EFFECT OF SOYBEAN EXTRUSION ON NITROGEN METABOLISM, NUTRIENT FLOW AND MICROBIAL PROTEIN SYNTHESIS IN THE RUMEN OF LAMBS

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Summary

Soybeans were dry extruded at three different temperatures (125, 135 and 145℃) for 30 s. Four lambs fitted with cannulae in the rumen and abomasum were used in a balanced 4 × 4 Latin square design. Lambs were fed at 2 h intervals for 12 times a day with automatic feeder to maintain steady state conditions in digestive tract. A dual-phase marker system was used to estimate ruminal flow rate of both liquid and solid digesta. Objectives of this study were to determine the effect of extrusion temperature of raw soybean on the ruminal liquid and solid dilution rate, nitrogen digestion and flow at the abomasum and availability of amino acid in lambs.

There were no significant effects of extrusion on liquid and solid dilution rate, and liquid volume. Ruminal liquid flow rate was not influenced by extrusion and ranged from 389 to 435 ml/hr. Extrusion had no influence on ruminal OM digestion and flow rate to the abomasum. Dietary N flow to the abomasum increased ($p < 0.05$) as extruding temperature increased. Extruding temperature had a significant effect ($p < 0.05$) on flow of N escaping ruminal degradation and ranged from 34.91 to 57.38%. Microbial N synthesized/kg OMTDR ranged from 27 to 37 g and highest with 145℃ ESB diet. Extrusion decreased the amount of degradable amino acid in the rumen and increased the supply of amino acid to the lower gut, especially with 135 and 145℃ ESB diets.

(**Key Words**: Soybean Extrusion, Dual-Phase Marker, Dilution Rate, Flow Rate, Lamb)

Introduction

Although oilseed meals have been studied extensively as nitrogen sources for ruminant, the use of full fat oil seeds for energy sources has received little attention. Raw soybean can be a good source of both protein and energy for ruminants, however, several antinutritional factors appear to limit its use in the ruminant feed.

Extrusion can destroy antinutritional factors in soybean such as trypsin inhibitor (Mielke and Schingoethe, 1981), and reduce the solubility and degradability of protein in the rumen (Keele et al., 1989; Stern et al., 1985). In general, N utilization and the performance of ruminants are improved by feeding extruded soybean. Although soybean seeds are generally too expensive for cattle, circumstances could arise where soybean seed would be economically available.

However, relatively little is known about an optimal extruding condition for subsquent amino acid availability in the intestine. Ruminal escape of extruded protein has been proven in many studies, but a limited amount of studies on the effect of extruding on intestinal amino acid supply in ruminants has been conducted due to the difficulties of using animals surgically prepared with cannulae at lower gut (Stern et al., 1985).

Objectives of this study are to determine the effect of extrusion temperature of raw soybean on the protein degradation in the rumen, nitrogen digestion and flow at the abomasum and availability of amino acid in lambs.

Materials and Methods

Operational condition of extrusion treatment

Soybeans were dry extruded at three different temperatures (125, 135 and 145℃) for 30 seconds using the Instra Pro Dry Exturder 2,000 R (Triple

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Extruding conditions with the Instra Pro Dry Extruder were as follows; screw speed, 500 rpm; feed moisture content, 12%; barrel temperatures, 125, 135 and 145℃; diameter, 5/8"; high shear screw design.

Experimental animal and design

Four weather lambs (Corridale) weighting an average of 45 kg were used in a balanced 4 × 4 Latin square design with 29-d periods to determine the effect of extruding soybean on ruminal nitrogen metabolism and nutrient flow. Lambs were fitted with cannulae in the rumen and abomasum adjacent to the pylorus and maintained in metabolism cages in a temperature controlled building (15℃) with continuous light. Water and mineral block left available at all times. Lambs were fed equal portions of diet at 2 h intervals for 12 times a day with automatic feeders to maintain steady state conditions in digestive tract.

Experimental diets

Complete diets were formulated to be isonitrogenous and isocaloric, and composed of 55.3% corn, 13% soybean sources, 30% roughages and 1.7% supplements formulated to meet NRC (1985) requirements (table 1). The roughages used were beet pulp (15%) and NaOH treated rice straw pellet (15%). Chemical composition and amino acid contents of experimental diets are presented in table 2 and 3. Soybean protein sources were provided approximately 45% of the total dietary protein. Each lamb was fed 840 g of dry matter daily, representing approximately 1.8% of body weight.

Marker preparation and infusion

A dual-phase marker system was used to estimate abomasal and ruminal flow rate of both solid and liquid digesta. Chromic oxide (Cr_2O_3) was used as a solid marker and was mixed with experimental diets in an amount to provide a dietary concentration of 0.2%. Cr_2O_3 was fed during the entire adaptation period to ensure uniform mixing with digesta.

^{14}C-Fe-ethylene diamine tetra acetic acid (^{14}C-Fe-EDTA) was used as a liquid marker and was prepared according to Harrison (1974).

The administration of liquid marker was as follows; To ensure established steady state condition a prime dose (50 ml) of ^{14}C-Fe-EDTA solution (7.78 μCi/100 ml) was injected into the rumen. Following the prime dose, a continuous intra-ruminal infusion of the marker solution started and maintained for 5 days. Infusion stopped and rumen samples were taken for the determination of rumen liquid dilution rate.

