Asian-Aust. J. Anim. Sci.
Vol. 22, No. 5 : 643 - 650
May 2009

www.ajas.info

Effects of Feeding Different Protein Supplements on Digestibility, Nitrogen Balance and Calcium and Phosphorus Utilization in Sheep*

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ABSTRACT : Two metabolism trials were conducted with 24 wether lambs to investigate the effects of feeding crab meal and other protein supplements on N utilization, digestibility and Ca and P balance in sheep. The lambs (avg. BW, 25 kg) were randomly allotted to eight diets in each of two trials. The supplements were: i) none, negative control (NC); ii) soybean meal (SBM), control; iii) supplement based on industrial byproducts of both plant and animal origin (IPA); iv) experimental supplement based on byproducts of animal origin (ESA); v) hydrolyzed supplement No 4. (HESA); vi) commercial supplement based on animal protein (CS), Pro-Lak®; vii) crab meal (CM); and viii) urea (U). The supplements supplied 33% of the total dietary N (CP, 9.8%; DM basis). Lambs fed the NC diet had lower ($p<0.05$) DM and OM digestibility. Lower ($p<0.05$) apparent absorption of N was recorded for the lambs fed the HESA and NC diets. Sheep fed CM had lower Ca absorption compared to SBM. Highest ($p<0.05$) P absorption was observed for lambs fed CS and CM and lowest for U and NC diets. Sheep fed CM had higher ($p<0.05$) total VFA concentration (65.7 μmol/ml), compared to those fed ESA, CS, and NC diets (47.3, 49.8, and 49.5 μmol/ml, respectively). Highest ($p<0.05$) ruminal NH_3N (29.6 mg/dl) was observed in lambs fed the U diet, while those fed the NC diet had the lowest ($p<0.05$) average value (7.66 mg/dl). Lambs fed the U diet had the highest ($p<0.05$) blood urea N (10.67 mg/dl). The present study showed that N utilization of diets supplemented with experimental supplements based on feather meal and blood meal; commercial supplement based on animal protein, Prolak®; supplement based on plant protein and blood meal; and crab meal are comparable with that of soybean meal. (**Key Words** : Digestibility, Escape Protein, N Balance, Protein Supplement, Sheep)

INTRODUCTION

Feeding combinations of different escape protein supplements such as blood meal (BM) and feather meal (FTM) (Blasi et al., 1991; Sindt et al., 1993) and BM and corn gluten meal (CGM) to growing calves (Ludden and Cecava, 1995) has been shown to be more efficient than feeding these protein supplements separately. Various combinations of different protein supplements are available commercially, but their rumen escape potential and their effect on digestibility are not known.

Several studies conducted in this laboratory (Ayangbile, 1989; Samuels et al., 1991;1992; Abazinge et al., 1993; 1994) and elsewhere (Patton et al., 1975; Velez et al., 1991; Eastridge, 2006) have shown that crab processing waste could be processed and fed as protein supplement either in the form of silage in combination with roughage or as dehydrated meal for ruminants. Lubitz et al. (1943) reported that quality of CM protein is higher than that of fish meal (FM) protein. Later, Patton et al. (1975) reported that there were no significant reductions in digestibility of DM, N, and Ca when cattle were fed 10 or 20% CM. Higher DM and OM digestibilities were observed when sheep were fed silage containing 60% crab waste than those fed silage containing 40% crab waste (Samuels et al., 1992). Higher N retention has been reported when sheep were fed crab waste-straw silage compared to wheat straw silage (Samuels et al., 1992; Abazinge et al., 1994). Ayangbile (1989) reported that apparent digestibility of DM, OM, CP, energy, NDF, ADF, cellulose and hemicellulose decreased linearly ($p<0.01$) with increased levels of crab waste-straw silage. Nitrogen retention increased linearly ($p<0.05$) with increased levels of crab waste-straw silage.

* The research was supported, in part, by Harmon Products, Inc., Chesapeake, VA.

