EFFECT OF SOYBEAN LIPID ON GROWTH AND RUMINAL NITROGEN METABOLISM IN CATTLE FED SOYBEAN MEAL OR GROUND WHOLE SOYBEANS

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ABSTRACT

Three experiments were conducted to determine the effect of soybean lipid on ruminal proteolysis of soybean meal (SBM) and ground whole soybeans (GSB). Experiment 1 was a 92-d growth experiment using 120 calves (206 kg) allotted to 12 pens of 10 calves each. Three replicate pens were assigned to each of the treatment supplements: low SBM (LSBM), low GSB (LGSB), high SBM (HSBM) and high GSB (HGSB). Calves received ad libitum amounts of corn silage top-dressed with the respective supplement (.81 kg/head). High protein supplements produced greater (P<.05) gains than low protein supplements, with HSBM calves gaining faster (P<.05) than HGSB calves and LSBM and LGSB calves having similar (P>.10) gains. In Exp. 2, 15 ruminally cannulated Angus × Hereford heifers (380 kg) fed corn silage were used to determine ammonia-N release from the treatment supplements: ground corn (control), GSB, SBM and SBM coated with soybean oil (SBMO). Heifers fed the control supplement had lower (P<.05) ruminal NH₃-N concentrations than those consuming soybean protein. Ruminal NH₃-N concentrations were similar (P~.10) for GSB and SBM; whereas, SBMO had lower (P<.10) concentrations than SBM through 3 h. In Exp. 3, two ruminally cannulated Angus × Jersey steers (250 kg) were used to determine in situ disappearance of SBM, GSB and SBMO. Total and feed N disappearances were greater (P<.001) for GSB than SBM or SBMO. Although SBM and SBMO were resistant to microbial attachment through 4 h, SBMO tended to have lower (P>.10) N disappearance than SBM when corrected for microbial N. Data from these experiments suggest that the endogenous lipid fraction of GSB did not protect soybean protein from ruminal proteolysis; however, physically coating SBM with oil apparently reduced proteolysis.

(Key Words: Beef Cattle, Soybeans, Protected Protein, Nitrogen Metabolism, Protein Degradation.)

Introduction

Corn silage is frequently utilized in many growing beef cattle systems. However, maximum performance is achieved only when it is supplemented with N (Thomas and Wilkinson, 1975). Less than 25% of the total corn silage N has the potential to escape ruminal degradation due to high concentrations of water-soluble N (Bergen et al., 1974; Van Soest, 1982). Therefore, supplementation with protein resistant to ruminal degradation should improve performance of calves consuming corn silage.

Peterson et al. (1975) and Glenn et al. (1977) suggested that lipid coating was an effective method for reducing ruminal protein degradation. They reported reduced ruminal ammonia-N (NH₃-N) concentrations and increased N flow to the abomasum when linseed meal was coated with various lipids. Ground whole soybeans (GSB) contain approximately 37.9% crude protein and 18.0% ether extract. Early research showed that growing cattle supplemented with GSB had daily gains comparable to those fed soybean meal (SBM), cottonseed meal and linseed meal (Morrison, 1956). Data that show how the endogenous lipid fraction of GSB influences ruminal degradation when fed as a source of supplemental protein are not available. Therefore, three experiments were conducted to determine the effects of soybean lipid on ruminal degradation of protein in GSB and SBM.

Materials and Methods

Growth Experiment. One hundred twenty calves (83 steers and 37 heifers) were used to...
TABLE 1. INGREDIENT AND CHEMICAL COMPOSITION OF SUPPLEMENTS FED IN GROWTH EXPERIMENT

<table>
<thead>
<tr>
<th>Item</th>
<th>LSBM</th>
<th>LGSB</th>
<th>HSBM</th>
<th>HGSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean meal</td>
<td>45.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground corn</td>
<td>54.85</td>
<td>43.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground soybeans</td>
<td>56.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis, %&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>87.86</td>
<td>85.69</td>
<td>89.29</td>
<td>83.96</td>
</tr>
<tr>
<td>Crude protein</td>
<td>28.14</td>
<td>28.33</td>
<td>41.47</td>
<td>41.95</td>
</tr>
<tr>
<td>Crude fat</td>
<td>3.69</td>
<td>11.26</td>
<td>3.48</td>
<td>17.68</td>
</tr>
<tr>
<td>TDNd</td>
<td>87.30</td>
<td>90.56</td>
<td>85.18</td>
<td>91.00</td>
</tr>
</tbody>
</table>

<sup>a</sup>Supplements are: low soybean meal (LSBM), low ground soybeans (LGSB), high soybean meal (HSBM) and high ground soybeans (HGSB).