TABLE 1. FORMULA OF EXPERIMENTAL DIETS (%)

Ingredient	Raw soybean	Extruded soybean		
		125℃	135℃	145℃
Corn, yellow	55.3	55.3	55.3	55.3
Whole soybean	13.0	–	–	–
ESB at 125℃	–	13.0	–	–
ESB at 135℃	–		13.0	–
ESB at 145℃	–	–	–	13.0
Tricalcium phosphate	0.9	0.9	0.9	0.9
Limestone	0.3	0.3	0.3	0.3
Salt	0.3	0.3	0.3	0.3
Vitamin mineral mixture[1]	0.2	0.2	0.2	0.2
NaOH treated rice straw	15.0	15.0	15.0	15.0
Beet pulp	15.0	15.0	15.0	15.0
Cr_2O_3	0.2	0.2	0.2	0.2

[1] Composition (per kg): Vit. A, 4,000,000 IU; Vit. D_3, 800,000 IU; Vit. E, 4,000,000 IU; Mn, 8,000 mg; Cu, 4,000 mg; Fe, 4,000 mg; I, 200 mg; Se, 80 mg; Zn, 8,000 mg; Co, 160 mg; Antioxidant, 2,000 mg.

TABLE 2. CHEMICAL COMPOSITION OF EXPERIMENTAL DIETS (%)

Item	Raw soybean	Extruded soybean		
		125℃	135℃	145℃
Dry matter	90.84	88.79	88.71	87.67
Crude protein	12.72	12.07	12.89	12.54
Ether extract	4.41	4.72	4.52	4.73
Crude ash	6.78	6.96	6.98	6.91
NDF	31.08	39.07	34.75	33.55
ADF	13.27	13.15	12.76	13.49
Cellulose	11.27	10.65	9.55	8.13
Lignin	1.62	1.72	1.62	1.74
Silica	1.15	1.34	1.37	1.41
Ca	0.62	0.62	0.62	0.62
P	0.39	0.39	0.39	0.39

TABLE 3. AMINO ACID CONTENTS OF EXPERIMENTAL DIETS (mg / 100 mg DM)

Amino acid	Raw soybean	Extruded soybean		
		125℃	135℃	145℃
Essential				
Arg	0.853	0.864	0.816	0.755
His	0.768	0.688	0.734	0.678
Ile	0.541	0.529	0.552	0.503
Leu	1.057	1.125	1.105	1.169
Lys	0.800	0.780	0.740	0.627
Met	0.163	0.193	0.160	0.174
Phe	0.716	0.631	0.588	0.575
Thr	0.412	0.457	0.459	0.425
Val	0.680	0.770	0.795	0.764
Sub total	5.990	6.037	5.949	5.781
Non essential				
Ala	0.645	0.730	0.729	0.698
Asp	1.129	1.126	1.131	1.077
Cys	0.262	0.319	0.302	0.293
Glu	1.978	2.102	2.129	2.028
Gly	0.534	0.570	0.556	0.513
Ser	0.551	0.581	0.590	0.538
Tyr	0.416	0.450	0.439	0.414
Sub total	5.515	5.878	5.876	5.566
Total	11.506	11.915	11.825	11.347

Experimental period and procedure

The experimental protocol is outlined in table 4. Experiment lasted for 29 d and consisted of 10 d adjustment, 6 d excreta collection and 13 d digesta sampling period. On day 19-20, solid marker was excluded from the diet and ruminal digesta were taken for determination of solid dilution rate and ruminal liquid volume.

During a continuous infusion of liquid marker

TABLE 4. PROTOCOL FOR MARKER INFUSION AND SAMPLING

Day	Sampling	Marker infusion
1-10	Preliminary periods	Solid marker dose
11-16	Collection of feces and urine for 6 days	
16-17	Collection of abomasal digesta for 2 days, 6 hr interval	
18	Collection of rumen digesta for 1 day, 6 hr interval	
19-20	Collection of rumen digesta for 2 days (2, 4, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48 hr)	Solid marker stop at 09:00
21-27		Liquid marker infusion
26	Collection of abomasal digesta for 1 day, 6 hr interval	
27	Collection of rumen liquid for 1 day, 6 hr interval	
28-29	Collection of rumen liquid for 2 days (2, 4, 6, 8, 10, 12, 16, 20, 24, 32, 40, 48 hr)	Infusin stop at 09:00

for 6 days, abomasal digesta were taken at 6 h interval for digesta flow determination on day 26. Liquid maker infusion was stopped and ruminal liquid samples were taken to determine ruminal liquid dilution rate.

Preparation of rumen bacteria and abomasal digesta

Ruminal fluid was strained through four layers of cheese cloth and pH was measured. Ruminal bacteria was isolated by differential centrifugation as described by Santos et al. (1984). Rumen fluid was centrifuged at 500 × g for 10 min to remove feed particles and protozoa, and bacteria were isolated by centrifuging the supernatant at 20,000 × g for 20 min. After washing twice with saline and distilled water to remove rumen fluid, bacterial pellet was freeze-dried. Amino acid, diaminopimelic acid (DAPA) and chemical composition of the isolated bacteria were analyzed.

Whole abomasal digesta taken for flow rate measurements was composited, freeze dried and ground for analysis.