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Received January 16, 2008; Accepted October 27, 2008

Table 1. Composition of mixed protein supplements[a,b]

Ingredient	Protein supplement[c]		
	IPA	ESA	HESA
	%		
Ground corn grain	17.50	-	-
Wheat middlings	31.50	-	-
Corn gluten meal	8.75	-	-
Distillers dried grains	5.00	-	-
Feather meal	-	73.20	73.20
Blood meal	8.75	9.15	9.15
Megalac®[d]	20.00	-	-
Fat[e]	-	9.15	9.15
Sodium bicarbonate	5.00	5.00	5.00
Monoammonium phosphate	2.50	2.50	2.50
Yea-sacc[f]	0.50	0.50	0.50
Niacin[g]	0.30	0.30	0.30
Dairy flavor[h]	0.15	0.15	0.15

[a] As fed basis. [b] Harmony Products Inc., Chesapeake, VA.
[c] IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.
[d] Ca salts of palm oil fatty acids, Church and Dwight Co., Inc., Princeton, NJ.
[e] Mixture of animal and plant fats. [f] Alltech Inc., Nicholasville, KY.
[g] 2767 mg/kg. [h] Feed Flavors, Inc., Oregon, WI.

An experiment was conducted to determine digestibility, N balance, and Ca and P metabolism in lambs fed crab meal and other protein supplements.

MATERIALS AND METHODS

Two metabolism trials were conducted, each with 24 wether lambs (1/2 Dorset, 1/4 Finn, 1/4 Rambouillet, avg. BW, 25 kg), aged 4-6 mo. In each trial, the lambs were allocated into three blocks of eight according to BW, and were randomly allotted within blocks to eight experimental diets containing the following supplements: i) none, negative control (NC); ii) soybean meal (SBM) control; iii) supplement based on industrial byproducts of both plant and animal origin (IPA); iv) experimental supplement based on byproducts of animal origin (ESA); v) hydrolyzed supplement No 4. (HESA); vi) commercial supplement based on animal protein (CS), Pro-Lak®; vii) crab meal (CM); and viii) urea (U). The hydrolyzed supplement No 3 (HESA) was processed in a high intensity mixer and hydrolyzed under basic conditions at 110°C at atmospheric pressure for approximately 10 min. Protein supplements, IPA, ESA, and HESA, were obtained from Harmony Products Inc. Chesapeake, Virginia. The commercial supplement (CS) is manufactured and marketed as Pro-Lak® by H. J. Baker and Bro. Inc., New York, NY, USA. Crab meal was obtained from Graham and Rollins, Hampton, Virginia. The mixed protein supplements, IPA, ESA, and HESA were formulated as shown in Table 1. A period of five days was provided between the trials. In randomizing the lambs for the second trial the lambs were not allowed to receive the same supplement as in the first trial. The ingredient and chemical composition of different experimental diets are presented in Table 2 and 3, respectively. Diets were isonitrogenous (9.8%, CP) and isocaloric (58%, calculated TDN) on a DM basis, except for the negative control diet in which the CP was 6.5%. Lambs were kept in metabolism stalls similar to those described by

Table 2. Ingredient composition of experimental diets fed to sheep[a]

Item	Supplement[b]							
	NC	SBM	IPA	ESA	HESA	CS	CM	U
	%							
Hay	45.9	45.9	45.9	45.9	45.9	45.9	45.9	45.9
Cottonseed hulls	33.0	31.0	28.2	29.0	30.2	31.7	27.7	30.5
Glucose[c]	9.3	3.9	-	7.8	6.3	6.5	6.5	10.4
SBM	-	7.5	-	-	-	-	-	-
IPA	-	-	15.1	-	-	-	-	-
ESA	-	-	-	4.9	-	-	-	-
HESA	-	-	-	-	5.4	-	-	-
CS	-	-	-	-	-	4.5	-	-
CM	-	-	-	-	-	-	9.4	-
Urea	-	-	-	-	-	-	-	1.3
Corn grain	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dicalcium phosphate	0.8	0.6	-	0.5	0.3	0.4	-	0.8
Limestone	0.5	0.6	0.3	0.6	0.6	0.5	-	0.6
Vit.-min. premix[d]	-	-	-	0.8	0.8	-	-	-

[a] DM basis.
[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.
[c] Cerelose, Corn Products, Summit-Argo, IL. [d] Custom additive premix, Formulated by Wilson Enterprises, Disputana, VA.

