# RUMINAL AND POST-RUMINAL DIGESTION AND NITROGEN BALANCE IN EARLY WEANED CALVES FED SOYBEAN MEAL AND HEATED SOYBEAN MEAL

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## Summary

Two digestion trials were conducted to investigate the effect of feeding heated soybean meal (HSBM) on ruminal and post-ruminal digestion of organic matter (OM) and nitrogen (N), bacterial N flow to the duodenum and N balance in young calves weaned at 6 weeks of age. In trial 1, calves were fed concentrate diets containing soybean meal (SBM) or HSBM and hay mixed in the ratio of 6:4 to support daily weight gain of 0.5 kg. The same concentrate diets were used in trial 2, but the ratio of concentrate to hay was 7:3 to support body weight gain of 0.7 kg/d. Measurements were made 10 and 13 weeks of age in trial 1, and at 10 and 15 weeks in trial 2. Ruminal OM digestibility increased with advancing age in both trials. Ruminal OM digestion was not affected by the diets in trial 1, but it was greater for the SBM diet than for the HSBM diet at 10 weeks in trial 2. Net N loss from the rumen was lower for the HSBM diet than for the SBM diet in trial 1, but it was not affected by the diets in trial 2. Bacterial N flow to the duodenum, N digestion in the total digestive tract and N retention were not affected by the diets in either of the trials.
(**Key Words** : Degradability, Soybean Meal, Bacterial Nitrogen, Calves)

## Introduction

The amino acid supply derived from ruminal microbial protein may be insufficient to meet amino acid requirements for maintenance and rapid growth in young calves (Ørskov, 1977). Thus, feeding low-degradable protein sources to early weaned calves is considered to be important. However, effects of feeding the low-degradable protein source on nitrogen (N) balance and body weight gain in young calves are not consistent (Abdelgadir et al., 1984; Trotta et al., 1984; Zerbini and Polan, 1985; Chester-Jones et al., 1990), because feeding different protein sources alters not only the quantity but also the quality of ruminal escape protein (Koeln and Paterson, 1986). The heat treatment of diets may be useful to decrease the ruminal degradability without changing the quality of ruminal escape protein (Thomas et al., 1979; Plegge et al., 1985).

In this study, two digestion trials were conducted to investigate the effects of feeding heated soybean meal on the ruminal and post-ruminal digestion of organic matter (OM) and N, bacterial nitrogen (BN) flow to the duodenum and N balance in early weaned calves. The calves were fed diets to support daily weight gains of 0.5 kg in trial 1 and of 0.7 kg in trial 2.

## Materials and Methods

### Diet

Two concentrate diets containing rolled corn plus soybean meal (SBM) or heated soybean meal (dry heated in an air-forced oven at 130℃ for 2 hours; HSBM) as major ingredients were used (table 1). These concentrates were given to the calves with chopped orchardgrass hay.

### Digestion and nitrogen balance trial

Two trials of digestion and nitrogen balance were conducted with young calves weaned at 6 weeks of age.

In trial 1, six male Holstein calves were used. The calves were housed in individual metabolism crates at 1 week of age and were fed whole cow's milk at 3 kg/d until 47 days of age. Three calves were assigned to each of the two treatments at 2 weeks of age. Calves in each treatment were fed the ration containing the SBM or HSBM diet and the hay mixed in the ratio of 6:4 (dry matter basis) at 09:00 and 17:00 in two equal portions to

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Received April 16, 1994
Accepted September 26, 1994

support daily weight gain of 0.5 kg (Agricultural Research Council, 1980). The hay used in trial 1 contained 5.8% crude protein and 75.0% cell wall constituents (CWC) on a dry matter basis. Calves were fitted with duodenal re-entrant cannulae (Obitsu et al., 1986) at 8 weeks of age. Then, at 10 and 13 weeks of age, duodenal digesta, feces and urine were collected to measure the ruminal and post-ruminal digestion of OM and N, BN flow to the duodenum and N balance. Average body weight at 10 weeks of age was 65.5 kg for calves fed the SBM diet and 64.8 kg for those fed the HSBM diet.

