Influence of Processing of Barley Grain on Characteristics of Digestion, Ruminal Fermentation and Digestible Energy of Diet in Lactating Cows

Research Article

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ABSTRACT

A digestion trial using cannulated lactating cows was conducted to evaluate the influence of barley grain processing on characteristics of ruminal fermentation and the site and extent of digestion. The experiment consisted in 4 periods and lasted 84 days. The total mixed rations contained 39.86% of grains and 42.90% of alfalfa hay and the rest of ration was composed mainly by cane molasses, fat, fishmeal and minerals. The barley grains were processed by dry-rolled and steam-flaking with two densities of flake (0.39 and 0.26 kg/L). Dry rolled corn was used as reference to determine energy value of barley grain. Compared to dry rolled barley, steam-flaked barley increased ruminal digestion of organic matter (OM) and starch, and energy of diet, but decreased dry matter intake. Decreasing steam-flaked density of barley from 0.30 to 0.26 kg/L increased ruminal digestion of starch and ruminal propionate and decreased dry matter intake and ruminal nitrogen digestion. Compared to corn, cows fed barley diets shown a greater dietary energy as result of greater total tract OM digestion, greater microbial protein efficiency and lower ruminal acetate and methane production. However, barley treatments had a lower ruminal pH and this was exacerbated as flake density decreased. The energy value of barley was improved ($P<0.05$) 8% by steam-flaking. However, flaking barley too thinly depress ($P<0.05$) feed intake. The optimal flake density for barley fed to lactating dairy cattle is around of 0.39 kg/L.

KEY WORDS barley grain, corn grain, digestion, lactating cows, metabolism, processing.

INTRODUCTION

The current standard (NRC, 2001) assigns barley energy values of 3.64, 2.92 and 1.86 for digestible energy (DE), metabolizable energy (ME) and to NE_l respectively (dry matter basis). These estimates are based on the assumption that the total digestible nutrient (TDN) of grain-rolled barley is 82.7%. No corresponding values for steam-flaked barley (SFB) are given, leading to the presumption that no distinction in feeding value due to nature of processing is warranted. In general, steam flaking of corn and sorghum increases both the proportion starch that is fermented in the rumen and the intestinal digestion of the starch that escapes ruminal fermentation, resulting in higher total tract digestion of starch, and thus, available energy for milk production (Theurer *et al.* 1995). This response is usually im-

pacted by the degree of processing, or flake density (Zinn, 1990b). Similar to the latter, previous *in vitro* and *in vivo* studies (Hironaka *et al*. 1992; Zinn, 1993; Huntington, 1997; Ahmad *et al*. 2010) have shown that steam flaking increases ruminal starch digestibility of barley in feedlot cattle. However, with corn grain, responses to steam flaking on starch utilization have been markedly lower to lactating cows than for feedlot cattle (Plascencia and Zinn, 1996). For the latter, the objective of this experiment was to evaluate the influence of steam flaking of barley on characteristics of digestion and ruminal fermentation in lactating Holstein cows.

MATERIALS AND METHODS

The trial was conducted at the Ruminant Metabolism Experimental Unit of the Instituto de Investigacíones en Ciencias Veterinarias of the Universidad Autónoma de Baja California located 10 km south of Mexicali City in northwestern México (32° 40' 7"N and 115° 28' 6"W). The area is about 10 m above sea level, and has Sonoran desert conditions (BWh classification according Köppen). All animal management procedures were conducted according to the guidelines of locally-approved techniques for animal use and care (NOM-051-ZOO-1995: humanitarian care of animals during mobilization of animals; NOM-062-ZOO-1995: technical specifications for the care and use of laboratory animals. Livestock farms, farms, centers of production, reproduction and breeding, zoos and exhibition hall, must meet the basic principles of animal welfare; NOM-024-ZOO-1995: animal health stipulations and characteristics during transportation of animals.