Determination of ruminal dilution rate and flow rate

The decline in Cr and ^{14}C was plotted in [Cr] versus time (t) and ln [^{14}C] versus time (t) (Uden et al., 1980). Ruminal dilution rate of liquid and solid digesta were determined as regressions of the natural logarithms of ^{14}C or Cr concentration on time (Faichney, 1975). Liquid volume was estimated from the total marker dosed divided by the antilog of the Y-intercept. Abomasal nutrient flow was calculated according to Faichney (1980) using whole abomasal digesta and liquid-phase abomasal digesta marker concentration of both Cr and ^{14}C to estimate solid and liquid flow, respectively.

Bacterial N synthesized in the rumen was estimated from the amount of DAPA passing to the abomasum. The proportion of bacterial N in the abomasal total N was estimated according to Smith et al. (1978) as follows;

$$\frac{\text{N (bacteria)}}{\text{DAPA (bacteria)}} \times \frac{\text{DAPA (abomasal digesta)}}{\text{N (abomasal digesta)}}$$

Analytical procedure

Chemical composition of experimental diet and digesta

Proximate chemical compostion of feed and digesta was determined by procedures of AOAC (1984). Cell wall constituents, NDF, ADF, cellulose, and lignin were analyzed according to Goering and Van Soest (1970).

Ruminal fluid

Rumen samples were immediately strained through four layers of cheese cloth and pH was measured. VFA in rumen fluid were analyzed by gas liquid chromatography (Packard 439-GLC) using 10% SP 1,200/1% phosphoric acid on 80/100 mesh chromosob W AW (Supelco, Inc., Bellefonte, PA) according to Erwin et al. (1963).

Ruminal fluid and abomasal liquid were analyzed for NH_3-N by Chaney and Marbach (1962). A 12 ml aliquot of the filtrate was centrifuged at 475 × g for 15 min. The supernatant was decanted and mixed with phenol color reagent and alkali-hypochlorite reagent. The optical density was determined by using spectrophotometer at 630 nm.

Amino acid and DAPA

Amino acid contents of feed, rumen bacteria and whole abomasal digesta were oxidized with performic acid at 0℃ for 16 hours. Following oxidation, samples were hydrolyzed in 6N HCl solution containing 50 mg phenol under reflux at 110℃ for 23 hours. Hydrolysates was diluted with sodium citrate buffer (pH 2.2) and filtered. Separation and determination of the individual amino acids was carried out using an automatic amino acid analyzer (Biotornic LC 5,000) according to the procedure described by Mason et al. (1980). Diamino pimelic acid (DAPA) was used as a bacterial marker and determined in freeze-dried samples of bacteria and whole abomasal digesta with automatic amino acid analyzer according to Mason et al. (1980).

Marker analysis

The concentration of Cr in feed, ruminal and abomasal digesta was determined with a atomic absorption spectrophotometry (Perkin Elmer, model 2380) using a multielement hallow cathode lamp at 357.9 nm with an air: acetylene flame after digestion with sulfuric acid and perchloric acid by the method of Fenton and Fenton (1979).

Radioactivity of ^{14}C in the liquid phase was determined by the method of Harrison (1974). Radioactivity was measured by liquid scintillation spectrophotometer (Packard Tricab, model 3255) using a commercial scintillation cocktail.

Statistical analysis

Results from present study were analyzed as a 4 × 4 latin square using the General Linear Model (GLM) of SAS (1984), with Duncan's multiple range test (Duncan, 1955) used to compare treatment means with significant F values.

Results and Discussion

Ruminal liquid and solid dilution rate, volume and flow rate

There was no significant effects of extrusion treatment on liquid and solid dilution rate, and liquid volume (table 5). Dilution rate of the rumen liquid, measured by ^{14}C-Fe-EDTA, was between 6.54 and 6.89%/h and did not differ among extrusion treatments. This result agrees with results of Plegge et al. (1985) and Stern et al. (1985). Teeter and Owens (1983) reported similar results to our study and values ranged from 5.5 to 6.3%/h. Stern et al. (1985) observed that ruminal liquid dilution rate in cows was not influenced by extrusion treatment with average value of 9.6%/h. In addition, Plegge et al. (1985) reported that liquid dilution rate was not influenced by roasting treatment and the average value was 5.6%/h. However, some workers (Caton,

TABLE 5. RUMINAL DILUTION RATE, LIQUID VOLUME AND LIQUID FLOW RATE OF SHEEP FED SOYBEANS EXTRUDED AT DIFFERENT TEMPERATURE

Items	Raw soybean	Extruded soybean			SEM
		125℃	135℃	145℃	
Liquid dilution rate (%/hr)	6.89	6.69	6.54	6.77	0.16
Solid dilution rate (%/hr)	5.43	4.81	4.82	4.90	0.30
Rumen liquid volume (liter)	6.00	6.38	5.94	6.44	0.24
Liquid flow rate (ml/hr)	412.20	434.98	389.37	433.89	19.07

1987; McCollum and Galyean, 1985) have reported that supplemental protein increased liquid dilution rate in steers.

Ruminal liquid dilution rate exerts a major influence upon the type and extent of fermentation, and is largely a function of both salivation (Poutianen, 1968) and ruminal motility (Sissons et al., 1984). All of these processes are highly related to the physical form and nutrient density of the feed consumed (Bull et al., 1979).