TABLE 1. INGREDIENTS AND CHEMICAL COMPOSITION OF CONCENTRATE DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) ON DRY MATTER BASIS

| Item | Diets | |
|---|---|---|
| | SBM | HSBM |
| Ingredients | ..... % ..... | |
| Rolled corn | 71.2 | 71.2 |
| Soybean meal | 22.3 | — |
| Heated soybean meal[1] | — | 22.3 |
| Linseed meal | 3.0 | 3.0 |
| Yellow grease | 1.0 | 1.0 |
| Calcium carbonate | 1.1 | 1.1 |
| Sodium chloride | 0.5 | 0.5 |
| Calcium phosphate | 0.6 | 0.6 |
| Sodium propionate | 0.1 | 0.1 |
| Vitamin premix | 0.2 | 0.2 |
| Chemical composition | | |
| Organic matter | 96.1 | 95.8 |
| Crude protein | 19.1 | 19.2 |
| Cell wall constituents | 10.3 | 10.5 |
| Acid detergent fiber | 5.1 | 4.9 |

[1]Dry heat at 130℃ for 2 hours.

In trial 2, eight male Holstein calves were used. The calves were housed in individual metabolism crates at 1 week of age and were fed whole milk at 4 kg/d to 47 days of age. Four calves were assigned to each of the two treatments at 2 weeks of age. Calves in each treatment were fed the ration containing the SBM or HSBM diet and the hay mixed in the ratio 7:3 (dry matter basis) at 09:00 and 17:00 to support daily weight gain of 0.7 kg (Agricultural Research Council, 1980). The hay used in trial 2 contained 10.2% crude protein and 66.5% CWC (dry matter basis). Calves were fitted with duodenal re-entrant cannula at 8 weeks of age. Then, at 10 and 15 weeks of age, duodenal digesta, feces and urine were collected. Average body weight at 10 weeks of age in trial 2 was 78.9 kg for calves fed the SBM diet and 79.0 kg for those fed the HSBM diet.

### Sample collection and analytical procedure

Samples of feed, feed refusals, feces and urine were collected daily for 5 days at each experimental period in trials 1 and 2. Samples of feed, feed refusals and feces for each calf were dried at 60℃ for 48 hours, then dried samples were ground (1 mm). Daily urine samples were combined for each calf and stored at −20℃.

The day after the period of fecal and urinary collection, duodenal digesta was collected over 24 hours by the same procedure described in the previous study (Obitsu et al., 1992). The sample of duodenal digesta from each calf was divided into two portions, one of which was stored at −20℃ for later analysis of ammonia N and the other was dried at 60℃ for 72 hours. For 10 days prior to duodenal collection, chromium-mordanted CWC (Udén et al., 1980) prepared with the same hay given to calves, as a marker in duodenal digesta, was given orally with diets at 15 g/d. The amount of digesta flowing to the duodenum was corrected by recovery of chromium. The quantity of BN entering the duodenum was estimated with diaminopimelic acid (DAPA), as a bacterial marker in the duodenal digesta, assuming that 1 g DAPA was equivalent to 18 g BN (Hutton et al., 1971). Rumen degradable nitrogen (RDN) and undegradable nitrogen (UDN) entering the duodenum were estimated by the same procedure as described previously (Obitsu et al., 1992).

Organic matter, N, chromium and DAPA were analyzed by the procedures described previously (Obitsu et al., 1992). Ammonia N was determined by steam-distillation. Data for each digestion trial was analyzed as a split-plot design (Steel and Torrie, 1980) with treatments (diets) as main plots and age as sub-plots (where $p < 0.05$ was accepted as significant). Means were separated using t-test when significant treatment or treatment × age effects ($p < 0.05$) were detected.

### *In situ* degradability

*In situ* degradability of protein of the concentrate diets used in the digestion trials 1 and 2 was determined by a nylon bag technique with a Holstein steer (body weight 300 kg) fitted with a ruminal cannula. The steer was fed at 6.0 kg/d of a mixed ration containing formula feed and chopped orchardgrass hay with a ratio 6:4. The nylon bag was made of 300 mesh (pore size, 48 μm) nylon fabric. The bag was 7 × 15 cm in size and contained 2 g of the

concentrates ground through 3 mm screen and 2 steel balls as a weight. Bags, in duplicate, were incubated in the rumen for 3, 6, 9, 15, 24 and 48 hours. After incubation, the bags were washed in running water until the rinsing water was colourless, and then residuals were dried in a forced air oven at 55℃ for 48 hours. Air dried residuals were determined for nitrogen by the Kjeldhal method (A.O.A.C., 1975).