Three primiparous cows (135±23 dry matter intake (DMI) and 589±18 kg) with ruminal and t-shaped duodenal cannulas (15 cm from the phyloric sphincter; Zinn and Plascencia, 1993) were used in a 3 × 4 Youden's square experiment to evaluate barley (BRL) processing on characteristics of ruminal fermentation and total alimentary tract digestion. Dry-rolled grains were prepared by passing grain (corn or barley) through rollers that had been adjusted so that kernels were coarsely broken to obtain for corn a density of 0.54 kg/L dry rolled corn (DRC), and for barley a density of 0.45 kg/L dry rolled barle (DRB). The steamflaked barley (SFB) was prepared as follows: A chest situated directly above the rollers (46×61cm rolls, 5.5 corrugations/cm; Memco, Mills Rolls, Mill Engineering and Machinery Co., Oklahoma, CA) was filled to capacity (397 kg) with barley and brought to a constant temperature (102 °C) at atmospheric pressure using steam (boiler pressure 60 psi). The barley was steamed for 20 min before starting the rollers. Approximately, 454 kg of the initial steamprocessed grain that exited the rollers during warm-up (of

the rollers) was set aside and not fed to cows on this study. Tension of the rollers was adjusted to provide the indicated flake density of 0.39 kg/L steam flaked barley medium (SFBM) or 0.26 kg/L (steam flaked barley thin (SFBT). Retention time of grain in steam chamber was approximately 18 min. The bulk density of DRC and processed barley grains was measured using a standard bushel tester (OHAUS grain scale Model 8324915, Parssipani, NJ, USA) following the method prescribed by the USDA 1999. The steam-flaked barley was allowed to air-dry (5 d) before use in diet preparation. The alfalfa hay was ground to pass through a 7.6 cm screen. Composition of the experimental diets is shown in Table 1. Chromic oxide (Cr_2O_3) was added to the diets as an inert marker for calculating DM flow to the small intestine and fecal DM excretion. The diets were formulated to meet or exceed all nutritional requirements for a 589 kg BW cow with a daily milk production of 22 kg/d (NRC, 2001).

Cows were housed in the individual stalls and were allowed *ad libitum* access to complete mixed diets. Fresh feed was provided at 07:00 and 19:00 daily. All cows received treatment 1 (Table 1) for 7 d before initiation of the trial, which consisted of four 21 d experimental periods (17 d for diet adjustment and 4 d for sample collection). Daily feed allotments to each cow were adjusted to allow minimal (<5%) feed refusals in the feed bunk. The amounts of feed offered and feed refused were weighed daily. Feed bunks were visually assessed between 06:40 and 06:50 h each morning, refusals were collected and weighed and feed intake was determined. Feed and refusal samples were collected daily for DM analysis, which involved oven drying the samples at 105 °C until no further weight loss occurred (method 930.15, AOAC, 2000).

During sample collection, duodenal and fecal samples were taken from each cow twice daily over four successive days as follows: d1, 06:50 and 12:50; d 2, 08:00 and 14:00; d 3, 09:50 and 15:50; and d 4, 11:00 and 17:00 h. Individual samples consisted of approximately 500 mL of duodenal chyme and 400 g (wet basis) of fecal material. Samples from each cow and within each collection period were pooled for analysis. On the final day of each collection period, ruminal samples from ventral sac (using tygon tubing with 1.90 cm of internal diameter adapted to a vacuum pump, Cole PARMER, Vernon Hills, ILL) were obtained via ruminal cannula from each cow at 4, 8 and 12 hours after feeding (07:00, 11:00 and 15:00 h). Ruminal pH was determined (Orion 261S, Fisher Scientific, Pittsburgh, PA) on fresh samples and subsequently, 2 mL of freshly prepared 25% (wt/v) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples then were centrifuged (17000×*g* for 10 min) and supernatant fluid stored at -20 °C for VFA analysis. Upon completion of the trial, ruminal

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fluid was obtained for all cows and composited for isolation of rumen bacteria via differential centrifugation (Bergen *et al.* 1968). The microbial isolate served as the purine: N reference for the estimation of microbial nitrogen (MN) contribution to chyme entering the small intestine (Zinnand Owens, 1986).

Samples were subjected to all or some of the following analysis: (DM, oven drying at 105 ˚C until no further weight loss; AOAC, 2000); ash (AOAC, 2000), Kjeldahl nitrogen (AOAC, 2000), chromic oxide (Hill and Anderson, 1958), starch (Zinn, 1990a), and acid detergent fiber (ADF) (Goering and Van Soest, 1970). In addition, gross energy (GE, using the adiabatic bomb model 1271; Parr Instrument Co., Moline, IL. USA) was determined for feed and fecal samples. Ammonia N (AOAC, 2000) and purines (Zinnand Owens, 1986) were determined in duodenal samples. Organic matter (OM) of feed, duodenal, and fecal samples was determined by difference between DM and ash content.