Table 3. Chemical composition of experimental diets fed to sheep[a]

Component	Supplement[b]							
	NC	SBM	IPA	ESA	HESA	CS	CM	U
	%							
Dry matter	90.1	89.9	90.1	90.1	90.1	90.0	90.2	89.8
Organic matter	93.9	93.5	93.2	93.4	92.4	93.9	91.3	94.0
Crude protein	6.5	9.8	9.7	9.9	10.0	9.9	9.9	10.1
RUP (%CP)[c]	28.0	36.6	50.1	55.0	51.7	52.7	45.4	28.0
ADF	40.8	40.6	38.3	39.3	39.3	40.1	39.3	39.1
Cellulose	33.7	33.5	31.9	32.0	32.4	33.2	31.7	32.4
Calcium	0.62	0.63	0.69	0.68	0.66	0.66	1.34	0.64
Phosphorus	0.34	0.31	0.29	0.33	0.34	0.33	0.31	0.32

[a] DM basis, except for DM.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c] RUP = Rumen undegraded CP; based on measured ruminal escape N content of protein supplements and reported values for other ingredients.

Briggs and Gallup (1949) designed for separate collection of feces and urine. All animals were treated with Ivomec® (1 ml/50 kg BW, s.c.; MSD, Division of Merck and Co., Inc., Rahway, New Jersey) for internal parasites and were given 500,000 IU of vitamin A and 75,000 IU of vitamin D, i.m. before starting the first trial.

Metabolism trials consisted of 7 d adaptation, 2 d transition, 10 d preliminary, and 10 d collection periods. Each lamb was fed 700 g feed daily in equal portions at 12 h intervals at 08:00 h and 20:00 h. Proportionate quantities of grass hay, cottonseed hulls, and concentrate (combination of other ingredients of the respective diets) were weighed separately for each lamb at each feeding. Water was provided throughout the trials except during the two 2 h feeding periods. Samples of feed (hay, cottonseed hulls, and concentrate) were collected beginning 2 d prior to start of the trial until 2 d prior to the end of the trial. At the end of each trial, the feed samples (10 d) were composited, subsampled and ground through 1 mm mesh in a Wiley mill (Thomas Wiley, Laboratory Mill Model 4, Arthur H. Thomas Co., Philadelphia, PA) for chemical analysis.

Procedures for collection and sampling of excreta were as described by Bhattacharya and Fontenot (1965). At the end of the trial, ruminal fluid samples were collected 2 h post feeding using a stomach tube and vacuum pump. Ruminal fluid was strained through eight layers of cheese cloth and pH was measured immediately using a portable pH meter (Accumet® Mini pH Meter, Model 640A, Fisher Scientific Company). Samples (5 ml each) for VFA and NH_3 N determination were collected in 15 ml tubes containing 1 ml of 25% metaphosphoric acid or one drop of sulfuric acid, respectively. Blood was drawn by jugular venipuncture from all wethers 6 h after feeding and was centrifuged at 1,800×g for 15 min and serum was separated. Urea N in serum was determined in an Autoanalyzer, Centrifichem® System 500, using blood urea N (BUN) (Rate) reagent, Sigma Diagnostic, St. Louis, MO. Care and handling of the animals was approved by the VA Tech Animal Care Committee.

Feed components and feces were analyzed for DM and ash (AOAC, 1990), Ca (atomic absorption Spectrophotometer, Perkin Elmer 5100 PC, Norwalk, CT), P (colorimetric method of Fiske and Subbarow, 1925), ADF (Van Soest, 1963), and cellulose (Van Soest and Wine, 1968). Feed, fecal and urinary N were determined by the Kjeldahl method (AOAC, 1990). Ruminal NH_3 N was determined by the method described by Beecher and Whitten (1970). Volatile fatty acid analyses were performed by gas chromatography (Varian Vista 6,000 gas Chromatograph, column packed with 10% SP-1200/10% H_3PO_4 on 80/100 chromosorb WAW). The detector, column, and inlet temperatures were 175, 125, and 180°C, respectively. Sample VFA concentrations were determined by integration, using a VFA standard containing acetic (51.66 μmol/ml), propionic (30.63 μmol/ml), butyric (10.4 μmol/ml), valeric (5.18 μmol/ml), isobutyric (4.96 μmol/ml), and isovaleric (4.95 μmol/ml) acids.