The rate of disappearance of protein (p) in the rumen was expressed as a function of incubation time (t), fitting the following equation (Ørskov and McDonald, 1979);

$p = a + b(1-e^{-ct})$,

where 'a' is soluble component which is rapidly washed out of the bag, 'b' is potentially degradable fraction and 'c' is degradation rate of 'b' fraction. Values for constants, a, b and c were determined using the iterative least-squares method. The effective degradability (dg) was calculated with the following equation, $dg = a + bc/(c+k)$, using the values obtained for constants of a, b and c (Ørskov and McDonald, 1979). In the above calculation, the rate of passage of ruminal digesta (k) was assumed to be 0.04 of that obtained from steers (Oura et al., 1986) fed similar diets to those used in the present study.

## Results

### *In situ* degradability

The proportion of soluble fraction of dietary protein (a) and the degradation rate of potentially degradable fraction (c) were greater for the SBM diet than those for the HSBM diet (table 2). Effective protein degradability was estimated to be 65% for the SBM diet and 52% for the HSBM diet.

### Digestion and nitrogen balance in trial 1

Organic matter intake and apparent OM digestion in the rumen and total digestive tract (kg/d) did not differ between the diets, but increased ($p < 0.01$, 0.05 and 0.01, respectively) from 10 to 13 weeks (table 3). Apparent OM digestibility in the rumen, intestine and total digestive tract (% of intake) also did not differ between the diets. Apparent OM digestibility in the rumen and total digestive tract tended to increase ($p < 0.20$) with advancing age.

TABLE 2. CONSTANT VALUES OF REGRESSION EQUATION[1] FOR PREDICTING THE *IN SITU* PROTEIN DEGRADABILITY OF CONCENTRATE DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM)

| Diets | Constant values | | | Effective degradability[2] (%) |
|---|---|---|---|---|
| | a | b | c | |
| SBM | 24.0 | 76.0 | 0.047 | 65.1 |
| HSBM | 10.2 | 89.8 | 0.035 | 52.1 |

[1] $p = a + b \cdot (1-e^{-ct})$, where p denotes the rate of protein degradation corresponding with the duration of the incubation time (t), and a, b and c are the constant values fitted by a least-squares procedure.

[2] Assuming a constant passage rate of 0.04.

TABLE 3. RUMINAL AND INTESTINAL DIGESTION OF ORGANIC MATTER FOR CALVES FED DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) AT 10 AND 13 WEEKS OF AGE IN TRIAL 1

| Item | Age | | | | Standard error of difference | |
|---|---|---|---|---|---|---|
| | 10 wk. | | 13 wk. | | | |
| | SBM | HSBM | SBM | HSBM | Treatment | Age |
| Intake[a] (kg/d) | 1.49 | 1.45 | 1.78 | 1.69 | 0.07 | 0.06 |
| Flow to the duodenum (kg/d) | 0.75 | 0.76 | 0.77 | 0.82 | 0.05 | 0.05 |
| Fecal output (kg/d) | 0.49 | 0.45 | 0.47 | 0.48 | 0.05 | 0.04 |
| Apparent digestion in: | | | | | | |
| Rumen[b] (kg/d) | 0.74 | 0.69 | 1.02 | 0.88 | 0.08 | 0.08 |
| Intestine (kg/d) | 0.26 | 0.31 | 0.29 | 0.33 | 0.05 | 0.05 |
| Total digestive tract[a] (kg/d) | 1.00 | 1.00 | 1.31 | 1.21 | 0.03 | 0.05 |
| Apparent digestibility in: | | | | | | |
| Rumen, % of intake | 49.2 | 47.5 | 56.9 | 51.7 | 3.9 | 3.8 |
| Intestine, % of intake | 17.9 | 22.2 | 16.5 | 19.9 | 4.1 | 3.9 |
| Total digestive tract, % of intake | 67.1 | 69.7 | 73.4 | 71.6 | 2.0 | 2.0 |

[a] Age effect ($p < 0.01$). [b] Age effect ($p < 0.05$).

Nitrogen intake, N flow to the duodenum, apparent N digestion and N balance in trial 1 are shown in table 4. Nitrogen intake did not differ between the diets, but the flow of total N and non-ammonia N (NAN) to the duodenum was greater ($p < 0.08$ and 0.05, respectively) for the HSBM diet than for the SBM diet. Bacterial N entering the duodenum did not differ between the diets. Undegradable N flow to the duodenum tended to be greater for the HSBM diet than for the SBM diet, but the difference was not significant ($p > 0.05$). Nitrogen intake increased ($p < 0.01$) from 10 to 13 weeks, but the flow of total N, NAN and UDN to the duodenum did not differ between the ages.

