# INFLUENCE OF PROCESSING ON THE SITE AND EXTENT OF DIGESTION OF HIGH MOISTURE BARLEY IN CATTLE

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## Summary

Two experiments were conducted to evaluate the effect of processing and method of ensiling on the digestion and utilization of high moisture barley (HMB) in cattle. In experiment 1, four Holstein heifers were assigned in a Latin square design to diets containing 70% barley, 25% alfalfa hay and 5% supplement on a dry matter (DM) basis. Diets differed only in the type of barley fed: rolled dry barley (R-DB), rolled HMB (R-HMB), ground HMB (G-HMB) or unprocessed HMB (U-HMB). In experiment 2, three Holstein steers were fed 85.2% barley, 10.2% whole plant barley silage and 4.6% supplement on a DM basis. Again, diets differed only in the type of barley fed: R-DB, rolled HMB from a pit silo (Pit-HMB) or rolled HMB from a Harvestore silo (HAV-HMB). In experiment 1, digestibility coefficients for animals fed R-HMB were significantly higher than observed for U-HMB. While not significant, a similar trend for decreased digestibility was observed for R-DB and G-HMB. Animals fed HMB had significantly lower ruminal propionate concentrations. In addition, the rate of degradation of the degradable DM and crude protein (CP) fractions was slower for HMB than for dry barley. In experiment 2, a trend to lower digestibility coefficients was observed for animals fed R-DB compared to those fed Pit-HMB or HAV-HMB. Ruminal propionate concentrations for animals fed R-DB also tended to be higher than for those fed the HMB diets. Dry matter and CP disappearances from nylon bags was substantially lower for Pit-HMB than for R-DB or HAV-HMB.

The results suggest that replacement of dry barley by rolled or unprocessed HMB in the diet of animals fed high grain diets may contribute to a more stable rumen environment.
(Key Words: High Moisture Barley, Digestion, Processing, Cattle)

## Introduction

Barley is an important ingredient in the diet of dairy and beef cattle in many areas of the world. Some is harvested as high moisture barley (HMB) at 20 to 30% moisture and ensiled. Recent excellent reviews (Ørskov, 1986; Owens et al., 1986; Rooney and Pflugfelder, 1986; Theurer, 1986) have discussed the effect of processing on the digestion and utilization of high starch grains by ruminants. While these reviews provide extensive data on factors affecting utilization of corn and sorghum by cattle, data for other high starch grains, such as barley, are extremely limited (Theurer, 1986).

Data for dry barley generally show substantial increases in digestibility due to grinding (Nicholson et al., 1971) and rolling (MacLeod et al., 1972). Similar data for HMB is not available, although lower digestion with ground HMB compared to rolled HMB has been reported (Kennelly et al., 1988). Kung et al. (1983) reported that whole barley (82% DM) was not degraded in nylon bags incubated in the rumen, but treatment of whole barley with NaOH gave results similar to grinding. Beneficial effect of ammonia treatment of HMB has been attributed to a reduced rate of ruminal starch digestion and increased starch flow to, and digestion in, the small intestine (Robinson and Kennelly, 1988a; 1988b; 1989).

The objectives of this study were to examine the influence of processing (whole, ground or rolled) and storage system (pit or Harvestore silo) on digestion and utilization of HMB in cattle.

## Materials and Methods

### Animals, Diets and Feeding

*Experiment 1*

Four Holstein heifers (average weight 315±45

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kg) fitted with a permanent cannula in the rumen and duodenum were assigned in a 4 x 4 Latin square design to four dietary treatments. Heifers were maintained in metabolic crates during each Latin square period (14-d adjustment, 5-d total fecal collection and 3-d ruminal and duodenal sampling), and were allowed a minimum of 3-d rest period in pens between each Latin square period.

Urine was diverted by attaching a flexible tube to a plastic hardness, which was constructed around the vulva and held in place with a multi-purpose adhesive. Experimental diets consisted of 70% barley, 25% alfalfa hay and 5% supplement on a DM basis. Diets differed only in the type of barley fed: rolled dry barley (R-DB), unprocessed whole HMB (U-HMB), rolled HMB (R-HMB) and ground HMB (G-HMB) (table 1). Animals were fed at 8 h intervals at a level designed to maintain about 10% oats.

