

Table 1. Ingredient composition of diets fed to steers.

	Growth Study				
	Control		Laidlomycin Propionate		Metabolism Trial[a]
Item	10.5% CP	12.5% CP	10.5% CP	12.5% CP	
Ingredient, % of DM					
Corn silage	90.00	90.00	90.00	90.00	90.00
Soybean meal	2.39	7.04	2.39	7.04	7.75
Corn	5.61	.96	5.60	.95	-
Urea	.25	.25	.25	.25	.50
Choice white grease	.12	.12	.12	.12	.12
Limestone	.79	.79	.79	.79	.79
Dicalcium phosphate	.51	.51	.51	.51	.51
Trace mineral salt[b]	.30	.30	.30	.30	.30
Vitamins A, D, and E[c]	.03	.03	.03	.03	.03
Cattlyst[d]	-	-	.01	.01	-
Chemical					
CP, % of DM	10.8	13.0	10.7	13.0	13.0

[a]Control treatment received basal diet, while the monensin and laidlomycin propionate treatments received the basal diet and 33 and 11 mg/kg DM, respectively, of monensin and laidlomycin propionate.

[b]98.5% NaCl, .35% Zn, .34% Fe, .20% Mn, 330 ppm Cu, 70 ppm I, 50 ppm Co, and 90 ppm Se.

[c]8,800 IU/g vitamin A, 1760 IU/g vitamin D, and 1.1 IU/g vitamin E.

[d]11.02% laidlomycin propionate.

Fifty milliliters of anaerobic dilution solution (102° F) containing 1.5g of Amicase were added in duplicate to 125-mL Erlenmeyer flasks and capped with neoprene stoppers equipped with vacuum check valves for release of gas resulting from fermentation. An equal volume (50 mL) of ruminal fluid was added to each flask to bring the final concentration of Amicase to 15 g/L. Amicase is a casein acid hydrolysate consisting of approximately 80% free amino acids and 20% di-and tri-peptides. Treatments (control, laidlomycin propionate, or monensin) were dependent on the diet that each donor animal received. Ionophores were dissolved in ethanol and included in the inoculum at 6 μg/L and 2mg/L for monensin and laidlomycin propionate, respectively. The control treatment received an ethanol blank. The flasks were incubated for 8 h at 102°F with samples (2 mL) taken after 0, 1, 2, 3, 4, 5, 6, 7, and 8 h. Preliminary experiments indicated that NH_3 N production was first order with respect to time for this incubation period. Samples were placed in prechilled 2 mL microcentrifuge tubes and centrifuged (15,000 × g; 5 min) to terminate fermentation and isolate bacteria. An aliquot of supernatant (750 μL) was acidified with 150 mL of 25% meta-phosphoric acid (wt/vol) and stored (-4°F). An additional 750 μL aliquot was stored (-4°F) for analysis of alpha-amino N. The bacterial pellet was washed once with 1 mL of .9% NaCl (wt/vol) and stored (-4°F) for analysis of protein. Protein was determined following treatment of the pellet with 1.5 mL of .11 N NaOH (212°F, 30 min), using the BCA procedure. The acidified samples were centrifuged as before and supernatant collected and stored (-4°F) for analysis of NH_3 N and alpha-amino N using a centrifugal analyzer (COBAS FARA II, Roche Diagnostic Systems). Upon thawing, a .5 mL aliquot of the non-acidified sample and 2 mL of 7.5 N HCl were placed in a 30 mL serum bottle, bubbled with N for 30 sec, tightly sealed with a rubber stopper, and capped with an aluminum seal for hydrolysis. The bottles were placed in a 230°F oven for 24 h. Upon cooling, 2 mL of 7.5 N NaOH was added to neutralize excess HCl, and samples analyzed for alpha-amino N. Rate of NH_3 N production (specific activity of deamination; nmol NH_3 N/(mg protein•min)) and alpha-amino N degradation (nmol alpha-amino N/(mg protein•min)) were calculated.