Apparent N disappearance from the rumen (g/d or % of intake) tended to be greater ($p < 0.10$) for the SBM diet than for the HSBM diet (table 4). The extent of the difference between the diets was greater at 13 weeks than at 10 weeks. Apparent N disappearance from the intestine (g/d or % of intake) tended to be greater ($p < 0.15$) for the HSBM diet than for the SBM diet. Apparent N digestion in the total digestive tract (g/d) did not differ between the diets, but that was greater ($p < 0.01$) at 13 weeks than at 10 weeks. Although apparent N digestibility in the total digestive tract at 10 weeks did not differ between the diets, it was greater ($p < 0.05$) for the SBM diet than for the HSBM diet at 13 weeks.

Urinary N excretion and N retention did not differ between the diets (table 4). When expressed as a percentage of intake, urinary N increased ($p < 0.05$) from 10 to 13 weeks, but N retention decreased ($p < 0.05$).

TABLE 4. RUMINAL AND INTESTINAL DIGESTION, URINALY EXCRETION AND RETENTION OF NITROGEN (N) FOR CALVES FED DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) AT 10 AND 13 WEEKS OF AGE IN TRIAL 1

| Item | Age | | | | Standard error of difference | |
|---|---|---|---|---|---|---|
| | 10 wk. | | 13 wk. | | | |
| | SBM | HSBM | SBM | HSBM | Treatment | Age |
| Intake[b] (g/d) | 36.0 | 36.2 | 42.7 | 41.9 | 0.8 | 0.7 |
| Flow to the duodenum (g/d) | | | | | | |
| Total N | 33.0 | 38.6 | 31.8 | 40.2 | 2.9 | 3.1 |
| Non-ammonia N[a] | 30.2 | 36.2 | 29.2 | 36.8 | 2.4 | 3.1 |
| Bacterial N | 16.1 | 18.6 | 19.7 | 21.2 | 1.5 | 1.4 |
| Undegradable dietary N | 14.1 | 17.6 | 9.5 | 15.6 | 3.4 | 3.4 |
| Fecal output[d] (g/d) | 12.3 | 10.6 | 11.8 | 13.7 | 1.4 | 0.6 |
| Apparent disappearance in: | | | | | | |
| Rumen (g/d) | 3.0 | −2.4 | 10.9 | 1.7 | 3.3 | 3.0 |
| % of intake | 8.2 | −6.8 | 25.6 | 3.7 | 8.6 | 7.7 |
| Intestine (g/d) | 20.8 | 28.1 | 20.0 | 26.4 | 3.5 | 2.6 |
| % of intake | 57.7 | 77.8 | 46.6 | 63.6 | 10.1 | 6.8 |
| Apparent digestion in | | | | | | |
| Total digestive tract (g/d)[b] | 23.8 | 25.7 | 30.9 | 28.2 | 0.9 | 0.8 |
| % of intake[d] | 65.9 | 71.0 | 72.4 | 67.3 | 3.1 | 1.6 |
| Urinary excretion (g/d)[b] | 9.9 | 9.3 | 15.1 | 15.2 | 1.2 | 0.8 |
| % of intake[c] | 27.4 | 25.7 | 35.4 | 36.5 | 3.4 | 2.2 |
| Retention (g/d) | 13.9 | 16.4 | 15.8 | 12.9 | 1.5 | 1.2 |
| % of intake[c] | 38.5 | 45.3 | 37.0 | 30.8 | 3.8 | 2.6 |

[a] Treatment effect ($p < 0.05$).

[b] Age effect ($p < 0.01$).

[c] Age effect ($p < 0.05$).

[d] Treatment × age interaction ($p < 0.05$).

### Digestion and nitrogen balance in trial 2

Ruminal and intestinal digestion of OM in trial 2 is shown in table 5. Organic matter intake at 10 weeks was greater ($p < 0.05$) for the SBM diet than for the HSBM diet, but that at 15 weeks did not differ between the diets. Although ruminal OM digestibility (% of intake) did not

differ significantly ($p > 0.05$) between the diets, it tended to be greater ($p < 0.10$) for the SBM diet than for the HSBM diet at 10 weeks. Apparent OM digestion in the intestine (kg/d) did not differ between the diets. Apparent OM digestion in the total digestive tract (kg/d) at 10 weeks were greater ($p < 0.05$) for the SBM diet than for the HSBM diet, but that at 15 weeks did not differ between the diets. Apparent OM digestibility in the total digestive tract did not differ between the diets.