*Experiment 2*

Three mature Holstein steers with ruminal, duodenal and ileal cannulae were allotted to R-DB, Pit-HMB, or HAV-HMB diets. Animals were fed 85.2% barley, 10.2% whole plant barley silage and 4.6% supplement (DM basis), 12 times daily in equal amounts. Pit-HMB, HAV-HMB and barley silage, obtained from a commercial farm, were all stored in plastic bags at 4°C under $CO_2$ gas. Pit-HMB was rolled prior to ensiling while the HAV-HMB was ensiled whole and rolled through the same roller as the Pit-HMB upon removal from the Harvestore. The experimental design was a 3 x 3 Latin square with each period consisting of a minimum 7-d adjustment period, a 5-d digesta and fecal collection period, and a 2-d nylon bag study. Animals were allowed a minimum of 7-d rest period between each period.

TABLE 1. FORMULATION AND CHEMICAL ANALYSIS OF DIETS, EXPERIMENT 1

| Items | Treatment[1] | | | |
|---|---|---|---|---|
| | R-DB | R-HMB | G-HMB | U-HMB |
| Ingredients (% dry matter basis) | | | | |
| HMB[2] | – | 70 | 70 | 70 |
| Dry barley | 70 | – | – | – |
| Hay | 25 | 25 | 25 | 25 |
| Supplement[3] | 5 | 5 | 5 | 5 |
| Chemical analysis (% dry matter basis) | | | | |
| Organic matter | 93.6 | 93.2 | 93.2 | 93.2 |
| Dry matter | 86.9 | 77.4 | 77.4 | 77.4 |
| Crude protein | 15.3 | 15.3 | 15.3 | 15.3 |
| Starch | 44.4 | 46.2 | 46.2 | 46.2 |
| Gross energy (MJ/kg) | 18.4 | 18.6 | 18.6 | 18.6 |

[1]Treatments were rolled dry barley (R-DB), rolled HMB (R-HMB), ground high moisture barley (G-HMB) and unprocessed HMB (U-HMB).

[2]High moisture barley.

[3]Containing %: canola meal 50.5; barley 15.5; urea 5.0; molasses 3.0; limestone 15.0; trace mineral salt 10.0 (composition %: salt 94; Cu .25; Co .004; I .01; Mn .35; Zn .75 and Se .025); vitamin A, 750,000 IU; vitamin D, 120,000 IU; vitamin E, 750 IU.

**Ruminal, Intestinal and Fecal Sampling**

Ruminal, duodenal and ileal (experiment 2) digesta (150 ml of each) were collected twice daily, at 1 and 4 h post-feeding in experiment 1 and at 1 and 1.5 h post-feeding in experiment 2, during the final 3 d of each experimental period. pH was measured immediately, 5% saturated mercury chloride (V/V) was added, and samples were stored at −22°C until analysis. Data reported are mean values for the two sampling times.

Total fecal material was collected once daily from each animal and weighed. A 5% subsample from each daily collection was pooled for each period on a per animal basis prior to being dried in a forced-air oven at 65°C for 48 h. Dried samples were ground through a 1 mm screen prior to analysis.

**In situ DM and CP Disappearance**

Bags (7 x 10 cm) were made from nylon cloth (B and SH Thompson and Co. Ltd., Montreal) having an average mesh size of 48 μm. The nylon cloth was sewn with a double row of stitches, with rounded corners, to allow easy removal of particulate matter. Barley was from the same batch as that being fed to the animals, and was not subjected to further processing prior to being placed in nylon bags. In experiment 1, a total of 40 bags (four animals x five incubation times x duplicate samples) were prepared for each of the four test feeds; R-DB, R-HMB, G-HMB and U-HMB. In experiment 2, 12 bags (three animals x two incubation times x duplicate samples) were prepared for each test feed; R-DB, Pit-HMB and HAV-

HMB. Bags were tied to a 70 cm main line, one end of which was attached to a 250 mL sand-filled bottle while the other end was secured at the rumen cannula. The bags were suspended in the ventral sac of the rumen for 4, 8, 12 and 24 h in experiment 1, and for 12 and 24 h in experiment 2.