Statistical Analysis

GROWTH TRIAL: Dry matter intake, average daily gain (ADG), gain/feed, and ruminal pH, NH_3 N, and VFA were analyzed as a randomized complete block design. The statistical model included weight block, protein level, LP, and protein level × LP. There were only four observations for ruminal data associated with the 10.5% CP treatment that received LP because of sample loss.

RUMINAL METABOLISM AND IN VITRO FERMENTATION: Data were analyzed as a replicated 3 × 3 Latin square design. The statistical model included Latin square, treatment, period within Latin square, and steer within Latin square. Orthogonal contrasts were: 1) control vs LP and monensin and 2) LP vs monensin. Response variables included percentage in situ N degradation/h, percentage of undegradable intake protein (UIP), rumen volume, rumen fluid dilution rate, rate of NH_3 N production, and alpha-amino N degradation. Ruminal VFA, NH_3 N, and pH data collected at fixed times throughout the sampling day were analyzed as repeated measures. No treatment × time interactions were observed (P > .10); therefore, measurements were averaged across time and treatment means compared as described above.

Results and Discussion

Growth Trial

Steer final weight and total gain were greater (P < .07) for 12.5% CP and LP compared with 10.5% CP and control steers, respectively (Table 2). Dry matter intake increased (P = .08) for 12.5% CP compared with 10.5% CP but not for LP supplemented steers (P = .36). However, average daily gain and gain/feed were increased (P < .03) for 12.5% CP and LP. No interactions between LP and CP occurred.

Ruminal pH was decreased (P = .01) for 12.5% CP compared with 10.5% CP (Table 3). LP and 12.5% CP increased (P < .09) ruminal NH_3 N (mM) compared with no ionophore and 10.5% CP supplemented steers. The concentration of total VFA was not affected (P > .12) by protein level or LP. Molar proportion of acetate was not affected by protein level or LP (P > .24); however, propionate (mol/100 mol) was increased for 12.5% CP (P = .08) and LP (P = .005). Consequently, acetate:propionate was decreased (P = .02) for LP-supplemented steers.

RUMINAL METABOLISM AND IN VITRO FERMENTATION: Rumen fluid dilution rate (%/h) was increased (P = .01) for LP and monensin compared with control; however, no difference (P = .13) was noted between LP and monensin (Table 4). Rumen volume and pH were not affected (P > .29) by treatment. Ruminal NH_3 N (mM) was greater (P = .08) for control compared with the ionophores and for LP compared with monensin (P = .02). This is in contrast to the results observed in the growth trial, where LP increased ruminal NH_3 N compared with the control. However,

Table 2. Effect of laidlomycin propionate (LP) and crude protein (CP) on steer dry matter intake (DMI), gain (ADG), and gain/feed.

	Control		LP			P-Value		
Item	10.5% CP	12.5% CP	10.5% CP	12.5% CP	SEM[a]	CP	LP	CP X LP
Initial wt, lb	564	564	564	560				
Final wt, lb	774	811	794	829	9	.001	.06	.96
Total gain, lb	210	247	230	269	9	.001	.02	.90
Days 0 to 91								
DMI, lb/d	13.9	14.6	14.4	14.8	.3	.08	.36	.65
ADG, lb/d	2.29	2.71	2.56	2.95	.09	.01	.02	.90
Gain/feed	.167	.185	.179	.200	.005	.01	.01	.76

[a]n = 6.

Table 3. Effect of laidlomycin propionate (LP) and crude protein (CP) on ruminal pH, NH_3 N, and volatile fatty acids (VFA) - growth study.