Organic matter intake, apparent OM digestion in the rumen and total digestive tract increased ($p < 0.01$, 0.05 and 0.01, respectively) from 10 to 15 weeks (table 5). Apparent OM digestibility in the rumen tended to be higher ($p < 0.08$) at 15 weeks than at 10 weeks, but apparent OM digestibility in the total digestive tract did not differ between the ages.

TABLE 5. RUMINAL AND INTESTINAL DIGESTION OF ORGANIC MATTER FOR CALVES FED DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) AT 10 AND 15 WEEKS OF AGE IN TRIAL 2

| Item | Age | | | | Standard error of difference | |
|---|---|---|---|---|---|---|
| | 10 wk. | | 15 wk. | | | |
| | SBM | HSBM | SBM | HSBM | Treatment | Age |
| Intake [a] (kg/d) | 1.85 | 1.65 | 2.10 | 2.27 | 0.07 | 0.07 |
| Flow to the duodenum (kg/d) | 0.99 | 1.02 | 1.07 | 1.10 | 0.05 | 0.05 |
| Fecal output (kg/d) | 0.48 | 0.45 | 0.52 | 0.54 | 0.04 | 0.03 |
| Apparent digestion in: | | | | | | |
| Rumen[b] (kg/d) | 0.86 | 0.64 | 1.03 | 1.17 | 0.05 | 0.10 |
| Intestine (kg/d) | 0.51 | 0.57 | 0.55 | 0.56 | 0.05 | 0.05 |
| Total digestive tract [a,c] (kg/d) | 1.38 | 1.21 | 1.59 | 1.73 | 0.05 | 0.05 |
| Apparent digestibility in: | | | | | | |
| Rumen, % of intake | 46.1 | 38.0 | 49.1 | 51.6 | 2.5 | 3.7 |
| Intestine, % of intake | 28.0 | 35.1 | 26.4 | 24.5 | 3.0 | 3.7 |
| Total digestive tract, % of intake | 74.4 | 73.2 | 75.5 | 76.1 | 1.7 | 1.3 |

[a] Age effect ($p < 0.01$).
[b] Age effect ($p < 0.05$).
[c] Treatment × age interaction ($p < 0.05$).

Nitrogen intake, N flow to the duodenum, apparent N digestion and N balance in trial 2 are shown in table 6. Nitrogen intake at 10 weeks was greater ($p < 0.05$) for the SBM diet than for the HSBM diet, but that at 15 weeks did not differ between the diets. The flow of total N, NAN, BN and UDN to the duodenum did not differ between the diets. Nitrogen intake, the flow of total N, NAN and UDN to the duodenum increased ($p < 0.01$, 0.01, 0.01 and 0.05, respectively) from 10 to 15 weeks, but BN flow did not differ between the ages.

Apparent N disappearance from the rumen and intestine (g/d or % of intake) were not affected by the diets (table 6). Apparent N digestion in the total digestive tract (g/d or % of intake) did not differ between the diets. Apparent N digestion in the total digestive tract (g/d) increased ($p < 0.01$) from 10 to 15 weeks of age, but N digestibility in the total digestive tract was not affected by ages. Urinary N excretion and N retention did not differ between the diets (table 6).

## Discussion

### *In situ* degradability

Heat treatment of soybean meal is effective in protecting dietary protein from ruminal degradation. Thomas et al. (1979) suggested, on the basis of an *in vitro* study and a growth trial with rats, that heating of soybean meal at 138 up to 149℃ was needed to minimize ruminal degradation of protein without appreciably injuring postruminal availability. However, overheating probably decreases postruminal availavility of dietary protein escaping ruminal degradation. Roasting of soybean meal at 145℃ increased acid detergent insoluble N which is less digested in the small intestine (Plegge et al., 1985). In this study, thus, heat treatment of soybean meal was conducted at 130℃ for 2 hours due to the prevention of overheating. Although the temperature of heat treatment was lower and the time was shorter in this study as compared with the optimal condition proposed by Thomas

et al. (1979), *in situ* protein degradability of the concentrate diet containing heated soybean meal was lower by 13 percentage unit than that containing unheated soybean meal.