At the end of each incubation time two bags were removed from the rumen and washed under running tap water until the rinsing water was colorless. An additional two bags, prepared and washed as outlined above, were used for zero time values. Washed nylon bags were dried in a forced-air oven at 65°C for 48 h. Bag contents were subjected to Kjeldahl N analysis (AOAC, 1980). The percent disappearance of DM and CP at each incubation time was calculated from the proportion remaining after incubation in the rumen.

In experiment 1, disappearing DM and CP were fitted separately by individual animal and test feed to the equation $a + b\ (1 - e^{-ct})$ (Ørskov and McDonald, 1979) by an iterative least-square procedure (Statistical Analysis Systems, 1982). Best fit values were chosen using the smallest sum of squares after 10 iterations. Effective degradability of DM (EDDM) and CP (EDCP) were also calculated using the equation $a + (bc/(c + r))$ (Ørskov and McDonald, 1979), where r represents the estimated fractional ruminal outflow rate.

**Chemical Analysis**

Determination of DM, organic matter (OM), starch, energy and N were according to AOAC (1980). Dry matter content of HMB was calculated on the basis of water content as measured by gas chromatography (Fenton et al., 1981). Starch analysis were by acid hydrolysis (AOAC, 1980) and the Nelson-Somogyi (Hawk's, 1964) method

TABLE 2. INFLUENCE OF ROLLED DRY BARLEY (R-DB), UNPROCESSED HIGH MOISTURE BARLEY (U-HMB), ROLLED HMB (R-HMB), AND GROUND HMB (G-HMB) ON RUMEN VOLATILE FATTY ACID (VFA) CONCENTRATIONS AND PROPORTIONS, PH AND $NH_3$-N CONCENTRATIONS, EXPERIMENT 1

| Items | Treatment | | | | |
|---|---|---|---|---|---|
| | R-DB | U-HMB | R-HMB | G-HMB | SEM[1] |
| VFA concentrations (mM) | | | | | |
| Acetate | 65.00 | 60.20 | 60.50 | 64.20 | 3.57 |
| Propionate | 36.70[a] | 18.50[c] | 28.80[ab] | 25.30[bc] | 2.43 |
| Isobutyrate | 0.90 | 1.03 | 0.79 | 1.02 | 0.10 |
| N-butyrate | 11.40 | 13.44 | 12.90 | 13.70 | 0.83 |
| Isovalerate | 1.20 | 2.30 | 1.41 | 1.95 | 0.33 |
| N-valerate | 2.25 | 1.94 | 2.80 | 1.86 | 0.29 |
| Total VFA | 117.80 | 101.40 | 108.20 | 104.10 | 5.20 |
| Molar proportions (%) | | | | | |
| Acetate | 55.40 | 63.70 | 55.50 | 57.80 | 1.62 |
| Propionate | 30.90[a] | 18.00[b] | 28.10[a] | 24.40[a] | 1.93 |
| Isobutyrate | 0.77 | 1.04 | 0.72 | 0.99 | 0.10 |
| N-butyrate | 9.70[b] | 13.00[a] | 11.80[a] | 13.10[a] | 0.38 |
| Isovalerate | 1.39 | 2.30 | 1.28 | 1.88 | 0.27 |
| N-valerate | 1.90 | 1.93 | 2.59 | 1.78 | 0.29 |
| Acetate/propionate | 1.88[a] | 3.69[a] | 2.30[a] | 2.60[a] | 0.26 |
| pH | 5.58 | 5.90 | 5.64 | 5.85 | 0.1 |
| $NH_3$-N (mg/L fluid) | 122.9 | 128.6 | 101.9 | 112.3 | 13.1 |

[1]Standard error of means.

[a-c]Means with the same letters in same row are not significantly different ($p < .05$).

of glucose analysis. Ammonia in ruminal and duodenal samples was determined according to Fawcett and Scott (1960). For the determination of volatile fatty acids (VFA), strained rumen fluid (2.0 mL) was acidified with 0.5 mL of 25% (W/V) metaphosphoric acid, 0.5 mL of 0.2% (W/V) n-caproic acid was added as an internal standard, samples were centrifuged (17,000 x g) for 10 min and the supernatant was analysed for VFA by gas chromatography (Baumgardt, 1964).