	Control		LP			P-Value		
Item	**10.5% CP**	**12.5% CP**	**10.5% CP**	**12.5% CP**	**SEM[a]**	**CP**	**LP**	**CP X LP**
pH	6.79	6.65	6.79	6.55	.08	.01	.45	.48
NH_3 N, mM	.7	2.8	1.9	4.7	.97	.01	.08	.70
Total VFA , mM	90.6	100.0	96.8	100.4	4.7	.12	.41	.48
VFA, mol/100 mol								
Acetate	65.8	66.0	65.3	63.5	1.5	.52	.24	.44
Propionate	17.3	18.5	19.6	20.8	.8	.08	.005	.93
Isobutyrate	1.7	2.0	2.1	1.8	.2	.76	.37	.05
Butyrate	12.5	11.2	11.0	11.3	1.1	.58	.46	.36
Isovalerate	1.2	1.3	1.9	1.3	.2	.26	.06	.06
Valerate	1.3	1.7	.9	1.0	.2	.19	.005	.43
Acetate:propionate	3.8	3.6	3.4	3.1	.2	.14	.02	.64

[a]n = 6 except for 10.5% CP with laidlomycin propionate where n = 4; therefore, the largest SEM is presented.

Table 4. Effect of laidlomycin propionate (LP) and monensin (M) on rumen characteristics, crude protein (CP) degradation rate, undegradable intake protein, and in vitro NH_3 N production and alpha amino N (AAN) degradation–ruminal metabolism study.

Item	**Control**	**LP**	**M**	**SEM[a]**	**Control vs LP & M**	**LP vs M**
Rumen dilution rate, %/h	8.24	9.08	9.74	.27	.01	.13
Rumen volume, L	31.9	30.6	29.8	1.2	.29	.656
pH	6.62	6.64	6.69	.03	.34	.31
NH_3 N, mM	5.28	5.20	4.28	.20	.07	.02
Total VFA, mM	90.2	88.0	85.6	1.7	.16	.36
VFA, mol/100 mol						
Acetate	65.8	63.3	63.5	.6	.02	.80
Propionate	16.9	19.0	19.4	.5	.01	.61
Isobutyrate	2.68	2.77	2.93	.09	.19	.27
Butyrate	11.3	11.4	10.4	.2	.10	.01
Isovalerate	2.03	2.31	2.39	.20	.25	.79
Valerate	1.29	1.23	1.29	.04	.59	.42
Acetate:propionate	4.03	3.41	3.36	.14	.01	.82
CP degradation rate/h, %	8.73	9.81	10.34	.55	.09	.52
Undegradable intake protein, %	32.6	29.8	30.9	1.5	.26	.61
Microbial specific activity, nmol/mg protein/min						
NH_3 N	40.1	29.3	24.3	3.8	.03	.40
Hydrolyzed AAN	-30.8	-21.4	-16.0	3.0	.02	.25

[a]n = 6.

these results are consistent with prior data, indicating that LP does not decrease ruminal NH_3 N concentrations.

Results observed for VFA support those observed in the growth trial. Total VFA were not affected (P > .16) by ionophore, but molar proportions of acetate were decreased (P = .01) and propionate increased (P = .01) for LP- and monensin-supplemented steers compared with the control. Monensin increased (P = .01) butyrate (mol/100 mol) compared with LP. Because of decreased acetate and increased propionate (molar proportions) with the ionophore treatments, acetate:propionate was decreased (P = .01) compared with the control. In situ CP degradation rate/h (%) tended to be greater (P = .09) for the ionophore treatments compared with the control; however, ruminal escape protein was not influenced (P > .26) by treatment.

Free amino acids and peptides were provided as a substrate in the in vitro study. Preliminary experiments indicated alpha amino N (AAN) degradation was not correlated with NH_3 N production. As a result, samples were hydrolyzed (to yield free amino acids) and re-analyzed for AAN (the AAN procedure used in this study would measure peptides as one alpha-amino group).

This provided us with AAN degradation rates similar to NH_3 N production. Based on this data, ruminal bacteria were preferentially using AAN from peptides (and possibly soluble proteins and peptides from the rumen fluid inoculum). Therefore, NH_3 N production and hydrolyzed AAN degradation were used as indicators of amino acid deamination by ruminal microbes.