TABLE 6. RUMINAL AND INTESTINAL DIGESTION, URINALY EXCRETION AND RETENTION OF NITROGEN (N) FOR CALVES FED DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) AT 10 AND 15 WEEKS OF AGE IN TRIAL 2

| Item | Age | | | | Standard error of difference | |
|---|---|---|---|---|---|---|
| | 10 wk. | | 15 wk. | | | |
| | SBM | HSBM | SBM | HSBM | Treatment | Age |
| Intake [a,c] (g/d) | 53.5 | 49.2 | 60.8 | 64.9 | 1.7 | 1.6 |
| Flow to the duodenum (g/d) | | | | | | |
| Total N [a] | 47.9 | 50.8 | 64.0 | 60.4 | 2.8 | 2.8 |
| Non-ammonia N [a] | 46.8 | 48.5 | 62.0 | 58.2 | 2.2 | 3.0 |
| Bacterial N | 30.8 | 29.2 | 35.8 | 30.8 | 2.9 | 3.5 |
| Undegradable dietary N [b] | 16.1 | 19.4 | 26.3 | 27.4 | 2.0 | 3.5 |
| Fecal output (g/d) | 15.4 | 13.7 | 17.8 | 17.5 | 1.2 | 1.6 |
| Apparent disappearance in: | | | | | | |
| Rumen (g/d) | 5.6 | −1.5 | −3.2 | 4.6 | 2.7 | 3.5 |
| % of intake | 10.2 | −4.0 | −5.2 | 7.0 | 4.8 | 6.1 |
| Intestine (g/d) [b] | 32.5 | 37.1 | 46.2 | 42.8 | 3.1 | 2.9 |
| % of intake | 61.0 | 76.4 | 76.0 | 66.0 | 5.8 | 6.5 |
| Apparent digestion in: | | | | | | |
| Total digestive tract (g/d) [a] | 38.1 | 35.6 | 43.0 | 47.4 | 1.5 | 1.5 |
| % of intake | 71.2 | 72.4 | 70.8 | 73.0 | 2.0 | 2.5 |
| Urinary excretion (g/d) [a] | 12.5 | 11.3 | 18.6 | 17.2 | 0.9 | 1.5 |
| % of intake | 23.4 | 23.1 | 31.0 | 26.5 | 2.2 | 2.7 |
| Retention (g/d) | 25.6 | 24.3 | 24.3 | 30.2 | 2.3 | 1.9 |
| % of intake | 47.8 | 49.3 | 39.8 | 46.5 | 3.1 | 3.3 |

[a] Age effect ($p < 0.01$).
[b] Age effect ($p < 0.05$).
[c] Treatment × age interaction ($p < 0.05$).

### Digestion of organic matter

Ruminal OM digestibility tended to increase from 10 to 13 weeks of age in trial 1, and increased from 10 to 15 weeks of age in trial 2. Thus, the ruminal OM digestibility in calves weaned at 6 weeks of age probably reaches the mature level after 4 months of age. However, Leibholz (1975a) reported that the ruminal digestibility of dry matter and acid detergent fiber in calves weaned at 5 weeks of age reached the adult level by 8 and 13 weeks of age, respectively, when calves were fed a high concentrate diet containing barley and soybean meal *ad libitum*. This difference between our results and other (Leibholz, 1975a) was probably due to the difference in diets used.

Ruminal OM digestibility was not affected by feeding heated soybean meal in trial 1, but was lower for the HSBM diet than for the SBM diet at 10 weeks in trial 2. When calves are fed diets containing urea or soybean meal which has high degradability, ruminal digestibility of dry matter is not affected by the protein sources (Leibholz, 1975b). Thus, for a few weeks after weaning, the extent of ruminal OM digestion in calves fed diets at high levels might have depended on the degradability of dietary protein.

### Nitrogen utilization

In trial 1, apparent N disappearance in the rumen and flow of total N and NAN to the duodenum in calves fed the HSBM diet seemed to reflect *in situ* degradability of dietary protein, but not in trial 2. The ruminal degradability of dietary protein decreases with an increase in feed intake due to a reduction in the retention time of the ruminal digesta (National Research Council, 1985). In addition, a fall in ruminal pH with high concentrate diets

reduces ruminal degradability of soybean meal (Loerch et al., 1983). Although the ruminal pH and the retention time of ruminal digesta were not measured in this study, actual degradability of the SBM diet may have been reduced with increases of concentrate ratio and of feeding level in trial 2.