<sup>b</sup>As-fed basis.

<sup>c</sup>Dry matter basis.

<sup>d</sup>Total digestible nutrient values were calculated using NRC (1984).

study the effects of source and level of protein supplementation on feedlot performance of calves consuming corn silage. The calves (mean initial weight, 206 kg) were of Angus, Hereford, Angus x Hereford and Beefmaster breeding. They were allotted by breed, sex and weight to 12 groups of 10 calves. The 12 pens were randomly assigned across four treatments of three replicate pens each. Treatment groups consisted of a low level of SBM (LSBM), a low level of GSB (LGSB), a high level of SBM (HSBM) and a high level of GSB (HGSB). Low and high protein supplements were formulated to contain .20 and .31 kg crude protein (CP), respectively. Supplements (.81 kg/head) were top-dressed on corn silage once daily. Ingredient and chemical composition of the four supplements are presented in table 1. During the 92-d growth experiment, calves were given ad libitum access to corn silage, which contained 35.2% dry matter (DM), 1.33% N and .70% non-protein N (NPN) as a percentage of DM. Calves were provided with steamed bone meal and trace mineralized salt<sup>3</sup> in separate mineral boxes. Each calf was initially injected with selenium (150 µg), vitamin A (1,500,000 IU) and vitamin D (225,000 IU).

Daily feed intake was recorded throughout the experiment. Feed refusals were weighed and discarded daily. Silage and supplements were sampled weekly and frozen for subsequent analyses. Individual full weights were obtained on d 0, 34, 57 and 92. Animal performance measurements were average daily gain (ADG) and feed conversion (F/G).

Ruminal fluid and blood samples were collected on d 34 and 92 from three steers and one heifer randomly chosen from each pen. Calves were bled via jugular puncture 2 to 4 h after the morning feeding. Blood samples (50 ml) were immediately placed in chilled heparinized tubes, centrifuged at 3,000 × g for 15 min and frozen until analyzed for urea-N (PUN). Ruminal fluid (30 ml) was collected via stomach tube, filtered through four layers of gauze into vials containing .5 ml 6 N HCl and frozen until analyzed for NH₃-N.

**Ruminal NH₃-N Release Experiment.** Fifteen Angus x Hereford heifers (mean weight, 380 kg) fitted with permanent ruminal cannulae were utilized to determine liberation of ruminal NH₃-N over a 12-h period from three isonitrogenous soybean supplements. The supplements were ground corn (control), GSB, commercially processed SBM and SBM coated with soybean oil (SBMO). Four heifers were randomly allotted to each of the SBM, GSB and SBMO supplements with the remaining three heifers assigned to the control supplement.

<sup>3</sup>To provide (mg/kg diet): NaCl, 9,900; Mn, 20.0; Fe, 10.0; Mg, 10.0; S, 5.0; Cu, 1.0; Zn, .8 and I, .7.
Composition and analysis of the supplements are presented in Table 2. Whole soybeans were ground through a 5-mm screen to obtain GSB. The SBMO supplement was prepared by mixing SBM and soybean oil (19.42%) in a Hobart mixer for 15 min and storing in an aluminum can for 5 d to allow complete saturation by the oil.

Steers were housed in individual concrete-floored pens and adapted to a basal diet containing corn silage (6.8 kg/d) and a SBM supplement (.36 kg/d) for a 15-d period. Equal portions of the basal diet were fed twice daily at 0800 and 2000. The basal diet was formulated to contain 12% CP (as-fed basis) and adequate Ca and P (NRC, 1984). Corn silage analyzed 38.0% DM, 1.46% N and .91% NPN as a percentage of DM. Water was provided ad libitum throughout the experiment.