When corrected for microbial protein, NH_3 N production (nmol/(mg protein•min)) was increased (P = .03) on the control treatment compared with the ionophores (Table 4). Consequently, hydrolyzed AAN degradation (nmol/(mg protein•min)) was lower (P = .02) for LP and monensin compared with the control. No differences (P = .25) were observed in hydrolyzed AAN degradation between LP and monensin.

Laidlomycin propionate and monensin appear to affect ruminal CP degradation and amino acid degradation in a similar fashion. However, LP increases ruminal NH_3 N concentration compared with monensin. Laidlomycin propionate may increase ruminant performance by improving efficiency of dietary energy use through modification of ruminal fermentation.

By-Product Feeds for Postweaning Feeding of Calves

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Summary

Four trials and one demonstration involving 283 weaned calves were conducted to study the effects of various alternative feeds for weaned calves. High-fiber by-product feeds, such as soyhulls (soybean seed coats) and dry corn gluten feed (a by-product from the manufacturing of high-fructose corn syrup) can be excellent substitutes for corn in high-forage diets. Depression of forage digestibility, sometimes seen with high-starch supplements, is minimized with these high-fiber supplements, which contain highly digestible fiber. They are also very palatable to calves and less likely to cause founder and acidosis in calves than grains. When these products can be purchased at prices which are competitive with corn, they can be excellent feeds to use in situations where forage utilization is a priority.

This research indicates that 1) calves can make rapid and efficient gains during short postweaning feeding periods, 2) some high-fiber feeds can be excellent supplements for high-forage diets, and 3) soyhulls and corn gluten feed worked better than the other alternative feeds used in these studies.

Introduction

By-product feeds may be utilized to replace more expensive feed ingredients. Some by-products are high in fiber, but the fiber is low in lignin and highly digestible. Some highly digestible fiber sources can give performance similar to or greater than starch-type supplements, like corn, when used with high-forage diets. Objectives of these trials were to identify economical systems for feeding weaned calves and to evaluate some high-fiber by-product feeds on high-forage diets.

Experiment 1. Postweaning feeding regimes for steer calves.

Fifty-eight steer calves averaging 618 lb were used to study different feeding regimes for short-term (56-day) feeding for weaned calves. Calves were weaned in the fall of 1996 and placed in drylot for seven days to accomplish weaning. They were subsequently divided into four groups, which were assigned to one of three treatments: 1) drylot with large, rolled bales of hay and corn/soybean meal/soyhulls, 2) drylot with large, rolled bales of hay and ad libitum intake of commercial preconditioning feed, 3) stockpiled fescue pasture (6 acres) with corn/soybean meal/soyhulls, and 4) drylot with large, rolled bales of hay and corn/alfalfa hay.

Results are shown in Table 1. Calves gained more (P < .05) when fed the commercial preconditioning feed than those on the other treatments. However, feed cost per pound gain was cheaper for the other treatments. Feeding calves while strip-grazing stockpiled fescue (valued at $20/acre) gave the lowest cost of gain (28.64 $/lb). The alfalfa hay and corn diet would be more economical at lower prices for the alfalfa hay than used in this trial ($3.50 per 65-pound bale).

Experiment 2. Postweaning feeding of different supplements for heifer calves fed corn silage.

Sixty-four heifer calves averaging 570 lb were divided into eight groups of eight calves and assigned to one of four supplements containing corn with 1) soybean meal, 2) soyhulls, 3) whole, raw soybeans, and 4) wheat midds. Each supplement mixture was formulated to contain 1.0 lb crude protein and 4.5 lb of TDN per day. Calves were permitted ad libitum intake of corn silage (32% dry matter; 7.8% crude protein, 65.6% TDN) during the 56-day trial.