### Statistical Analysis

Data were analysed using analysis of variance procedures with treatment, animal and period as factors. When treatment effects were significant ($p < .05$), treatment means were compared using Student-Newman-Keuls multiple range test (Steel and Torrie, 1980).

## Results and Discussion

### Experiment 1

Data on the influence of treatment on VFA concentrations and molar proportions, ruminal pH and $NH_3$-N concentrations are in table 2. With the exception of propionate, treatment did not significantly influence VFA concentrations. Elevated ($p < .05$) propionate concentrations were the major factor contributing to the tendency for higher total VFA concentration observed for animals fed R-DB. Propionate and total VFA concentrations tended to be greater for R-HMB than U-HMB or G-HMB. Animals fed R DB generally had higher propionate, lower N-butyrate molar percent and lower acetate/propionate ratio compared with those fed HMB. The exceptionally low propionate concentrations observed for animals

TABLE 3. DRY MATTER AND CRUDE PROTEIN DISAPPEARANCE (%), FROM NYLON BAGS, AND EFFECTIVE DEGRADABILITY OF DRY MATTER (EDDM) AND CRUDE PROTEIN (EDCP) OF ROLLED DRY BARLEY (R-DB), UNPROCESSED HIGH MOISTURE BARLEY (U-HMB), ROLLED HMB (R-HMB) AND GROUND HMB (G-HMB), EXPERIMENT 1

| Items | Incubation time (h) | Treatment | | | | |
|---|---|---|---|---|---|---|
| | | R-DB | U-HMB | R-HMB | G-HMB | SEM[1] |
| | | | | Dry matter | | |
| Disappearance rate | 0 | 8.0[b] | 3.2[c] | 16.8[a] | 16.4[a] | 1.7 |
| | 4 | 48.0[a] | 2.9[b] | 42.0[a] | 39.3[a] | 4.4 |
| | 8 | 59.8[a] | 3.4[b] | 53.3[a] | 54.6[a] | 3.7 |
| | 12 | 68.0[a] | 3.5[b] | 59.0[a] | 63.7[a] | 3.2 |
| | 24 | 76.1[a] | 5.5[b] | 68.3[a] | 74.1[a] | 3.5 |
| EDDM .05[2] | | 57.7 | – | 53.2 | 56.8 | – |
| EDDM .08 | | 50.8 | – | 47.3 | 49.0 | – |
| | | | | Crude protein | | |
| Disappearance rate | 0 | 2.4[b] | 4.9[c] | 21.0[a] | 17.4[a] | 3.5 |
| | 4 | 44.3[a] | 4.5[b] | 37.8[a] | 38.4[a] | 4.5 |
| | 8 | 58.9[a] | 4.9[b] | 50.7[a] | 54.7[a] | 3.8 |
| | 12 | 69.6[a] | 5.0[b] | 57.0[a] | 66.4[a] | 3.4 |
| | 24 | 83.7[a] | 6.2[b] | 71.2[a] | 80.9[a] | 4.2 |
| EDCP .05[2] | | 60.2 | – | 56.9 | 62.4 | – |
| EDCP .08 | | 50.5 | – | 47.9 | 51.7 | – |

[1]Standard error of the means.
[2]Effective degradability was calculated from the a, b and c values according to the equation EDDM or EDCP = a + (bc/(c + r)) where r = fractional outflow rate.
[a-c]Means in the same row with the same letters are not significantly different ($p < .05$).

fed U-HMB may be due to a slower rate of digestion associated with restricted bacterial access to starch in unprocessed grain. The small particle size of R-DB likely contributed to the higher propionate and VFA concentrations observed for this treatment. Ruminal pH was not ($p > .05$) influenced by treatment with values ranging from 5.58 to 5.90. Ruminal ammonia concentrations (mean 116.4 mg/L) were also similar across treatments.

Ruminal VFA, pH, or $NH_3$-N concentrations can be markedly influenced by time of sampling when animals are fed once or twice a day. Less fluctuation in these ruminal parameters were expected in this experiment because of the more frequent feeding and sampling schedules used. The results of the present study and others (Ingalls et al., 1974; Kennelly et al., 1988) indicate that feeding dry barley results in greater propionate concentrations than feeding HMB.