Although not significant, the ruminal solid dilution rate of RSB diet tended to be greater than that of the ESB diets and ranged from 4.8 to 5.4%/h. Differences in physical form and hydration capacity between RSB and ESB diets are likely responsible for this phenomenon. These results agree with those of Judkins et al. (1987) and Krysl et al. (1987), but disagree with results of other researchers (Caton, 1987; McCollum and Galyean, 1985). Caton et al. (1988) reported that solid dilution rate was not affected by cottonseed meal supplementation. In addition, Cecava et al. (1988) indicated that solid dilution rate in steers was not influenced by soybean source.

Ruminal liquid volume which was ranged from 5.9 to 6.4 liter was not influenced by extrusion treatment. Krysl et al. (1987) with sheep and McCollum and Galyean (1985) with cattle both reported no influence on ruminal liquid volume among treatments. Recently, Caton et al. (1988) also suggested that ruminal fluid volume was not influenced by cottonseed meal supplementation in lambs. Although volume estimates are higher than those reported by Krysl et al. (1987), lack of a response to supplementation agrees with their results. Difference in ruminal liquid volume may be due to differences in saliva production, liquid flow rate and/or ruminal capacity (Froetschel et al., 1987).

Liquid flow rate was greater for ESB diets than RSB diet except for 135℃ ESB diet. It is not certain why the liquid flow rate in 135℃ ESB was lower than others. These results do not appear to be associated with any specific dietary characteristics and may be due to variation in experimental techniques or errors. On the other hand, Firkins et al. (1984) suggested that the rapid solubilization may have increased rumen osmolarity and this could have resulted in increased water flux through the rumen, leading to increased liquid flows. Froestchel et al. (1987) noted that ruminal liquid flow rate in wethers fed diet containing 8.5% SBM ranged from 500 to 700 ml/h.

In animals fed once a day, volume and dilution rate were high soon after feeding, but these parameters did not change significantly when the cows were fed 12 times a day (Chen et al., 1987). Some workers indicated that faster fluid turnover rates in the rumen are correlated with greater efficiency of microbial growth (Isaacson et al., 1975; Walker et al., 1975).

Organic matter digestion and flow rate

Ruminal digestion and abomasal flow data are shown in table 6. Despite the nonsignificant effect of diet on the amount of OM flow at the duodenum and feces, there was a tendency for higher flow at the abomasum with 145℃ ESB.

OM digestion in the rumen of sheep was not affected by extrusion. Apparent OM digestion in the rumen (% of intake) was ranged from 48.3 to 56.5%. These agree with values of 49 to 56% found in sheep fed diets at the same level of intake (Siddons et al., 1985) but are higher than other reports with cattle (Santos et al., 1984; Stern et al., 1985; Tamminga, 1979).

If correction is made for bacterial OM synthesized in the rumen, then an estimated true digestibility of OM in the rumen is ranged from 71.5 to 76.5%. These values were similar to findings (68 to 79%) in sheep of Yoon et al. (1986), however, these were slightly higher than other reports (Ikwuegbu and Sutton, 1982; Siddons et al., 1985). In addition, Santos et al. (1984) and Cecava et al. (1988) observed greatly lower values of 48 to 59% in cows than present data. The reason for these discrepancies between studies can be partially attributed to animal, diet and feeding level, whereas the major reason for these differences is unclear and need more investigation. In conclusion, extruding treatment had no influence on ruminal OM digestion and flow rate to the abomasum. Stern et al. (1985) reported that OM digestion at various sites in digestive tract of cows was not affected by extrusion of soybean at 132 and 149℃. Pena et al. (1986) also suggested that OM digestion and flow rate were not affected by extrusion at 150 ℃.

TABLE 6. EFFECT OF FEEDING EXTRUDED SOYBEANS ON FLOW RATE AND DIGESTION OF ORGANIC MATTER IN THE RUMEN OF SHEEP

Items	Raw soybean	Extruded soybean			SEM
		125℃	135℃	145℃	
Intake (g/d)	699.94	696.20	690.82	691.14	4.00
Flow to					
abomasum (g/d)	318.58	303.07	304.93	356.35	13.00
feces (g/d)	91.47	88.91	84.24	91.65	3.87
Apparent digestion in					
rumen (g/d)	381.37	393.13	385.89	334.79	14.95
postrumen (g/d)	227.10	214.16	220.69	264.70	11.03
Bacterial OM flow to					
abomasum (g/d)	139.96	138.40	137.15	159.92	7.02
True OM digestion					
in rumen (g/d)	521.32	531.52	523.04	494.71	12.82
Rumen digestibility (%)					
apparent	54.38	56.49	55.76	48.33	2.01
true	74.40	76.48	75.63	71.46	1.72
Apparent digestibility					
in total GI tract (%)	86.93	87.37	87.43	86.57	0.59

Nitrogen flow and microbial protein synthesis

Data on N flow and digestibility, and microbial protein synthesis are in table 7. N flow to the abomasum (% intake) ranged from 106 to 125%, and increased ($p < 0.05$) with higher extruding temperature. Flow of NAN to the abomasum that are higher than N intake are commonly observed in ruminant animals (Ha et al., 1986; Lee and Armstrong, 1985; Offer et al., 1978).