Performance is shown in Table 2. Calves gained more (P < .05) when fed the corn/SBM or corn/soyhulls (2.29 and 2.39 lb/day) than when whole soybeans or wheat midds were fed (1.68 and 1.85 lb/day, respectively). Feed cost per lb of gain was similar for all treatments except whole soybeans. Whole soybeans could best be sold on the cash market and one of the other supplements used. Intake of corn silage was decreased when steers were fed whole soybeans or wheat midds.

Experiment 3. Corn vs soyhulls for steer calves on stockpiled fescue pastures or fescue hay.

Thirty-nine weaned steer calves averaging 630 lb were used to study the effects of supplementing with either corn or soyhulls

on forage diets. Calves were allotted to four groups and randomly assigned to one of four treatments: stockpiled fescue with corn or soyhulls, and fescue hay with corn or soyhulls for 60 days. In this study calves received either 7 lb of soyhulls or 7 lb of the corn mixture (6 lb corn and 1 lb soybean meal) per head daily. Supplements contained equal protein levels.

Results are shown in Table 3. Calves receiving soyhulls gained more than those fed equal amount of corn/soybean meal on either pasture or in drylot with hay. In each case, soyhull-supplemented calves gained 0.4 lb per day more. The results indicate that soyhulls 1) are an excellent choice to supplement high forage diets and 2) can replace corn on a pound per pound basis with slightly better results.

Experiment 4. Various supplements for heifer calves on stockpiled fescue.

Fifty-six heifer calves averaging 570 pounds were used to study the use of various feed supplements on stockpiled fescue pasture. Calves were allotted into four groups of 14 calves and randomly assigned to one of four treatment groups: no supplement, corn, soyhulls, or dry corn gluten feed. Calves were fed 9 lb/hd/day of their respective feed. Each pasture consisted of 5 acres of fescue. Grazing began on November 16, 1998, and continued until January 15, 1999.

Results are shown in Table 4. Calves receiving no supplementation gained less (P < .05) at 0.65 lb/day while those receiving corn or soyhulls were intermediate (1.45 and 1.58 lb/day) and corn gluten feed was highest (P < .05) at 1.83 lb/day. Corn, soyhulls, and corn gluten feed contained approximately 10, 13, and 25% crude protein, respectively.

Demonstration: Soyhulls for steer calves during the weaning/preconditioning period.

Sixty-six steer calves averaging 517 lb were weaned and placed in drylot for 27 days after weaning. Calves were fed 10 lb of soyhulls and 0.3 lb of soybean meal which was top-dressed with Aureomycin crumbles. Calves were given access to large round bales of fescue hay. Results are shown in Table 5. Calves gained 70 lb (2.6 lb/day) during the 27-day period. Soyhulls were purchased for about $70/ton (3.54/lb). Feed cost was $.20 per lb of gain. This short postweaning-feeding regime gave a very favorable rate of gain and cost per pound of gain.

Table 1. Postweaning feeding regimes for steer calves, 1996-97 (56 days).

	Feeding Regime[a]			
Item	Rolled Hay/ SBM/Corn	Alfalfa Hay/ Corn	Commercial Precon	Stockpiled Fescue Pasture w/Supplement
Steer calves, number	15	15	15	13
Initial wt, lb.	621	627	612	621
Daily ration, lb (per 1)				
RB Hay (ad lib)	7.8	5.4	5.4	-
Alfalfa	-	6.5	-	-
Corn	6.0	6.0	-	6.0
SBM	0.7	-	-	0.7
Precond Pellet	-	-	15.5	-
Daily ration, lb (per 2)				
RB hay (ad lib)	7.8	5.4	5.4	-
Alfalfa	-	7.5	-	-
Corn	6.3	7.5	-	6.3
SBM	-	-	-	-
Precond Pellets	-	-	16.7	-
Soyhulls	5.0	-	-	5.0
Gain, lb				
ADG (period 1)	2.1	2.4	3.0	2.0
ADG (period 2)	1.9	2.0	3.5	2.4
ADG (56 days)	2.0[b]	2.2[b]	3.2[c]	2.2[b]
Feed cost lb of gain, ¢ [d]	31.5	43.5	44.2	28.6

[a]Soyhulls = 13.2% crude protein; preconditioning feed = 13.4% crude protein, 84.7% TDN; alfalfa hay = 20.7% crude protein, 55.2% TDN; fescue hay = 13.4% crude protein, 42% TDN.