Data on in situ DM and CP disappearance and degradation rate (table 3) show that only about 5% of U-HMB disappeared from nylon bags after 24 hr incubation, while mean DM and CP disappearance rates of the processed barley samples were 72.8 and 78.6%. Similar observation have been reported by Kung et al. (1983). In the absence of any significant loss of DM and CP over time, data for U-HMB was not subjected to non-linear analysis to determine EDDM and EDCP. Both EDDM and EDCP of R HMB tended to be lower than those of R-DB and G-HMB. Present data clearly indicate that particle size of

TABLE 4. INFLUENCE OF ROLLED DRY BARLEY (R-DB), UNPROCESSED HIGH MOISTURE BARLEY (U-HMB), ROLLED HMB (R-HMB) AND GROUND HMB (G-HMB) ON INTAKE, DIGESTIBILITY COEFFICIENTS AND FECAL, AND DUODENAL PARAMETERS, EXPERIMENT 1

| Items | Treatment | | | | |
|---|---|---|---|---|---|
| | R-DB | U-HMB | R-HMB | G-HMB | SEM[1] |
| Intake (kg/d, dry matter (DM)) | | | | | |
| Dry matter | 6.1 | 6.3 | 6.7 | 5.6 | 0.31 |
| Organic matter | 5.7 | 5.9 | 6.2 | 5.2 | 0.29 |
| Crude protein | 0.93 | 0.96 | 1.02 | 0.86 | 0.05 |
| Starch | 2.70 | 2.90 | 3.08 | 2.59 | 0.07 |
| Duodenal parameters | | | | | |
| $NH_3$-N (mg/L)[2] | 62.7 | 49.5 | 54.2 | 50.6 | 5.8 |
| Starch (% of DM) | 7.39 | 11.64 | 6.50 | 8.50 | 1.91 |
| Organic matter (% of DM) | 83.2 | 84.0 | 83.2 | 83.9 | 1.4 |
| Crude protein (% of DM) | 27.6 | 22.6 | 25.0 | 24.1 | 1.2 |
| Fecal parameters | | | | | |
| pH | 6.75 | 6.90 | 6.89 | 7.01 | 0.14 |
| Organic matter (%) | 88.6 | 88.6 | 86.5 | 86.5 | 0.60 |
| Crude protein (%) | 14.5 | 13.9 | 15.2 | 15.0 | 0.39 |
| Starch (%) | $3.2^{b}$ | $14.0^{c}$ | $3.6^{b}$ | $2.2^{a}$ | 0.38 |
| Apparent digestibilities (%) | | | | | |
| Dry matter | $69.4^{ab}$ | $66.0^{b}$ | $74.7^{a}$ | $68.8^{b}$ | 1.42 |
| Crude protein | $71.3^{ab}$ | $68.9^{ab}$ | $75.1^{a}$ | $69.6^{ab}$ | 1.56 |
| Organic matter | $71.7^{ab}$ | $67.7^{b}$ | $76.5^{a}$ | $71.0^{ab}$ | 1.34 |
| Starch | $97.8^{a}$ | $89.7^{b}$ | $97.9^{a}$ | $98.5^{a}$ | 0.21 |
| Energy | $68.5^{b}$ | $66.4^{b}$ | $74.3^{a}$ | $68.1^{b}$ | 1.60 |

[1]Standard error of means.
[2]Ammonia nitrogen.
[a-c]Means with the same letters in the same row are not significantly different ($p < .05$).

HMB has an important modulating effect on rates of ruminal degradation. Decreasing particle size of HMB (whole < rolled < ground) increased degradation rate of DM and CP. Similar effects of particle size of HMB on ruminal degradation rate have been reported previously (Kennelly et al., 1988); in situ DM and CP disappearance was less for R-HMB than for G-HMB.

Dry matter intake ranged from 5.6 (G-HMB) to 6.7 (R-HMB) kg.d$^{-1}$ (table 4), while not significant ($p > .05$), variation in DM intake resulted in corresponding differences in DM, CP and starch intake. Duodenal parameters were not influenced ($p > .05$) by treatment, however, there was a tendency for elevated starch concentrations in the duodenal digesta of animals fed G-HMB.