Statistical analysis

All data are presented as least squares means. Data were analyzed using the GLM procedure of SAS (1989). All parameters were subjected to the design shown in the model which included trial, block, and diet.

Model: Randomized block design

$$Y_{ijk} = \mu + b_i + d_j + t_k + e_{ijk}$$

where,

Y_{ijk} = observation of wether in the i^{th} block given j^{th} diet

μ = unknown constant

b_i = effect of i^{th} block, where i = 1, 2, ...6.

d_j = effect of j^{th} diet, where j = 1, 2,....8

Table 4. Apparent digestibility by sheep fed experimental diets[a]

Item	Supplement[b]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
DM	57.02^{c}	61.46^{de}	62.52^{e}	61.76^{de}	60.09^{cde}	61.06^{de}	59.68^{cde}	58.85^{cd}	0.68
OM	57.79^{c}	62.17^{def}	62.98^{f}	62.51^{ef}	60.56^{de}	61.88^{def}	61.42^{def}	60.03^{d}	0.67
ADF	40.47^{c}	45.66^{ef}	46.03^{f}	44.95^{def}	43.87^{def}	43.46^{cdef}	42.61^{cde}	42.38^{cd}	1.00
Cellulose	52.87^{c}	57.61^{f}	57.38^{f}	56.74^{ef}	53.96^{cde}	55.91^{def}	55.55^{cdef}	53.83^{cd}	0.91
CP	28.19^{c}	50.96^{e}	51.58^{e}	48.95^{e}	41.15^{d}	48.37^{e}	48.26^{e}	52.34^{e}	0.94

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d, e, f] Numbers in the same row with different superscript letters differ ($p<0.05$).

t_k = effect of k^{th} trial, where k = 1 and 2

$e_{ijk} = Y_{ijk}-(\mu+b_i+d_j+t_k)$ is the experimental error of the observation of the sheep randomly allotted to diet j in block i in trial k.

Tukey's Studentized Range (HSD) Test was used for comparing the treatments for different variables.

RESULTS

Apparent digestibility

Apparent digestibility of DM ranged from 57.0 to 62.5% across diets (Table 4). The lowest numerical value for DM digestibility was for the lambs fed the diet with no supplemental N, which was lower ($p<0.05$) than values for diets supplemented with SBM, IPA, ESA and CS. The lower digestibility of DM for lambs fed the diet with no supplemental N might be due to lower microbial activity in the rumen.

Apparent digestibility of OM was in the range of 57.8 to 63.0% and the pattern was similar to that of DM digestion. Digestibility of OM was lower at ($p<0.05$) for the negative control diet than for the other diets. The value of the IPA supplemented diet was higher ($p<0.05$) than the diets supplemented with HESA and U. Values for the diets supplemented with SBM, ESA, CS, and CM were intermediate.

Trends for ADF and cellulose digestibilities were similar to the OM digestibility. Apparent digestibility of ADF ranged between 40.5 and 46.0%, and that of cellulose was from 52.9 to 57.6%.

Nitrogen utilization

Nitrogen intake was lower for the sheep fed no supplemental N and intake was similar for the lambs fed the supplements (Table 5). The highest ($p<0.05$) fecal N excretion was for the lambs fed HESA supplement (5.82 g/d) which shows that N that passed to the lower gut was not digested as efficiently as that of other supplements. Lowest fecal N excretion was for the lambs fed no supplemental N (which was a reflection of low N intake) and IPA supplement. Sheep fed ESA, CS, and CM had higher ($p<0.05$) fecal N excretion compared to those fed IPA and no supplemental N. This showed that N of IPA, which is a combination of plant protein and BM, was more digestible than that of FTM-BM combination (ESA) and the other animal protein-based supplements.