On d 16 and 18, approximately 10 g of each soybean preparation were placed in individual nylon bags (7.5 × 15.0 cm; pore size 50 to 70 μm), resulting in a sample weight-to-surface area ratio of 44.4 mg/cm². Twenty-one bags

<table>
<thead>
<tr>
<th>Item</th>
<th>Control</th>
<th>GSB</th>
<th>SBM</th>
<th>SBMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean meal</td>
<td>100.00</td>
<td>92.0</td>
<td>90.6</td>
<td>93.5</td>
</tr>
<tr>
<td>Ground soybeans</td>
<td>89.3</td>
<td>40.1</td>
<td>39.7</td>
<td>39.6</td>
</tr>
<tr>
<td>Ground corn</td>
<td>4.3</td>
<td>20.5</td>
<td>3.0</td>
<td>29.8</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>3.2</td>
<td>3.3</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Dry matter, %</td>
<td>91.3</td>
<td>92.3</td>
<td>92.1</td>
<td></td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>7.8</td>
<td>6.6</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Crude fat, %</td>
<td>2.3</td>
<td>20.4</td>
<td>14.9</td>
<td></td>
</tr>
<tr>
<td>NA-N, %</td>
<td>4.0</td>
<td>3.3</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Modulus of fineness</td>
<td>3.3</td>
<td>3.2</td>
<td>3.6</td>
<td></td>
</tr>
</tbody>
</table>

aSupplements are: corn (control), ground soybeans (GSB), soybean meal (SBM) and oil-coated soybean meal (SBMO).

bAs-fed basis.

cDry matter basis.

<table>
<thead>
<tr>
<th>Treatment a</th>
<th>SBM</th>
<th>GSB</th>
<th>SBMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>91.3</td>
<td>92.3</td>
<td>92.1</td>
</tr>
<tr>
<td>Nitrogen, %b</td>
<td>7.8</td>
<td>6.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Crude fat, %b</td>
<td>2.3</td>
<td>20.4</td>
<td>14.9</td>
</tr>
<tr>
<td>NA-N, %c</td>
<td>4.0</td>
<td>3.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Modulus of fineness</td>
<td>3.3</td>
<td>3.2</td>
<td>3.6</td>
</tr>
</tbody>
</table>

aTreatments are: soybean meal (SBM), ground soybeans (GSB) and oil-coated soybean meal (SBMO).

bDry matter basis.

cNucleic acid-N expressed as a percentage of total N.
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(7 bags/treatment) were attached with 9-kg-test nylon thread to a 75-cm stainless steel chain (links, .5 x 4 cm; weight, .8 kg). Bags were dampened in 37 C tap water to facilitate rapid entry of ruminal fluid, introduced into the rumen before the 0800 feeding and incubated 1, 2, 3, 4, 6, 8 and 12 h. Upon removal, bags were immediately rinsed in 10 liters of warm tap water followed by individual washing under a steady stream of running tap water for 90 s (Weakley et al., 1983; Nocek, 1985). Rinsed bags were then placed in a 50 C forced-air oven. Once all bags had been collected for a given day, they were dried at 100 C for 48 h. All residues and initial soybean preparations were ground through a 1-mm screen and analyzed for DM and N (AOAC, 1970) and nucleic acid N (Zinn and Owens, 1986).

Attached microbial N was estimated using the residual nucleic acid N concentration as the microbial marker. Ruminal fluid (75 ml) was collected from each steer before the 0800 feeding and at all sampling times, placed in vials containing .5 ml 6 N HCl and frozen. Each sample was centrifuged at 3,000 x g for 15 min to remove feed particles. The resulting supernatant was centrifuged at 18,000 x g for 15 min to obtain the microbial pellet. The microbial pellets of both steers were composited and dried at 100 C. A nucleic acid N-to-total N ratio of .21 was obtained for the composited microbial pellet and was used to compute microbial N.

Laboratory and Statistical Procedures. Chemical composition of silage and supplements was determined using AOAC (1970) procedures. Silage was analyzed for NPN by precipitating protein with 10% trichloroacetic acid. Plasma samples were analyzed for PUN as described by Skeggs (1957). The procedure of Imler et al. (1972) was used to analyze ruminal fluid for NH3-N. Modulus of fineness was determined for SBM, GSB and SBMO using the procedures of Pfost and Headley (1976). Data were analyzed by analysis of variance using the Statistical Analysis System (Barr and Goodnight, 1971). In the growth experiment, pen was used as the experimental unit for the performance data; whereas, individual animals were used for the PUN and NH3-N measurements. Planned orthogonal contrasts used in the growth experiment were LSBM vs LGSB; HSVM vs HGSB and high vs low protein. In the NH3-N release experiment the contrasts were control vs GSB, SBM and SBMO; GSB vs SBM and SBMO; and SBM vs SBMO. In the in situ experiment, time effects on DM and N disappearance were tested using orthogonal polynomials for linear, quadratic and cubic effects. Only linear effects were significant (P<.05); therefore, analysis of covariance, using time as the covariate, was used to determine treatment differences in slopes of the disappearance curves. The slope of each curve was expressed as the mean rate of disappearance from 1 to 12 h.