[b,c]Means on the same line with different superscripts differ (P < .05).

[d]Fescue pasture valued at $ 20/ac for N-fertilization; alfalfa values at $3.50/65-lb bale; commercial preconditioning feed at $175/ton.

Table 2. Postweaning feeding of different supplements for heifer calves fed corn silage diets, 1996-97 (56 days).

	Corn-Based Supplement with[a,b]...			
	SBM	Soyhulls	Whole Soybeans	Wheat Midds
Heifers, number	16	16	16	16
Pens	2	2	2	2
Calves/pen	8	8	8	8
Initial wt, lb	565.5	570.4	571.5	572.5
Daily ration, lb				
SBM	1.3	0.3	-	-
Soyhulls	-	5.1	-	-
Soybean, whole	-	-	2.6	-
Wheat midds	-	-	-	5.7
Corn	4.1	2.7	2.7	0.4
Corn silage (ad lib)	23.2	23.5	21.2	21.5
Gain, lb	128.4	134.0	94.1	103.6
ADG, lb	2.29[c]	2.39[c]	1.68[d]	1.85[d]
Feed cost per lb gain, ¢	26.7	28.1	37.8	28.0

[a]Supplement mixture contained 1.0 lb CP and 4.5 lb TDN per day.

[b]Wheat midds = 20% crude protein, 82.6% TDN; soyhulls = 13.2% crude protein.

[c,d]Means on the sale line with different superscripts differ (P< .05).

Table 3. Fescue pasture or hay supplemented with corn/soybean meal (SBM) or soyhulls for postweaning steer calves. Nov 17, 1997, to Jan 16, 1998 (60 days).

	Fescue pasture		Drylot w/hay	
	Corn/SBM	Soyhulls	Corn/SBM	Soyhulls
Steers, number	9	10	10	10
Average initial wt, lb	648	629	626	629
Suppl. feed, lb/hd/d	7	7	7	7
Hay, lb/hd/d	-[a]	-[a]	11.7	11.5
Performance				
Gain, lb/hd	85[b]	108[c]	110[c]	129[d]
ADG, lb	1.4[b]	1.8[c]	1.8[c]	2.2[d]
Feed cost/lb gain,¢ [e]	38.6	23.8	30.3	20.4

[a]One-half acre per calf.

[b,c,d]Means on the same line with different superscripts differ (P< 05).

[e]Based on the following prices: pasture – $20/acre, hay – $30/T, soyhulls – $75/T, SBM – $220/T, corn – $90/T ($2.52/bu).

Table 4. Various supplements for heifer calves grazing stockpiled fescue (Nov 16, 1998, to Jan 15, 1999).

	Feed Supplement			
	None	Corn	Soyhulls	Corn Gluten Feed
Heifers, number	14	14	14	14
Average initial wt, lb	567	566	573	573
Average final wt, lb	606	653	668	683
Gain, lb	39.3	87.3	94.9	110.0
ADG, lb	0.65[a]	1.45[b]	1.58[b]	1.83[c]
Feed, lb/day	-	9	9	9

[a,b,c]Means on the same line with different superscripts differ (P < .05).

Table 5. Soyhulls for weaned steer calves (1998).

Initial wt, lb	517
Final wt, lb	587
Gain, lb	70
ADG, lb	2.6
Feed cost per lb gain, ¢[a]	20

[a]Based on soyhulls @ $75/ton.

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