Microbial OM and microbial N (MN) leaving abomasum were calculated based on analysis of isolated bacteria and of duodenal samples using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in rumen was considered to be equal to OM intake minus the difference between the amount of total OM reaching the duodenum and microbial OM reaching the duodenum. Feed N escape to the small intestine was considered to be equal to total N leaving abomasum minus ammonia N and microbial N; this includes any endogenous N contributions. Methane production was calculated using the theoretical fermentation balance based on observed molar distribution of ruminal fluid volatile fatty acids (VFA) (Wolin, 1960) and true OM disappearance in the rumen. Primary assumption were that VFA, CO_2 and methane are the only end products of fermentation, that glucose represents the fermentable substrate (OM fermented was expressed as glucose equivalents), and that ruminal VFA concentrations were proportional to rates of productions (mol/mol of glucose equivalent fermented; Wolin, 1960). Endogenous urinary energy loss was estimated as 0.10 Mcal/kg $W_{kg}^{0.5}$ (Brouwer, 1965; NRC, 1984).

The comparative DE and ME values (Mega calories/kg) for DRB and steam-flaked barley were determined using the replacement technique. The energy value for BRL (independent of processing) was assumed to equal to the corresponding energy value for DRC it replaced plus the change in energy content of the completed diet caused by the replacement. Given that the DRC was 39.86% of diet DM and that the values for DE and ME for the DRC replaced were 3.40 and 2.98 Mcal/kg, respectively (tabular values; NRC, 2001). The trial was analyzed as a 4 × 3 Youden's square experiment. The model assumed in the analysis is:

$$Y_{ijk} = \mu + R_i + C_j + T_k + E_{ijk}$$

Where:

i, j, k: being the row, column and treatment numbers (i=3, j=4 and k=4).

E_{ijk}: being the residual effect, uncorrelated and distributed around zero with variance σ^2.

Statistical data were analyzed using the GLM procedure of SAS (2004). Treatment effects were tested for the following orthogonal contrast: 1) DRC *vs*. Barley; 2) DRB *vs*. SFB and 3) SFBM *vs*. SFBT. Contrasts were considered significant when the P ≤ 0.05, and tendencies were identified when the P > 0.05 and P ≤ 0.10.

RESULTS AND DISCUSSION

Intensity of barley processing on digestion

The influence of barley processing on dry matter intake, and characteristics of ruminal and total alimentary tract digestion is shown in Table 2. Likewise previous reports (Yang *et al.* 2000; Mutsvangwa *et al.* 2012), dry matter intake was lower (4.1%, P<0.05) for SFBT that SFBM. The decreases on DMI when cows were fed more extensively processed barley was attributed mainly to lower ruminal pH of cows fed DRB compared with those fed steam-flaked barley.

A similar effect of barley flake thickness on DMI was also observed in feedlot cattle (Zinn, 1990b). There were no effects (P>0.20) of barley processing on ruminal digestion of ADF and feed N. Ruminal digestibility of OM and starch were lower (9.2 and 37.7%, respectively; P<0.05) for DRB than for SFB. Previous *in vitro* and *in vivo* studies (Zinn, 1993; Huntington, 1997; Ahmad *et al.* 2010) have shown that steam flaking increases ruminal starch digestibility of barley.

Ruminal digestibility of starch was 42.5 and 68.5% for DRB and SFB, respectively. Previous studies, that used a similar barley-based diet than in the present experiment, observed a similar ruminal starch digestibility coefficients, ranging from 38 to 50% (Yang *et al.* 2001) and 61 to 71% (Yang *et al.* 2000).

However, those values are lower than observed in other studies with lactating cows (Herrera-Saldaña and Huber, 1989), and with feedlot cattle (Spicer *et al.* 1986; Zinn, 1993).The latter could be by the variability of quality of barley grain (hull-less *vs*. covered, high test weight, high percent plump, low percent thin kernels, etc.) and by the differences on the extents of grain processing.

Ruminal digestibility of ADF was 55.3% higher (P<0.05) for SFBM than SFBT. However, digestibility of OM was lower (P<0.05) for SFBM then for SFBT.