Results and Discussion

Growth Experiment. Low- and high-protein supplemented calves consumed diets containing 10 and 12% CP, representing daily CP intakes of .63 and .72 kg/head, respectively. Low and high levels provided 87.5 and 100% of the steer protein requirement, and 105 and 120% of the heifer protein requirement, respectively (NRC, 1984).

Protein source and level had no effect (P>.10) on DM intake (table 4). However, calves supplemented with GSB consistently consumed less feed than those fed SBM. Total energy intake of calves consuming GSB and SBM supplements was 65.5 and 65% total digestible nutrients, respectively. Therefore, the small reduction in DM intake could be attributed to the increased caloric density of the GSB supplements. Additionally, the lipid fraction of the GSB supplements could have a direct effect on DM intake since the addition of soybean oil has been shown to reduce silage consumption (Clapperton and Steele, 1985). The reduced DM intake may be a result of the inhibitory effect of supplemental fat on fiber digestibility (Brooks et al., 1954; Ward et al., 1957). Decreased fiber digestibility may increase ruminal retention time and lower feed intake (Kowalczyk et al., 1977). Nitrogen supplementation normally stimulates corn silage intake (Thomas and Wilkinson, 1975). However, in this experiment the stimulatory effect of N may have been offset by the increased lipid content and(or) caloric density, since HGSB calves had consistently lower DM intake than LSBM calves.

Average daily gains (ADG) were similar (P>.10) for LSBM and LGSB (.93 and .90 kg/d, respectively). The high level of protein supplementation resulted in greater (P<.05) ADG than the low level, with HSVM calves gaining at a faster (P<.05) rate than HGSB calves (1.03 kg/d and .94 kg/d, respectively). These results support those of Willard et al.
TABLE 4. INITIAL WEIGHT, DRY MATTER (DM) INTAKE, AVERAGE DAILY GAIN (ADG) AND FEED CONVERSION (F/G) OF CALVES

<table>
<thead>
<tr>
<th>Supplement</th>
<th>LSBM</th>
<th>LGSB</th>
<th>HSBM</th>
<th>HGSB</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial wt, kg</td>
<td>205.5</td>
<td>206.0</td>
<td>206.4</td>
<td>206.7</td>
<td>.48</td>
</tr>
<tr>
<td>DM intake, kg/d</td>
<td>5.96</td>
<td>5.80</td>
<td>6.07</td>
<td>5.89</td>
<td>.19</td>
</tr>
<tr>
<td>ADG, kg/d</td>
<td>.93</td>
<td>.90</td>
<td>1.03</td>
<td>.94</td>
<td>.05</td>
</tr>
<tr>
<td>F/G</td>
<td>6.41</td>
<td>6.44</td>
<td>5.89</td>
<td>6.28</td>
<td>.13</td>
</tr>
</tbody>
</table>

a Supplements are: low soybean meal (LSBM), low ground soybeans (LGSB), high soybean meal (HSBM) and high ground soybeans (HGSB).

b Standard error of mean.

c High vs low protein differ (P<.05).

d HSBM vs HGSB differ (P<.05).
e HSBM vs HGSB differ (P<.10).

(1971), who observed increased ADG when daily SBM supplementation was increased from .45 to .68 kg/head.

The low level of protein supplementation resulted in less (P<.05) efficient gains compared with high protein intakes. This supports the observation of Pendulum et al. (1978) that improved F/G resulted when corn silage was supplemented with graded levels of SBM. Feed conversion was similar (P>.10) for LSBM and LGSB calves; however, at the higher protein level, HSBM calves were more (P<.10) efficient than HGSB calves.