Total N flow to the abomasum increased ($p < 0.05$) as extruding temperature increased. This increased N flow may be the result of a decreased solubility and degradability in the rumen due to the extruding treatment. The dietary N flow to the abomasum was higher ($p < 0.05$) with ESB diets compared with RSB diet, suggesting that the extrusion treatments had substantial protection effect on protein in RSB. These data are in agreement with observations of higher N flow to the duodenum of lambs fed heated SBM at 149℃ for 4 h (Hudson et al., 1970), steers fed roasted SBM at 145℃ (Plegge et al., 1982), cows fed ESB at 132 and 149℃ (Stern et al., 1985), non lactating cows fed ESB at 150℃ (Keele et al., 1989) and cows fed extruded cotton seed at 150℃ (Pena et al., 1986).

Flow of total N and NAN to the abomasum were lower ($p < 0.05$) for RSB diet than ESB diets. This effect was presumably due to increased resistance of protein in ESB to microbial degradation. Keele et al. (1989) noted that duodenal NAN flow was 10% higher for cows fed ESB at 150℃ than that for the control diet. Stern et al. (1985) observed a 12% increase in the duodenal protein digested proximal to the ileum of cows fed ESB at 149℃ compared with those for RSB.

The RSB diet had the lowest N digestion in the postrumen. Lower digestion in the hindgut possibly could be attributed to higher trypsin inhibitor activity in RSB compared with ESB. Trypsin inhibitor activities were 66.14, 20.29, 12.88 and 5.50 TIU/mg for RSB, 125, 135 and 145℃ ESB, respectively.

Extruding temperature had a significant effect ($p < 0.05$) on flow of N escaping ruminal degradation (bapass protein) and ranged from 34.91 to 57.38%. Compared with RSB, the amount of

TABLE 7. EFFECT OF FEEDING EXTRUDED SOYBEANS ON NITROGEN FLOW TO THE ABOMASUM AND MICROBIAL NITROGEN SYNTHESIS IN THE RUMEN OF SHEEP

Items	Raw soybean	Extruded soybean			SEM
		125℃	135℃	145℃	
Nitrogen Intake (g/d)	16.74	17.88	17.89	17.68	0.27
Flow to abomasum (g/d)	17.79[a]	19.39[ab]	20.23[ab]	21.99[b]	0.59
% intake	106.18	109.01	113.67	124.86	3.81
Ammonia N	0.46	0.47	0.39	0.48	0.03
Non ammonia N (NAN)	17.33[a]	18.92[ab]	19.84[ab]	21.51[b]	0.59
Microbial NAN	11.50	10.72	10.65	11.36	0.45
% abomasal NAN flow	66.05	56.65	54.11	52.72	2.26
Dietary N	5.83[a]	8.20[ab]	9.19[b]	10.15[b]	0.59
N digestion in postrumen (g/d)	14.06[a]	15.76[ab]	16.61[ab]	18.11[b]	0.57
% of abomasal flow	79.06	81.26	81.95	82.37	0.65
N escaped from rumen fermentation (%)	34.91[a]	51.83[ab]	56.64[b]	57.38[b]	3.50
Microbial N synthesis					
g N/kg OMADR[1]	30.87	27.32	29.27	36.65	2.52
g N/kg OMTDR[2]	22.18	20.08	20.49	23.39	1.05
Apparent digestibility in total GI tract (%)	77.88	79.47	80.17	78.56	0.71

[a,b] Means in the same row with different superscripts differ ($p < 0.05$).
[1] Organic matter apparently digested in the rumen.
[2] Organic matter truely digested in the rumen.

bypass protein increased by 48.47, 62.25 and 64.37% when soybean was extruded at 125, 135 and 145℃, respectively. Stern et al. (1985) reported that bypass protein (%) content was 20.22, 34.05 and 39.95 for cows fed RSB, 132 and 149℃ ESB, respectively and increased by 68 and 98% with 132 and 149℃ ESB compared with RSB. Keele et al. (1989) observed that dietary N flow (% intake) averaged 34.2% and 43.5% for barley and 150℃ ESB diet, and was 24.3% larger for cow fed ESB than that fed control diet.

Efficiency of microbial N synthesis, expressed as g microbial N synthesized/kg OM apparently digested in the rumen, ranged from 27 to 37 g and highest with 145℃ ESB diet. Similar amounts were observed in sheep fed comparable diets at similar intakes with DAPA as a microbial marker (Ikwueybu and Sutton, 1982; Siddons et al., 1985) and in cows fed rapeseed (Murphy et al., 1987).

Microbial N synthesized/kg OMTDR ranged from 20.5 to 23.4 g. Similar amounts were observed in sheep (Ikwuegbu and Sutton, 1982) and steer (Whitelaw et al., 1984). However, these values are somewhat lower than that obtained with lactating cows fed RSB, ESB and SBM with DAPA as a microbial marker (Santos et al., 1984; Stern et al., 1985).

Slowly degraded protein sources may provide a more constant ruminal supply of amino acids and peptides necessary for optimal microbial growth (Ben-Ghedalia et al., 1978; Cummins et al., 1983). However, other reserarchers (McAllan and Smith, 1984; Redman et al., 1980; Stern et al., 1983) indicated that efficiency of bacterial protein synthesis was not increased when slowly degraded proteins were fed.

Hartnell and Satter (1979) indicated that greater efficiency of micorbial growth was correlated with faster fluid turnover rates in the rumen. The amount of ruminal bypass protein might be increased with increased turnover rates of the rumen liquid phase (Harrison et al., 1975).