Table 1 Composition (%, dry matter basis) of the experimental diets fed to cows[1]

			Barley	
Ingredient	Dry rolled corn	Dry rolled	Steam flaked medium	Steam flaked thin
Alfalfa hay[2]	42.90	42.90	42.90	42.90
Dry rolled corn (0.52 kg/L)	39.86	-	-	-
Barley grain				
Dry rolled (0.45 kg/L)	-	39.86	-	-
Steam flaked				
0.39 kg/L	-	-	39.86	-
0.26 kg/L	-	-	-	39.86
Fish meal	2.92	2.92	2.92	2.92
Cane molasses	9.98	9.98	9.98	9.98
Yellow grease	2.22	2.22	2.22	2.22
Urea	0.26	0.26	0.26	0.26
TM salt[3]	0.35	0.35	0.35	0.35
Magnesium oxide	0.18	0.18	0.18	0.18
Sodium bicarbonate	0.62	0.62	0.62	0.62
Dicalcium phosphate	0.44	0.44	0.44	0.44
Chromic oxide	0.27	0.27	0.27	0.27

[1] Total mixed ration.
[2] Ground to pass through a 7.6 cm screen.
[3] Trace mineral salt: $CoSO_4$: 0.68%; $FeSO_4$: 3.57%; ZnO: 0.75%; $MnSO_4$: 1.07%; KI: 0.52% and NaCl: 93.4%.

Table 2 Influence of processing barley on characteristics of digestion in cannulated lactating cows

			Barley		SEM
	Dry rolled corn	Dry rolled	Steam flaked medium	Steam flaked thin	
Intake, g/d					
Dry matter[1]	15098	15313	15612	14481	172
Organic matter[1]	13780	13391	14428	13257	155
Starch[2,3]	3961	3419	3662	3862	105
Acid detergent fiber[2]	2544	2889	2959	2731	74
N[2]	379	406	398	397	5
Gross energy, Mcal/d	25.59	25.82	25.83	25.97	0.10
Ruminal digestion, % intake					
Organic matter[1,3,4]	43.75	34.72	34.12	42.41	2.15
Starch[1,3,4]	39.36	42.50	46.01	90.51	12.7
Acid detergent fiber[2,3]	32.14	22.81	26.49	11.83	4.50
Feed N[1,4]	55.55	42.30	38.90	27.91	1.7
Microbial efficiency[4,5]	28.92	47.24	48.81	36.03	3.4
N efficiency[1,6]	0.90	1.12	1.16	1.25	0.03
Total tract digestion, % intake					
Organic matter[4]	58.7	61.4	65.0	65.7	1.75
Starch[2]	74.5	87.6	95.4	91.0	5.1
Acid detergent fiber	35.9	29.5	28.6	27.7	3.9
N[2,3]	62.1	66.3	68.3	70.0	1.2
Digestible energy, %[2]	56.8	60.1	62.6	62.8	1.7
Digestible energy, Mcal/kg[3,4]	2.43	2.56	2.68	2.69	0.06
Metabolizable energy, Mcal/kg[3,4]	1.99	2.19	2.32	2.29	0.07

DRC: dry rolled corn; BRL: barley; DRB: dry rolled barley; SFB: steam flaked barley; SFBM: steam flaked barley medium and SFBT: steam flaked barley thin.
[1] SFBM *vs.* SFBT (P<0.05).
[2] DRC *vs.* BRL (P< 0.05).
[3] DRB *vs.* SFB (P<0.05).
[4] DRC *vs.* BRL (P<0.01).
[5] Microbial N, g/kg of OM fermented.
[6] Duodenal nonammonia N/N intake.
SEM: standard error of the means.

The reduction on ruminal fermentation of OM it's a direct reflection of the relative differences in the ruminal digestion of starch between SFBM and SFBT treatments (46.01 *vs.* 90.51% for SFBM and SFBT, respectively). Decreased (49.2%) ruminal starch digestion in SFBM fully explains the reductions (19.5%) in ruminal OM digestion for this treatment.

Ruminal digestion of N was lower (28.2%; P<0.05) and ruminal N efficiency was correspondingly greater (7.2%; P<0.05) for SFBT than for SFBM. A lower ruminal N digestion have been observed previously as response to extensively barley grain processing (Mutsvangwa *et al.* 2012). These researchers explained that the reduction of ruminal digestion of N was mediated by the reduction of microbial

proteolytic activity as a result of a more acidic ruminal environment. As will discuss later, in the present experiment, SFBT decreased the ruminal pH in 5.7% in first 4-h after feeding.