In order to estimate the efficiency of BN synthesis in the rumen in trials 1 and 2, duodenal BN flow per apparently digested OM in the rumen and per RDN intake were calculated and summarized in table 7. In trial 1, BN flow to the duodenum (table 4) and BN synthesis per apparently digested OM in the rumen (table 7) did not differ between the diets, but BN synthesis per RDN intake tended to be lower for calves fed the SBM diet than for the HSBM diet (table 7). This lower conversion ratio of RDN to BN with the SBM diet in trial 1 indicates that RDN supply may be beyond the N requirements of ruminal microbes. Consequently, net N loss from the rumen was greater for calves fed the SBM diet than for the HSBM diet (table 4). In trial 2, however, the conversion ratio of RDN to BN (table 7) and net N loss from the rumen (table 6) did not differ between the diets. An increase in supply of energy for ruminal microbes with an elevation in the feeding level (Zinn and Owens, 1983) may account for the improvement of the efficiency of ruminal BN synthesis in calves fed the SBM diet.

TABLE 7. EFFICIENCY OF BACTERIAL NITROGEN (BN) SYNTHESIS IN THE RUMEN FOR CALVES FED DIETS CONTAINING SOYBEAN MEAL (SBM) OR HEATED SOYBEAN MEAL (HSBM) IN TRIAL 1 AND 2

| Item | Age | | | | Standard error of difference | |
|---|---|---|---|---|---|---|
| | 10 wk. | | 13[1] or 15[2] wk. | | | |
| | SBM | HSBM | SBM | HSBM | Treatment | Age |
| Trial 1 | | | | | | |
| BN/ADOM[3] (g/kg) | 22.9 | 27.5 | 19.8 | 21.2 | 2.2 | 3.5 |
| BN/RDN[4] (%) | 77.7 | 98.1 | 59.5 | 85.0 | 14.4 | 8.7 |
| Trial 2 | | | | | | |
| BN/ADOM[3] (g/kg) | 36.9 | 49.4 | 35.7 | 26.5 | 5.3 | 6.5 |
| BN/RDN[4] (%) | 82.7 | 99.3 | 102.8 | 82.4 | 6.8 | 9.2 |

[1] Trial 1.
[2] Trial 2.
[3] BN synthesis (g) per kg apparently digested OM in the rumen.
[4] Percentage of BN synthesis among rumen degradable nitrogen intake.

Furthermore, the ability of BN synthesis in the rumen was considered to reach the mature level by 10 weeks of age, because the efficiency of BN synthesis seemed to be independent of age in both trial 1 and 2 (table 7). Quigley et al. (1985) reported that the contribution of BN to total N in abomasal contents was similar to that of mature ruminants by 5 and 7 weeks of age for calves weaned at 4 and 8 weeks, respectively.

In trial 1, N retention did not differ between the diets although N disappearance from the intestine tended to be greater for calves fed the HSBM diet than for the SBM diet. Koelen and Paterson (1986) found that the total amino acids disappearance from the small intestine was greater for calves fed toasted soybean meal or corn gluten meal than for those fed soybean meal, but N retention did not differ among these protein sources. In their experiment (Koelen and Paterson, 1986), the amount of intestinal disappearance of lysine, which is probably the limiting amino acid for growth, was not affected by these protein sources. Although amino acid disappearance from the small intestine was not measured in the present study, the disappearance of the limiting amino acids, e.g. lysine and (or) methionine, from the small intestine may not have differed between the diets. The other reason for the lack of difference in N retention between the diets in trial 1 could be that the energy supply to the calves fed the HSBM diet may have been relatively insufficient to meet the amount of N absorbed from the small intestine. This assumption is supported by an increase in N retention with an increase in the feeding level in trial 2, as compared with trial 1.

In conclusion, feeding heated soybean meal to early weaned calves under the low feeding level decreases net N loss from the rumen and increases intestinal N digestion without decreasing BN synthesis and OM digestion in the rumen. Under the high feeding level, however, the diet

containing soybean meal as well as that containing heated soybean meal may be utilized efficiently by early weaned calves due to a decrease in protein degradability of soybean meal.

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