Animal performance data suggest that GSB effectively replaced SBM without a significant reduction in performance at low protein intakes. However, as dietary protein intake ceased to be a factor limiting growth, performance of calves consuming GSB decreased compared with those fed the same quantity of protein as SBM.

Plasma urea-N and ruminal NH3-N concentrations are presented in table 5. Within protein level, PUN concentrations were similar (P>.10) at both sampling times. Calves fed low protein had reduced (P<.01) PUN compared with those fed high protein supplements. Increased protein

TABLE 5. PLASMA UREA NITROGEN (PUN) AND RUMINAL AMMONIA-N (NH3-N) CONCENTRATIONS IN CALVES ON D 34 AND 92 OF GROWTH EXPERIMENT

<table>
<thead>
<tr>
<th>Supplement</th>
<th>LSBM</th>
<th>LGSB</th>
<th>HSBM</th>
<th>HGSB</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUN, mg/100 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 34c</td>
<td>6.4d</td>
<td>7.5</td>
<td>10.7</td>
<td>10.4</td>
<td>.65</td>
</tr>
<tr>
<td>D 92c</td>
<td>4.8</td>
<td>4.8</td>
<td>9.7</td>
<td>8.8</td>
<td>.43</td>
</tr>
<tr>
<td>NH3-N, mg/100 ml</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D 34c</td>
<td>9.6</td>
<td>11.1</td>
<td>12.0</td>
<td>13.2</td>
<td>.76</td>
</tr>
<tr>
<td>D 92c</td>
<td>3.3</td>
<td>3.5</td>
<td>7.4</td>
<td>6.9</td>
<td>1.04</td>
</tr>
</tbody>
</table>

a Supplements are: low soybean meal (LSBM), low ground soybeans (LGSB), high soybean meal (HSBM) and high ground soybeans (HGSB).

b Standard error of mean.

c High vs low protein differ (P<.01).

d Each value based on 12 observations.
intake is generally associated with increased PUN concentrations in ruminants (Lewis, 1957). At both sampling times, HSBM calves tended (P>.10) to have higher PUN than HGSB calves, possibly reflecting the slightly higher DM intake of the HSBM calves.

Ruminal NH3-N concentrations were lower (P<.01) in calves consuming low protein compared to calves consuming high protein. The reduced ruminal NH3-N concentrations reflect N intake and support previously observed differences in performance of calves fed different levels of protein (Elliot and Topps, 1964; Haaland et al., 1982). Ground soybeans tended (P>.10) to produce higher NH3-N concentrations than SBM, except on d 92 when HGSB was slightly lower than HSBM (6.9 vs 7.4 mg/100 ml, respectively). Increased NH3-N concentrations in calves fed GSB suggest that the endogenous seed lipids did little to protect soybean protein from ruminal proteolysis. However, the single post-prandial ruminal fluid sample obtained in this experiment may not reflect the ultimate quantity of NH3-N liberated from these dietary protein sources.

Ruminal NH3-N Release Experiment. Ruminal NH3-N concentrations of calves fed four dietary supplements are presented in figure 1. The control calves had lower (P<.05) NH3-N concentrations throughout the 12-h sampling period compared with calves fed the soybean supplements. Ruminal NH3-N concentrations were similar (P>.10) for GSB and SBM through 12 h. Oil-coated SBM had lower (P<.10) NH3-N concentrations than GSB or SBM through 3 h post-prandial, but had no effect (P>.10) at time periods greater than 3 h.

The shape of the NH3-N release curves were comparable and consistent with those previously reported (Wohlt et al., 1976). Maximum NH3-N concentrations were observed at 1 h, with minimum concentrations at 6 h. From 8 to 12 h the NH3-N concentrations increased for control, SBM and SBMO treatments, while GSB remained essentially constant. Ruminal NH3-N release is a function of protein solubilization and bacterial deamination (El-Shazly, 1958), with highly soluble protein capable of producing maximum NH3-N concentrations within 1 to 2 h of ruminal incubation (Wohlt et al., 1976; Crawford et al., 1978). In this experiment a major portion of the NH3-N at 1 h was likely attributable to the soluble N fraction of corn silage (Bergen et al., 1974). The corn silage contained 59.8% of the total N as NPN, which is largely composed of free amino acids and labile amide N that are rapidly hydrolyzed to NH3-N during ruminal incubation (Annison, 1956).