Total tract digestion of OM and starch tended (P=0.07) to be greater (6.0 and 6.4%), and total tract digestion of N and diet energy concentration (Mcal/kg) of DE and ME (P<0.05) were increased by 4.1, 4.7 and 4.9%, respectively, for SFB compared with DRB. Total tract digestion of OM, N, ADF, DE and ME (P>0.10) were similar for SFBM and SFBT. Although a previous study (Yang *et al*. 2000) have not reported large improvements in total alimentary tract digestibilities of barley diets by altering the extent of processing, several studies have reported improvements by manipulating degree of processing of barley (Yang *et al*. 2000; Ahmad *et al*. 2010).

Dry rolled corn (DRC) *vs*. barley
Intakes of DM were similar (Table 2, P=0.92) for corn and barley diets, this is consistent with results of DePeters and Taylor (1985), and Yang *et al*. (1997b), in which they reported no effect on DMI in cows fed a 40 and 50% cracked corn or steam flaked barley diets compared with DRC diets, although in other studies (McCarthy *et al*. 1989; Yang *et al*. 1997a), DMI was lower with diets containing cracked or steam-flaked barley *vs*. corn. Even when DM intake was very similar (15098 *vs*. 15135 kg/d) among DRC and barley treatments, as a result of different chemical composition among DRC and barley (Zinn, 1993), replacing DRC with barley increased (P<0.05) ADF and N intakes and decreased (P<0.01) the starch intake.

Ruminal digestion of OM (12.8%; P<0.05), ADF (36.6%; P<0.05), and N (34.4%; P<0.01) were higher for DRC than for barley based diets. However, ruminal digestion of starch were lower (P<0.01) for DRC diets than for barley diets. Previous studies (Theurer, 1986; McAllister *et al*. 1993) have reported a greater rate and extent of ruminal digestion of starch from barley than for corn, which has been put down to the properties of the protein matrix that surround the starch grains and by the type of starch contained in the cereals.

The value for microbial efficiency (g of MN/kg of OM fermented) for DRC was 29. This value was higher than that reported by Plascencia and Zinn (1996) and Joy *et al*. (1997), but was in close agreement with Lykos *et al*. (1997). Microbial efficiency and ruminal N efficiency (flow of non-endogenous N to the small intestine as a proportion of N intake) were 34.3 and 23.0% lower (P<0.01), respectively for DRC than for barley based diets. Higher protein microbial yield for cows fed barley *vs*. corn based diets is well documented (Spicer *et al*. 1986; McCarthy *et al*. 1989; Feng *et al*. 1995).

Ruminal and total tract digestibility of starch for DRC were in close agreement with previous studies (Plascencia and Zinn, 1996; Joy *et al*. 1997; Lykos *et al*. 1997).

Total tract digestion of ADF tended to be greater (20.3%; P=0.09) for DRC than for barley. However, total tract digestion of OM was lower (8.2%, P<0.01) for DRC than for barley diets. As with ruminal digestion, the reduction in total tract OM digestion was expected, and was largely attributable to the differences in the total tract digestion of starch (14.4%, P<0.05) and N (8.9%, P<0.01). Consistent with effects on total tract OM digestion, barley diets increased (P<0.05) the digestibility of GE and this affect the dietary DE (8.0%, P<0.01) and dietary ME (11.9%, P<0.01).

Ruminal fermentation and energy of barley grain
Treatments effects on ruminal pH, VFA molar proportions, and estimated methane production are shown in Table 3. Except of lecture of the ruminal pH taken at 12 hours after feeding, the ruminal pH was consistently numerically higher (P=0.08) for DRC than for barley. The latter can be explained mainly, by higher ruminal availability of starch for barley compared with DRC (Yang *et al*. 1997b; Mutsvangwa *et al*. 2012). Consistent with previous studies (Casper and Schingoe, 1989; McCarthy *et al*. 1989; Grings *et al*. 1992), molar proportion of acetate, butyrate, and methane production were higher (P<0.05) for DRC than for barley. These shifts are due, in part, to the differences between DRC and barley in rate and extent of ruminal OM fermentation (Grings *et al*. 1992; Khorasani *et al*. 1994; Yang *et al*. 1997b).