Table 5. Nitrogen balance by sheep fed different diets[a]

Item	Supplement[a]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
Intake (g/d)	6.51	9.80	9.65	9.96	9.88	9.88	9.81	10.08	-
Excretion (g/d)									
Fecal	4.67^{c}	4.80^{cd}	4.66^{c}	5.08^{d}	5.82^{e}	5.10^{d}	5.08^{d}	4.80^{cd}	0.09
Urinary	2.05^{c}	4.28^{e}	3.90^{dc}	3.61^{d}	3.71^{dc}	3.57^{d}	3.76^{de}	4.90^{f}	0.13
Total	6.72^{c}	9.08^{def}	8.56^{d}	8.69^{d}	9.53^{ef}	8.67^{d}	8.86^{dc}	9.70^{f}	0.16
Apparent absorption									
g/d	1.84^{c}	4.99^{ef}	4.99^{ef}	4.88^{ef}	4.07^{d}	4.78^{e}	4.74^{e}	5.28^{f}	0.09
% of intake	28.19^{c}	50.96^{e}	51.58^{e}	48.95^{e}	41.15^{d}	48.37^{e}	48.26^{e}	52.34^{e}	0.94
Retention									
g/d	-0.21^{c}	0.71^{de}	1.09^{de}	1.27^{e}	0.36^{cd}	1.21^{e}	0.95^{de}	0.38^{cd}	0.16
% of intake	-3.35^{c}	7.26^{de}	11.15^{de}	12.73^{e}	3.64^{cd}	12.20^{e}	9.64^{de}	3.75^{cd}	1.75
% absorbed	-20.40^{c}	14.21^{d}	20.02^{d}	25.56^{d}	8.35^{d}	25.06^{d}	18.66^{d}	6.23^{d}	5.58

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d, e, f] Numbers in the same row with different superscript letters differ ($p<0.05$).

Table 6. Ruminal volatile fatty acids of sheep fed the different protein supplement diets[a]

Item	Supplement[b]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
Total VFA									
μmol/ml	49.54^{c}	54.65^{cd}	58.02^{cd}	47.26^{c}	51.57^{cd}	49.79^{c}	65.70^{d}	55.19^{cd}	3.42
mol/100 mol									
Acetate	60.66^{c}	65.84^{de}	69.30^{e}	63.41^{cd}	67.03^{de}	64.04^{cd}	65.98^{de}	59.93^{c}	1.13
Propionate	29.32^{cd}	21.31^{e}	19.75^{e}	25.71^{cde}	23.43^{cde}	26.15^{cde}	22.39^{de}	30.10^{e}	1.60
Isobutyrate	0.40^{cd}	0.61^{ef}	0.65^{f}	0.47^{cde}	0.52^{def}	0.50^{def}	0.47^{cde}	0.33^{e}	0.04
Butyrate	8.57	10.56	8.68	8.93	8.15	7.81	9.66	8.58	0.86
Isovalerate	0.49^{cd}	0.94^{e}	0.89^{e}	0.79^{cde}	0.76^{cde}	0.84^{de}	0.69^{cde}	0.44^{c}	0.08
Valerate	0.60	0.78	0.77	0.73	0.71	0.69	0.73	0.65	0.04
Acetate/propionate	2.16^{c}	3.14^{de}	3.56^{e}	2.49^{cd}	2.94^{cde}	2.52^{cd}	3.02^{cde}	2.09^{c}	0.21

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d, e, f] Numbers in the same row with different superscript letters differ ($p<0.05$).

Apparent absorption of N ranged between 28.2 to 52.3%. Expressed as g/d or as percent of intake, apparent absorption was lowest ($p<0.05$) for the sheep fed no supplemental N. There were no differences in apparent absorption of N for the sheep fed different protein supplements except for those fed HESA supplement, which was lower ($p<0.05$) than the others. Feeding the HESA supplement depressed the N absorption by 19.2% when compared with that of SBM-fed animals.