Using ruminal NH3-N concentration as an indicator of ruminal proteolysis suggests that the endogenous lipid fraction of GSB did not protect soybean protein from proteolysis when compared with SBM. These data verify the similar single post-prandial ruminal NH3-N concentrations observed for the SBM and GSB supplements fed in the growth experiment. Additionally, ruminal NH3-N concentrations were lower for SBMO than SBM through 6 h, suggesting that feed processing methods may affect ruminal degradation of soybean protein. Commercial production of SBM requires the application of heat to remove excess solvent (Gocring and Waldo, 1974). Numerous studies have reported reduced protein solubility and subsequently lower ruminal NH3 concentrations when processed proteins were exposed to additional heat (Little et al., 1963; Nishimuta et al., 1973; Thomas et al., 1979). These data suggest that solvent extraction and heating that occur during soybean processing may result in improved protein utilization by cattle. In addition to processing effects, physically

Figure 1. Ruminal NH3-N concentrations vs time after feeding in heifers fed corn silage and corn (control), soybean meal (SBM), ground soybeans (GSB) or oil-coated soybean meal (SBMO) supplement. Each value represents the mean concentration for the treatment group. Standard error of mean was 1.69, 1.98, 2.35, 2.31, 1.84, 1.77 and 2.08 for 1, 2, 3, 4, 6, 8 and 12 h, respectively.
TABLE 6. LINEAR RELATIONSHIPS for DRY MATTER, TOTAL N and FEED N DISAPPEARANCE WITH TIME

<table>
<thead>
<tr>
<th>Component</th>
<th>SBM</th>
<th>GSB</th>
<th>SBMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>2.1 (.90)</td>
<td>3.9 (.90)</td>
<td>1.5 (.82)</td>
</tr>
<tr>
<td>Total N</td>
<td>1.4 (.75)</td>
<td>4.0 (.90)</td>
<td>1.2 (.69)</td>
</tr>
<tr>
<td>Feed N</td>
<td>1.8 (.85)</td>
<td>3.1 (.89)</td>
<td>1.4 (.73)</td>
</tr>
</tbody>
</table>

- Slope and (coefficient of determination) for the disappearance curves with the slope expressed as mean percentage disappearing per hour.
- Treatments are: soybean meal (SBM), ground soybeans (GSB) and oil-coated soybean meal (SBMO).
- GSB vs SBM, SBMO differ (P<.001).
- SBM vs SBMO differ (P<.05).

Coating SBM with soybean oil apparently reduced ruminal proteolysis, as indicated by lower NH₃-N concentrations when compared with SBM. This supports studies by Peterson et al. (1975) and Glenn et al. (1977), who observed decreased ruminal NH₃-N concentrations and proteolysis when linseed meal was coated with lipid.

**In Situ Experiment.** Analysis of variance showed that during 1 to 12 h the disappearance of DM, total N and feed N were linear (P<.05) with time; therefore, the slope of each curve was used as an estimate of the mean disappearance rate for that component (table 6). Initial losses due to rapid solubilization of nutrients were not included in the estimates since 1 h was used as the initial time point.

Figure 2 shows that residual DM appeared greater for GSB and SBM compared with SBMO at 1 h. This may be attributed to partial washout of soybean oil when nylon bags containing SBMO were placed in the rumen. After 12 h, residual DM was 27.3, 45.3 and 45.6% for GSB, SBMO and SBM, respectively. Disappearance of GSB DM was 3.9%/h, which was greater (P<.001) than SBM and SBMO (2.1 and 1.5%/h, respectively). Initial differences in residual SBM and SBMO DM were reduced as incubation time progressed due to the higher (P<.05) DM disappearance of SBM.