Increasing the turnover rate of substrate or ingesta has been shown to increase yields of rumen microbial protein *in vitro* (Isaacson et al., 1975; Walker et al., 1975) and in steers (Cole et al., 1976).

Amino acid digestion and flow rate

Ruminal amino acid digestion and flow to the abomasum of sheep fed raw and extruded soybeans are in table 8. A major concern regarding naturally resistant or extruded protein sources is the question of availability of amino acids. Intake of amino acids was lower in RSB diet due to feed refusal. Amino acid flow to the abomasum was lowest in RSB diet and tended to be higher in the ESB diets but there was no significant influence by the extrusion temperature. Extrusion treatment of RSB at 125, 135 and 145℃ increased amino acids flow to the abomasum appoximately 3.0, 10.7, and 11.5% compared with RSB, respectively.

Stern et al. (1985) suggested that ESB at 132 and 149℃ increased amino acid flow to the duodenum about 10% compared with RSB. They also indicated that EAA absorption (g/d) was higher with 149℃ ESB diet than RSB diet. This effect was presumably due to increased resistance of protein in ESB diet to microbial degradation.

Microbial total AA flow to the abomasum ranged from 56.10 to 68.53 g/d. Calculated flow of dietary amino acid to the abomasum (total-microbial amino acid) was significantly different across treatments. Dietary TAA flow was 32.69, 48.17, 51.96 and 52.33 g/d for RSB, 125, 135 and 145℃ ESB diets, respectively, and lowest ($p < 0.05$) for RSB and tended to be increased with temperature. However, there was no significant difference ($p < 0.05$) between extruding temperature. These results were similar to those of Stern et al. (1985).

True digestion of amino acid in the rumen was highest in RSB and tended to increase as temperature increased, but there was no significant

TABLE 8. EFFECT OF FEEDING EXTRUDED SOYBEANS ON RUMINAL AMINO ACID DIGESTION AND FLOW TO THE ABOMASUM OF SHEEP

Items	Raw soybean	Extruded soybean			SEM
		125℃	135℃	145℃	
TAA[1] intake (g/d)	89.11	96.92	97.05	94.87	1.55
TAA flow to abomasum (g/d)	101.22	104.27	112.04	112.81	2.43
Microbial	68.53	56.10	60.09	60.49	1.18
Dietary	32.69[a]	48.17[b]	51.96[b]	52.33[b]	2.83
TAA true digestion in rumen (g/d)	56.42	48.45	45.10	42.54	2.91
TAA escape from rumen fermentation (%)	36.69[a]	49.86[ab]	53.53[ab]	55.16[b]	2.96

[a,b] Means in the same row with different superscripts differ ($p < 0.05$).
[1] Total amino acid.

difference. TAA of dietary origin escaped from rumen fermentation (% of intake) tended to increase as extrusion temperature increased. ESB at 135℃ had the highest ($p < 0.05$) bypass amino acid among all treatments, but there was no difference between ESB diets.

Data suggests that extrusion treatment has potential to increase the proportion of amino acid escaping ruminal fermentation. Exturding at 125, 135 and 145℃ increased ruminal escape amino acid by 36, 46 and 50%, respectively. Therefore, extruding would increase flow of digestible AA to the small intestine, which may be beneficial to growing and lactating ruminants.

MacRae et al. (1972) observed that disappearance of amino acids from the large intestine of sheep was smaller with dried grass, but larger with untreated casein and largest with formaldehyde-treated casein. Lindsay et al.(1980) reported that 50 g of TAA disappeared daily from the large intestine of sheep fed forage diets. It is not clear what nutritional significance has the disap-

pearance of TAA in this section of the digestive tract, because existing evidence suggests that amino acids are deaminated rather than absorbed, therefore contributing little to the amino acid supply of the animal (Hecker, 1971; ϕrskov et al., 1971a,b).

Literature Cited

AOAC. 1984. Official methods of analysis (12th. Ed.). Association of official analytical chemists. Washington, D.C

Ben-Ghedalia, D., N. P. McMeniman and D. G. Armstrong. 1978. The effect of partially replacing urea nitrogen with protein N on N capture in the rumen of sheep fed a purified diet. Brit. J. Nutr. 39:37.

Bull, L. S., W. V. Rumpler, T. F. Sweeney and R. A. Zinn. 1979. Influence of ruminal turnover on site and extent of digestion. Fed. Proc. 38: 2713.

Caton, J. S., W. C. Hoefler, M. L. Galyean and M. A. Funk. 1988. Influence of cottonseed meal supplementation and cecal antibiotic infusion in lambs fed low quality forage I. Intake, digestibility, nitrogen balance and ruminal and cecal digesta kinetics J. Anim. Sci. 66:2245.

Caton, J. S. 1987. Influence of protein supplementation on ruminal and cecal fermentation and digesta kinetics in steers grazing dormant blue grama rangeland and lambs fed low-quality hay. Ph. D. Dissertation. New Mexico State Univ., Las Cruces.

Cecava, M. J., N. R. Merchen, L. L. Berger and G. C. Fahey, Jr. 1988. Effects of dietary energy level and protein source on site of digestion and duodenal nitrogen and amino acid flows in steers. J. Anim. Sci. 66:961.

Chaney, A. L. and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8:130.