Highest ($p<0.05$, 4.90 g/d) urinary N excretion was for the lambs fed U and the lowest ($p<0.05$, 2.05 g/d) was for those fed no supplemental N. Wethers fed the ESA and CS supplemented diets had lower ($p<0.05$) urinary N excretion than those fed the SBM supplemented diet (4.28 g/d). A negative N balance was observed for lambs fed no supplemental N, which was lower ($p<0.05$) compared to all other experimental groups, except U and HESA. This indicated that a considerable amount of N was mobilized from body tissues. Higher ($p<0.05$) N retentions (percent of intake) were observed in lambs fed ESA and CS (12.7% and 12.2%, respectively) compared to those fed U, NC, and HESA diets. Sheep fed IPA, CM, and SBM had intermediate values. Retention of N was numerically higher for wethers fed CM compared to those fed the SBM supplemented diet.

Ruminal and blood parameters

Total VFA ranged from 47.3 to 65.7 μmol/ml (Table 6). Sheep fed CM had higher ($p<0.05$) total VFA (65.7 μmol/ml) compared to those fed no supplement, ESA and CS. Acetate proportions were higher ($p<0.05$) in wethers fed IPA, compared to those fed NC, ESA, CS and U diets. Wethers fed the U diet had higher ($p<0.05$) propionate proportions, compared to those fed CM, IPA and SBM supplements.

The ruminal pH of sheep fed different experimental diets averaged 6.38 (Table 7). There were no differences in ruminal pH for sheep fed different experimental diets. Highest ($p<0.05$) ruminal NH_3 N values were observed for sheep fed the U supplement, and sheep fed no supplemental N, numerically, had the lowest NH_3 N. Ruminal NH_3 N for sheep fed SBM, CS, and CM were higher ($p<0.05$) than those not fed a N supplement.

Blood urea N of sheep fed different experimental diets ranged from 3.06 to 10.67 mg/dl (Table 7). The BUN for the sheep fed no supplemental N was lower ($p<0.05$) than the value for those fed U supplement (10.7 mg/dl). The values for the other supplements were intermediate. The same trend as in BUN was observed in ruminal NH_3 N.

Ca and P metabolism

Calcium intake was higher for the lambs fed CM

Table 7. Blood urea nitrogen, and rumen pH and ammonia nitrogen of sheep fed experimental diets[a]

Item	Supplement[b]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
Ruminal pH	6.42^{c}	6.39^{c}	6.41^{c}	6.35^{c}	6.24^{c}	6.30^{c}	6.38^{c}	6.52^{c}	0.07
Ruminal NH_3-N (mg/dl)	7.66^{c}	17.58^{d}	14.17^{de}	12.75^{de}	14.45^{de}	15.36^{d}	16.13^{d}	29.59^{e}	1.52
Blood urea-N (mg/dl)	3.06^{a}	7.14^{dc}	6.50^{de}	5.61^{de}	5.18^{de}	6.25^{dc}	6.46^{dc}	10.67^{e}	0.75

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d, e] Numbers in the same row with different superscripts differ ($p<0.05$).

Table 8. Calcium balance by sheep fed different protein supplements[a]

Item	Supplement[b]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
Intake (g/d)	3.86	3.96	4.35	4.22	4.07	4.11	8.42	3.90	
Excretion (g/g)									
Fecal	3.80^{c}	3.62^{c}	3.84^{c}	3.72^{c}	3.79^{c}	3.73^{c}	7.99^{d}	3.80^{c}	0.10
Urinary	0.03^{c}	0.06^{c}	0.03^{c}	0.05^{c}	0.04^{c}	0.04^{c}	0.08^{c}	0.06^{c}	0.02
Total	3.83^{c}	3.68^{c}	3.87^{c}	3.77^{c}	3.83^{c}	3.77^{c}	8.07^{d}	3.86^{c}	0.10
Apparent absorption									
g/d	0.06^{c}	0.34^{d}	0.51^{d}	0.50^{cd}	0.28^{cd}	0.38^{cd}	0.43^{cd}	0.10^{cd}	0.10
% of intake	1.55^{c}	8.51^{cd}	11.99^{d}	11.80^{d}	6.86^{cd}	9.18^{cd}	5.03^{cd}	2.49^{cd}	2.18
Retention									
g/d	0.03^{c}	0.28^{cd}	0.48^{d}	0.45^{cd}	0.24^{cd}	0.34^{d}	0.35^{cd}	0.04^{c}	0.10
% of intake	0.77^{c}	7.03^{cd}	11.26^{d}	10.65^{cd}	5.91^{cd}	8.25^{cd}	4.04^{cd}	1.03^{c}	2.19
% of absorbed	50.00	76.58	91.42	86.84	78.07	89.83	69.94	40.00	

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d] Numbers in the same row with different superscript letters differ ($p<0.05$).