Figure 3 shows that total N (feed N plus microbial N) remaining after 1 h incubation was lower for GSB than SBM or SBMO (72.2, 82.0 and 81.1%, respectively). Initial N losses were attributed to the soluble N fraction and microbial degradation of the insoluble ruminally degradable fraction (Crawford et al., 1978). This suggests that GSB contained more readily soluble N than SBM or SBMO. These data support the value of 20.3% soluble N contained in SBM (Van Soest et al., 1982), which is attributed to its high proportion of albumins and...
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100
80
60
40
20

Figure 3. Percentage of total N remaining in nylon bags vs ruminal incubation time for soybean meal (——), ground soybeans (———), oil-coated soybean meal (••••••••••), and feed N for soybean meal (X———X), ground soybeans (X———X) and oil-coated soybean meal (X••••••••••). Each value represents the mean of four observations. Standard error of mean for total N and feed N was 2.08 and 1.75, respectively.

globulins (Sniffen, 1974). After 12 h, GSB, SBM and SBMO residues contained 26.7, 62.6 and 64.3% of the initial N, respectively. The mean disappearance of total N was similar (P>.10) for SBM and SBMO (1.4 and 1.2%/h, respectively); whereas, GSB had a higher (P<.001) rate (4.0%/h) compared with SBM and SBMO.

Microbial N values were used to obtain an estimate of microbial attachment to residues (figure 4). Although microbial attachment to GSB occurred within 1 h and increased through 4 h, SBM and SBMO were apparently more resistant to attachment through 4 h. From 4 to 12 h, the ratio of attached microbial N to feed N decreased for GSB (300 to 157 mg/g, respectively); whereas, the ratio of attached microbial N to feed N increased for SBM and SBMO (140 to 266 and 137 to 232 mg/g, respectively). These data suggest that SBMO was apparently more resistant to microbial attachment than SBM after 4 h.

The improved coefficients of determination (R²) presented in table 6 for feed N suggest that disappearance of SBM and SBMO N was more accurately estimated when corrected for attached microbial N. In contrast, correcting total GSB N for attached microbial N did not improve R². Correcting total SBM and SBMO N resulted in higher N disappearance values (1.4 to 1.8 and 1.2 to 1.4%/h, respectively); whereas, the N disappearance value for GSB decreased (4.0 to 3.1%/h). This conflicting trend likely reflects differences in microbial attachment over time. The increased microbial attachment to SBM and SBMO after 4 h underestimated true feed N disappearance. In contrast, GSB N disappearance was overestimated due to decreased attachment after 4 h. Regardless of

Figure 4. Attached microbial N vs ruminal incubation time for soybean meal (SBM), ground soybeans (GSB) and oil-coated soybean meal (SBMO). Attachment was estimated using the ratio of microbial N to feed N. Each value represents the mean of four observations. Standard error of mean was 12.8.
corrections for microbial N attachment, the disappearance of GSB N was greater (P<.001) than the disappearance of SBM and SBMO N. Correcting total SBM and SBMO N for attached microbial N showed that lipid coating tended (P>.10) to reduce feed N disappearance.

The objective of this study was to rank the resistance of the three soybean preparations to ruminal degradation. These data suggest that soybean processing was more effective than lipid coating in reducing ruminal protein degradation. Microbial attachment to GSB occurred more rapidly than SBM and SBMO, resulting in faster (P<.001) and more extensive protein degradation. Lipid coating appeared to inhibit microbial attachment to SBM and tended (P>.10) to reduce N disappearance when total N was corrected for attached microbial N. Apparently, the lower ruminal NH3-N concentrations and decreased ruminal proteolysis associated with lipid-coated protein (Peterson et al., 1975; Glenn et al., 1977) can be partially attributed to inhibition of microbial attachment. Commercial production of SBM appeared to affect ruminal proteolysis by inhibiting microbial attachment during the initial 4 h of incubation. Solvent extracting or heating to remove excess solvent apparently altered protein structure and its potential for microbial attachment and subsequent degradation (Little and Mitchell, 1967; Waldo and Goering, 1979; Sniffen and Hoover, 1978).

In summary, these data showed that physically coating processed SBM protein with soybean oil reduced ruminal degradation and subsequent NH3-N production. The three experiments showed that the endogenous lipid fraction of GSB apparently failed to provide appreciable protection of soybean protein from proteolysis during ruminal incubation. These in situ data suggest that removal of the lipid fraction from soybeans by solvent extraction and subsequent heating to remove solvent altered protein structure. The denatured protein resulted in increased resistance to ruminal degradation due to lower protein solubility and(or) altered microbial attachment sites. This would explain the reduced performance of calves consuming corn silage supplemented with GSB compared with those fed SBM. Apparently SBM provided greater quantities of absorbable amino acids to the small intestine than GSB, which was degraded more rapidly.

**Literature Cited**


SOYBEAN LIPID AND NITROGEN METABOLISM