No significant treatment effect on fecal OM and CP concentration or fecal pH was observed. However, fecal starch output (kg.d$^{-1}$) was significantly ($p < .05$) influenced by treatment with values for U-HMB significantly higher ($p < .05$) than those for R-DB and R-HMB, which in turn were higher ($p < .05$) than those observed for animals fed G-HMB.

Digestibility coefficients for DM, OM, starch, and energy were influenced ($p < .05$) by treatment. In general, digestibility values were highest for animals fed R-HMB and least for those fed U-HMB, indicating that some form of physical processing of whole grain is required for maximal barley digestion. Nicholson et al. (1971) have reported 10 to 30% loss in digestible DM, OM and energy by feeding ensiled whole barley compared to ground ensiled barley. Similar effects have been observed by MacLeod et al. (1972) who compared the digestibility of whole and ground barley. However, in situations where the price of barley is relatively low, processing of high moisture grain may not always be justifiable on an economic basis.

**Experiment 2**

Treatment did not significantly influence total VFA concentrations or molar percent (table 5). However, ruminal propionate concentrations tended to be higher, and butyrate concentrations lower in animals fed R-DB compared to those fed HMB diets. Acetate/propionate ratio tended to be lower in steers fed R DB than in those on HMB diets. Again, results are in agreement with experiment 1 and those of Ingalls et al. (1974). In situ DM and CP disappearance was significantly lower for Pit-HMB, at both 12 and 24 h, than for HAV-HMB or R-DB. Results from the in situ study indicate that pit-HMB DM and CP was 35-45% less degradable in the rumen at 12 and 24 h incubation than the DM and CP in R-DB or HAV-HMB.

TABLE 5. INFLUENCE OF BARLEY TYPE ON RUMEN FERMENTATION CHARACTERISTICS AND ON DRY MATTER AND CRUDE PROTEIN DISAPPEARANCE IN SITU, EXPERIMENT 2

| Items | Treatment[1] | | | SEM[2] |
|---|---|---|---|---|
| | R-DB | Pit-HMB | HAV-HMB | |
| Total VFA (mmole/100 ml) | 10.3 | 8.3 | 9.5 | .57 |
| Acetate (%) | 59.4 | 60.6 | 60.8 | .17 |
| Propionate (%) | 26.3 | 18.4 | 20.0 | 2.79 |
| Butyrate (%) | 8.0 | 14.6 | 12.1 | 2.09 |
| Isobutyrate (%) | .54 | .64 | .60 | .01 |
| Isovalerate (%) | 4.1 | 4.4 | 4.9 | .47 |
| Valerate (%) | 1.6 | 1.4 | 1.6 | .17 |
| Acetate/propionate | 2.4 | 3.3 | 3.4 | .43 |
| Disappearance from nylon bags (%) | | | | |
| Dry matter (12 h) | 49.6$^{a}$ | 27.4$^{b}$ | 43.5$^{a}$ | 3.06 |
| Dry matter (24 h) | 63.6$^{a}$ | 43.5$^{b}$ | 61.1$^{a}$ | 3.27 |
| Crude protein (12 h) | 55.2$^{a}$ | 29.0$^{b}$ | 47.6$^{a}$ | 2.28 |
| Crude protein (24 h) | 72.1$^{a}$ | 43.6$^{b}$ | 67.5$^{a}$ | 3.30 |

[1]R-DB, rolled dry barley; Pit-HMB, pit high moisture barley; HAV-HMB, Harvestore high moisture barley.
[2]Standard error of means.
$^{a,b}$Means with the same superscripts in same row are not different ($p < .05$).

Concentrations of soluble, degradable and digestible nitrogen fractions in alfalfa are influenced by silo type (Janicki and Stallings, 1987) and moisture content (Merchen and Satter, 1983). These differences may arise primarily as a result of temperature differences in the ensiled material (Weiss et al., 1986). While heat may be a factor causing pit-HMB to have lower rate of degradation in the rumen, it should also be noted that HAV-HMB was ensiled whole while pit-HMB was rolled prior to ensiling. Processing prior to ensiling therefore, may also have influenced the results.