Chen, G., C. J. Sniffen and J. B. Russell. 1987 Concentration and estimated flow of peptides from the rumen of dairy cattle: Effects of protein quantity, protein solubility and feeding frequency. J. Dairy Sci. 70:983

Cole, N. A., R. R. Johnson, F. N. Owens and J. R. Males. 1976. Influence of roughage level and corn processing method on microbial protein synthesis by beef steers. J. Anim. Sci. 43:497.

Cummins, K. A., J. E. Nocek, C. E. Polan and J. H. Herbein. 1983. Nitrogen degradability and microbial protein synthesis in calves fed diets of varying degradability defined by the bag technique J. Dairy Sci. 66:2356

Duncan, D. B. 1955 Multiple range and multiple F tests. Biometrics. 11:1

Erwin, E. S., G. J. Marcro and E. M. Emery. 1963. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

Faichney, G. J. 1975. The use of markers to partition digestion within the gastro-intestinal tract of ruminants. In digestion and metabolism in the ruminant Proceedings of the IV international symposium on ruminant physiology Sydney, Australia, August. Edited by I. W. McDonald and A. C. I. Warner. pp 277.

Faichey, G. J. 1980 The use of markers to measure digesta flow from the stomach of sheep fed once daily. J. Agric. Sci., Camb 94:313.

Fenton, T. W. and M. Fenton. 1979. An improved procedures for the determination of chromic oxide in feed and faeces. Can. J. Anim. Sci 59:631.

Firkins, J. L., L. L. Berger, G. C. Fahey, Jr. and N. R. Merchen. 1984. Ruminal nitrogen degradability and escape of wet and dry distiller grains and wet and dry corn gluten feeds. J. Dairy Sci. 67:1936.

Froetschel, M. A., W. J. Croom, Jr., W. M. Hagler, Jr., R. A. Argenzio, J. A. Liacos and H. P. Broquist. 1987. Effects of slaframine on ruminant digestive function: liquid turnover rate and fermentation patterns in sheep and cattle. J. Anim. Sci. 64:1241.

Goering, H. K. and P. J. Van Soest. 1970 Forage fiber analyses (apparatus, reagents, procedures and some application) Agric. Handbook 379, USDA, Washington, D.C.

Ha, J. K., J. J. Kennelly and R. Berzins. 1986. Effect of dietary nitrogen source on microbial protein synthesis, dietay protein degradation and nutrient digestion in steers. Anim. Feed Sci. Technol. 14:117.

Harrison, D. G. 1974. A simple method for the determination of rumen dilution rate in sheep. Newsletter to Biology and Agriculture. No. 3:8.

Harrison, D. G., D. E. Beever and D. F. Osbourn. 1979. The contribution of protozoa to the protein entering the duodenum of sheep. Brit. J. Nutr. 41:521.

Hartnell, G. F. and L. D. Satter. 1979. Determination of rumen fill, retention time and ruminal turnover rates of ingesta at different stages of lactation in dairy cows. J. Anim. Sci. 48:381.

Hecker, J. F. 1971 Metabolism of nitrogenous compounds in the large intestine of sheep. Brit. J. Nutr. 25:85.

Hudson, L. W., H. A. Glimp, C. O. Little and P. G. Woolfolk. 1970 Ruminal and postruminal nitrogen utilization by lambs fed heated soybean meal. J. Anim. Sci. 30:609

Ikwuegbu, O. A. and J. D. Sutton. 1982. The effect of varying the amount of linseed oil supplementation on rumen metabolism in sheep. Brit. J. Nutr. 48:365.

Isaacson, H. R., F. C. Hinds, M. P. Bryant and F. N. Owens. 1975. Efficiency of energy utilization by mixed rumen bacteria in continuous culture. J. Dairy Sci. 58:1646

Judkins, M. B., J. D. Wallace, M. L. Galyean, L. J. Krysl and E. E. Parker. 1987. Passage rates, rumen fermentation and weight change in protein supplemented grazing cattle. J. Range Manage. 40:100.

Keele, J. W., R. E. Roffler and K. Z. Beyers. 1989. Ruminal metabolism in nonlactating cows fed whole cottonseed or extruded soybeans. J. Anim. Sci. 67:1612.

Krysl, L. J., M. E. Branine, M. L. Galyean, R. E. Estell and W. C. Hoefler. 1987. Influence of cottonseed meal supplementation on voluntary intake, ruminal and cecal fermentation, digesta kinetics and serum insulin and growth hormone in mature ewes fed prairie hay. J. Anim. Sci. 64:1378.

Lee, N. H., D. G. Armstrong. 1985. Studies on the factors affecting rumen microbial protein synthesis and utilization of amino acids in the small intestine of sheep. II. Utilization of amino acid in the small intestine. Korean J. Anim. Sci. 27:515.

Lindsay, J. R., J. P. Hogan and J. B. Donnelly. 1980. The digestion of protein from forage diets in the small intestine of the sheep. Aust. J. Agric. Res. 31:589.

MacRae, J. C., M. J. Ulyatt, P. D. Pearce and J. Hendtlass. 1972. Quantitative intestinal digestion of nitrogen in sheep given formaldehyde-treated and untreated casein suppements. Brit. J. Nutr. 27:39.

Mason, V. C., S. Bech-Anderson and M. Rudemo. 1980. Hydrolysate preparation for amino acid determinations in feed constituents. 3rd EAAP Symposium on protein metabolism and nutrition, Braunschweig, May 1980. p. 351.