Table 9. Phosphorus absorption by sheep fed experimental diets[a]

Item	Supplement[b]								SE
	NC	SBM	IPA	ESA	HESA	CS	CM	U	
Intake (g/d)	2.05	1.95	1.81	2.05	2.12	1.99	1.95	1.96	
Excretion (g/d)									
Fecal	1.94^{c}	1.62^{def}	1.50^{ef}	1.74^{cdef}	1.79^{cde}	1.44^{f}	1.45^{f}	1.85^{cd}	0.07
Apparent absorption/retention[g] (g/d)	0.11^{c}	0.33^{cd}	0.31^{cd}	0.32^{cd}	0.33^{cd}	0.56^{d}	0.50^{d}	0.11^{c}	0.07
% of intake	5.26^{c}	16.83^{cd}	17.12^{cd}	15.61^{cd}	15.55^{cd}	27.88^{d}	25.03^{d}	5.49^{c}	3.46

[a] Each value represents the mean of six sheep.

[b] SBM = Soybean meal, control; IPA = Supplement based on industrial byproducts of both plant and animal origin; ESA = Experimental supplement based on byproducts of animal origin; HESA = Hydrolyzed supplement No 3.; CS = Commercial supplement based on animal protein; and CM = Crab meal.

[c, d, e, f] Numbers in the same row with different superscript letters differ ($p<0.05$).

[g] Phosphorus in urine was not in a detectable range, hence the value of absorption may be considered as retention could not be detected.

supplement, and intake was similar for the lambs fed the other supplements (Table 8). Fecal excretion was highest ($p<0.05$) for lambs fed CM, a reflection of higher intake. Urinary Ca excretion was low for the lambs fed all supplements with no difference among the different supplements. Apparent absorption of Ca was lower for lambs fed no supplement, compared to those fed SBM and IPA. Among sheep fed protein-supplemented diets, Ca absorption was similar. Retention of Ca was lower ($p<0.05$) for sheep fed diets supplemented with U or no supplemental N, compared to those fed IPA.

The fecal P excretion in sheep fed CS and CM was lower ($p<0.05$) than for those fed HESA, U, and no supplemental N (Table 9). Excretion of P for sheep fed no supplemental N was higher ($p<0.05$) than for those fed SBM, IPA, CS, and CM supplements. The absorption of P for the sheep fed CS and CM was higher than for lambs fed U and no supplemental N. The values for sheep fed diets supplemented with SBM, IPA, ESA, and HESA were intermediate.

DISCUSSION

Results of the present study agree with the findings of Christensen et al. (1993) who did not observe any differences in DM digestibility when protein with low ruminal degradability (55%) was fed as the sole supplemental protein, compared to a high ruminally degradable protein (70%). Tiwari et al. (2000) reported no differences in digestibilities of DM, OM, CP and ADF in buffalo calves fed untreated or formaldehyde-treated ground nut cake or fish meal. However, formaldehyde treatment of cottonseed meal increased digestibility and N balance in lambs (Khan et al., 2008). Liu et al. (1993) suggested that formaldehyde treatment could improve efficiency of protein utilization of rapeseed meal and cattle performance. Blasi et al. (1991) reported that DM digestibility of the BM diet was higher than that of the SBM and urea diets. In that same study, the DM digestibility of the diet containing FTM hydrolyzed for 18 min was greater than that of the diet containing FTM hydrolyzed for 10 min and slightly higher

than that of the diet containing FTM hydrolyzed for 12 and 15 min. Stock et al. (1981) reported that lambs fed a urea control diet had lower ($p<0.05$) DM digestibility than lambs fed SBM-urea, BM-urea, or CGM-SBM-urea supplemented diets. In contrast, Goedeken et al. (1990) detected no differences ($p>0.20$) in DM digestibilities when lambs were fed urea, SBM, BM, FTM or CGM supplemented diets.