Ruminal, duodenal or ileal pH was not ($p > .05$) influenced by treatment (table 6). There was

TABLE 6. INFLUENCE OF BARLEY TYPE ON RUMINAL, DUODENAL AND ILEAL PARAMETERS, EXPERIMENT 2

| Items | Treatment[1] | | | |
|---|---|---|---|---|
| | R-DB | Pit-HMB | HAV-HMB | SEM[2] |
| Ruminal | | | | |
| pH | 6.0 | 6.3 | 6.0 | .04 |
| Ammonia-N($mgL^{-1}$) | 141.4 | 109.2 | 155.8 | 1.8 |
| Duodenal | | | | |
| pH | 3.6 | 3.6 | 3.9 | .12 |
| Ammonia-N ($mgL^{-1}$) | 58.2 | 87.9 | 92.4 | 3.29 |
| Organic matter(% of DM) | 81.2 | 80.3 | 79.9 | 1.25 |
| Crude protein (% of DM) | 26.6 | 32.0 | 30.3 | 1.40 |
| Ileal | | | | |
| pH | 7.4 | 7.4 | 7.3 | .09 |
| Ammonia-N($mgL^{-1}$) | 74.0 | 80.3 | 49.1 | 1.41 |
| Organic matter(% of DM) | 84.4 | 82.7 | 81.8 | 1.13 |
| Crude protein (% of DM) | 14.0[a] | 18.7[b] | 16.8[c] | .16 |

[1]R-DB, rolled dry barley; Pit-HMB, Pit high moisture barley; HAV-HMB, Harvestore high moisture barley.
[2]Standard error of means.
[a-c]Means with the same superscripts in same row are not different ($p < .05$).

TABLE 7. INFLUENCE OF BARLEY TYPE ON INTAKE, FECAL PARAMETERS AND DIGESTIBILITY, EXPERIMENT 2

| Items | Treatment[1] | | | |
|---|---|---|---|---|
| | R-DB | Pit-HMB | HAV-HMB | SEM[2] |
| Intake, kg/(d) | | | | |
| Dry matter | 7.0 | 7.2 | 7.0 | |
| Organic matter | 6.7 | 6.8 | 6.7 | |
| Crude protein | 1.0 | 1.0 | 1.0 | |
| Fecal parameters | | | | |
| pH | 7.0 | 7.1 | 6.8 | .09 |
| Organic matter (%)[3] | 88.8 | 87.9 | 87.2 | .21 |
| Crude protein (%)[3] | 13.8[a] | 17.6[b] | 14.8[a] | .33 |
| Apparent Digestibilities (%) | | | | |
| Dry matter | 78.6 | 84.6 | 83.3 | 1.51 |
| Organic matter | 80.1 | 85.8 | 84.6 | .78 |
| Crude protein | 79.3 | 80.5 | 83.5 | 2.18 |

[1]R-DB, rolled dry barley; Pit-HMB, Pit high mositure barley; HAV-HMB, Harvestore high moisture barley.
[2]Standard error of means.
[3]Dry matter basis.
[a,b]Means in the same row with the same letters are not significantly different ($p < .05$).

a tendency for lower ruminal ammonia concentrations in animals fed Pit-HMB. The CP percent in ileal samples for Pit-HMB was significantly higher than observed for HAV-HMB or R-DB. The results correspond to a similar trend observed for CP percent in fecal and duodenal samples.

Dry matter, OM and CP intake were similar across treatments (table 7). Fecal CP % was higher ($p < .05$) in animals fed Pit-HMB than those fed R-DB or HAV-HMB but this difference was not reflected in CP digestibility coefficients. Dry matter and OM digestibility coefficients tended to be higher for both HMB diets, however, these differences were not significant.

Although significant differences were not observed in many instances, barley source affected rumen fermentation patterns and possibly the extent of digestion. Animals fed R-DB had higher ruminal propionic acid concentrations than those fed HMB.

Additionally, data from the in situ nylon bag study suggests that HMB is degraded at a slower rate than rolled dry barley. A reduction in the rate of degradation of barley in the rumen would provide a more stable rumen environment in animals fed diets containing a higher proportion of barley grain.

Comparing the two HMB sources, Pit-HMB produced less ruminal ammonia nitrogen and VFA, and had lower DM and CP disappearance rate from the nylon bags, suggesting that HMB stored in the pit silo was degraded more slowly in the rumen than HMB stored in the Harvestore. These differences would appear to be associated with the time of processing and/or the method of storage.

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