McAllan, A. B. and R. H. Smith. 1984. The efficiency of microbial protein synthesis in the rumen and the degradability of feed nitrogen between the mouth and abomasum in steers given different diets. Brit. J. Nutr. 51:77.

McCollum, F. T. and M. L. Galyean. 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation and rate of passage of praire hay in beef steers. J. Anim. Sci. 60:570.

Mielke, C. D. and D. J. Schingoethe. 1981. Heat-treated soybeans for lactating cows. J. Dairy Sci. 64:1579.

Murphy, M., P. Uden, D. L. Palmquist and H. Wiktorsson. 1987. Rumen and total diet digestibilities in lacting cows fed diets containing full fat rapeseed. J. Dairy Sci. 70:1572.

NRC. 1985. Nutrient requirements of domestic animal. Nutrient requirements of sheep. 6th ed., National Research Council. National Academy of Science. Washington, D.C.

Offer, N. W., R. F. E. Axford and R. A. Evans. 1978. The effect of dietary energy source on nitrogen metabolism in the rumen of sheep. Brit. J. Nutr. 40:35.

Ørskov, E. R., C. Fraser and J. McDonald. 1971a. Digestion of concentrates in sheep. 1. The effect of increasing the concentration of soya-bean meal in a barley diet on apparent disappearance of feed constituents along the digestive tract. Brit. J. Nutr. 25:225.

Ørskov, E. R., C. Fraser and J. McDonald. 1971b. Digestion of concentrates in sheep. 2. The effect of urea or fish-meal supplementation of barley diets on the apparent digestion of protein, fat, starch and ash in the rumen, the small intestine and the large intestine and calculation of volatile fatty acid production. Brit. J. Nutr. 25:243.

Plegge, S. D., L. L. Berger and G. C. Fahey, Jr. 1982. Effect of roasting on utilization of soybean meal by ruminants. J. Anim. Sci. 5:395.

Plegge, S. D., L. L. Berger and G. C. Fahey, Jr. 1985. Effect of roasting temperature on the proportion of soybean meal nitrogen escaping degradation in the rumen. J. Anim. Sci. 61:1211.

Poutianen, E. 1968. Factors influencing the flow of fluid, saliva and some cations through the reticulo-omasal orifice of the cow. Ann. Agr. Fenn. 7(3):1.

Redman, R. G., R. C. Kellaway and J. Leibholz. 1980. Utilization of low quality roughages: Effects of urea and protein supplements of differing solubility on digesta flows, intake and growth rate of cattle eating oaten chaff. Brit. J. Nutr. 44:343.

SAS. 1984. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

Santos, K. A., M. D. Stern and C. D. Satter. 1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactaing dairy cattle fed various protein sources. J. Anim. Sci. 58:244.

Siddons, R. C., J. Paradine, D. J. Gale and R. T. Evans. 1985. Estimation of the degradability of dietary protein in the sheep rumen by *in vivo* and *in vitro* procedures. Brit. J. Nutr. 54:545.

Sissons, V. W., S. M. Thurnston and R. H. Smith. 1984. Reticular mycoelectric activity and turnover of rumen digesta in the growing steer. Can. J. Anim. Sci. 64 (Suppl.):70.

Smith, R. H., A. B. McAllan, D. Hewitt and P. E. Lewis. 1978. Estimation of amounts of microbial and dietary nitrogen compounds entering the duodenum of cattle. J. Agric. Sci. Camb. 90:55.

Stern, M. D., K. A. Santos and L. D. Satter. 1985. Protein degradation in rumen and amino acid absorption in small intestine of lactating dairy cattle fed heat treated whole soybeans. J. Dairy Sci. 68:45.

Stern, M. D., L. M. Rode, R. W. Prange, R. H. Stauffacher and L. D. Satter. 1983. Ruminal protein degradation of corn gluten meal in lactation dairy cattle fitted with duodenal T-type cannulae. J. Anim. Sci. 56:194.

Tamminga, S. 1979. Protein degradation in the fores-

tomachs of ruminants. J.Anim. Sci. 49:1615.

Tecter, R. G. and F. N. Owens. 1983. Characteristics of water soluble markers for measuring rumen liquid volume and dilution rate. J. Anim. Sci. 56:717

Uden, P., P. E. Colucci and P. J. Van Soest 1980 Investigation of chromium, cerium and cobalt as markers in digesta rate passage studies. J. Sci. Food Agric. 31:625.

Walker, D. J., A. R. Egan, C. J. Nader, M. J. Vlyatt and G. B. Storer. 1975. Rumen microbial protein synthesis and proportions of microbial and non-microbial nitrogen flowing to the intestines of sheep. J. Agri. Sci. 26:699.

Whitelaw, F. G., J. M. Eadie, L. A. Bruce and W. J. Shand. 1984. Microbial protein synthesis in cattle given roughage-concentrate and all-concentrate diets: the use of 2, 6 diaminopimelic acid, 2-amino ethylphosphonic acid and 35S as markers. Brit. J. Nutr. 52:249.

Yoon, C. S., N. H. Lee and K. K. Jung. 1986. The effect of corn or barley plus urea and soybean meal on microbial protein production in the rumen of sheep. Korean J. Anim. Sci 28:588.