Keery et al. (1993) found that whole tract digestibilities of OM were not influenced by supplemental protein sources (SBM, heated SBM, menhaden FM). Ludden and Cecava (1995) did not observe any difference in total tract OM digestibility for diets supplemented with BM compared to SBM, urea and SoyPLUS® - a high ruminal escape SBM. These results agree in part with the results of the present study. When cows were fed a diet supplemented with CGM, Klusmeyer et al. (1990) did not find any decrease in digestibilities of OM, starch, NDF, and ADF compared to those fed a SBM supplemented diet. Hussein et al. (1991) suggested that replacing high ruminally degradable protein sources in the diets may improve ruminal fiber digestion. Contradictory to the above findings, McAllan and Griffith (1987) reported that ruminal fiber digestion was inversely related to ruminal protein degradation when diets containing casein, SBM, or FM were fed to steers.

In the present study, the CM supplemented diet was comparable with other protein-supplemented diets with regard to DM and OM digestibilities. These results are not in agreement with the results obtained by Velez et al. (1991). They reported that DM digestibility of a diet supplemented with CM was lower ($p<0.05$) than for a diet supplemented with SBM.

Total N excretion was highest in lambs fed U supplement, which was higher ($p<0.05$) than for those fed IPA, ESA, CS, and CM. This is probably a reflection of the lower efficiency of N utilization of urea. Sheep fed urea had lower ($p<0.05$) N retention (3.8%) compared to ESA and CS fed sheep (12.7 and 12.2%, respectively). These results agree with those reported by Cecava and Hancock (1994) who observed higher urinary excretion of N in steers fed a urea diet compared to a SBM-FTM combination. In the present study, generally, when the level of ruminal NH_3 N increased, there was a proportional increase in BUN. These results are in agreement with the results of Thomas et al. (1984).

Our results agree in part with those of Ayangbile (1989) who reported that total VFA and acetate tended to be higher for sheep fed 50% crab waste-silage compared to those fed a basal diet without crab waste. Ayangbile (1989) observed lower propionate, butyrate, and isovalerate concentrations for the sheep fed 50% crab waste-silage diet, compared with those fed a basal diet without crab waste. Khorasani et al. (1994) reported lower ($p<0.06$) ruminal concentrations of propionate, isobutyrate and valerate when cows were fed slowly degradable protein sources (FM, CGM, and MM) substituted for rapidly degradable protein sources (canola meal and SBM). In the present study, the ratio of acetate to propionate was lower ($p<0.05$) in sheep fed U and NC diets compared with those fed the SBM and IPA diets. Keery et al. (1993) found that the concentration of acetate was higher ($p<0.10$) in steers fed a SBM diet (96.8 m*M*/L) than those fed heated SBM, menhaden FM, and a combination of protein sources.

The results of the present study concerning pH agree with the results of several studies conducted with protein supplements (Titgemeyer et al., 1989; Seymour et al., 1992; Schloesser et al., 1993; Cozzi and Polan, 1994). A higher pH has been reported for sheep fed crab waste-straw silage, compared to a diet without crab waste (Ayangbile, 1989).

Our results concerning ruminal NH_3 N agree with the results reported by Khorasani et al. (1994). In the present study, ruminal NH_3 N concentrations observed in all the diet treatments were higher than the minimum (5 mg/dl) reported to be essential for optimum ruminal microbial growth (Satter and Slyter, 1974). Satter and Roffler (1975) reported that under normal feeding conditions this minimum level of 5 mg/dl rumen fluid will be achieved with a dietary CP between 11 and 14% in the diet DM.

CONCLUSIONS

Protein digestibilities of diets supplemented with experimental supplement based on feather meal and blood meal; supplement based on animal protein (Prolak®); supplement based on plant protein and blood meal; and crab meal are comparable with that of SBM supplemented diets. The hydrolyzed experimental supplement (HESA) was lower in value than all other protein supplements tested. Nitrogen utilization by sheep fed the protein supplements except HESA compare favorably to that of sheep fed soybean meal.

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