Ruminal pH 4 and 8 h after feeding was lower (P<0.05) for SFB than for DRB. Lowest pH values (5.56) were obtained with SFBT. Ruminal acetate, butyrate, and methane were higher (P<0.05), and propionate was lower (P<0.05) at 4 and 8 h after feeding for DRB than SFB. These effects were intensified (P<0.05) as flake density decreased.

Given that the DE and ME of DRC were 3.54 and 3.12 Mcal/kg, respectively (NRC, 2001); then the corresponding values were 3.73 and 3.48 Mcal/kg, respectively for DRB; and 4.03 and 3.77 for SFB. Thus, the energy value of barley was improved 7.4% by steam-flaking.

The DE estimates for DRB are consistent to the value of 3.64 Mcal/kg for rolled barley given by NRC (2001). However, the estimates of EM (Mcal/kg) for DRB in this study are substantially higher (16%) than tabular values (NRC, 2001). Similarly, Boss and Bowman (1996), in feedlot cattle, estimated a substantially higher NE value (13.9%) for DRB than NE value given by NRC (1984). The DE and ME values of SFB were 10.7 and 22% higher than tabular values. The impact of steam processing on the feed value of barley is not completely defined yet.

Table 3 Influence of barley processing on ruminal pH, volatile fatty acids (VFA) molar proportion, and estimated production of methane at 4, 8 and 12 h after feeding in lactating cows

Item	Barley				SEM
	Dry rolled corn	Dry rolled	Steam flake medium	Steam flaked thin	
Replicates	4	4	4	4	
pH					
4 h	5.65	5.64	5.63	5.18	0.11
8 h[1]	5.75	5.77	5.66	5.49	0.13
12 h[1]	6.12	6.18	6.25	6.02	0.19
Ruminal volatile fatty acids (VFA), mol/100 mol					
Acetate					
4 h[1,2,3]	63.7	64.0	62.7	61.2	0.09
8 h[1,2,3]	64.8	65.4	62.7	59.3	0.16
12 h[a,b]	65.1	64.2	62.2	62.4	0.08
Propionate					
4 h[1,2,3]	22.1	23.4	25.7	29.6	1.40
8 h[1,2,3]	21.9	23.7	26.6	30.7	1.10
12 h[1,2,3]	22.8	24.5	26.9	29.6	1.05
Butirate					
4 h[1,2,3]	14.0	12.4	11.4	9.0	1.05
8 h[1,2,3]	13.2	10.8	10.6	9.9	1.25
12 h[1,2,3]	12.0	11.1	10.7	7.9	0.05
Methane production[4]					
4 h[1,3,5]	0.58	0.57	0.55	0.51	0.02
8 h[1,3,5]	0.59	0.58	0.54	0.49	0.02
12 h[1,3,5]	0.58	0.56	0.53	0.51	0.01

DRC: dry rolled corn; BRL: barley; DRB: dry rolled barley; SFB: steam flaked barley; SFBM: steam flaked barley medium and SFBT: steam flaked barley thin.
[1] DRB *vs*. SFB (P<0.05).
[2] DRC *vs*. BRL (P<0.05).
[3] SFBM *vs*. SFBT (P<0.05).
[4] Methane, mol/mol of glucose equivalent fermented (Wolin, 1960).
[5] DRC *vs*. BRL (P<0.01).
SEM: standard error of the means.

Yang *et al*. (2000) and Yang *et al*. (2001) reported improved milk yields in cows fed more extensively processed barley compared with those fed coarsely rolled barley, a response that was partly explained by the greater energy available for extensively processed barley. In opposite, Mutsvangwa *et al*. (2012) reported greater milk yield for cows that feed a diet with rolled barley than those cows fed a diet with highly processed barley. Although, they explained that differences in milk yield between treatments were mediated mainly by differences on DMI. In feedlot cattle, early works (Garret, 1965; Hale *et al*. 1966) reported no difference on performance and/or diet net energy between the steamed barley and the cracked barley. Few authors (Beauchemin *et al*. 1997, Fife *et al*. 2008), speculated that, the insufficient degree of processing of barley and it variability in the quality of the barley (hull-less *vs*. covered, high test weight, high percent plump, low percent thin kernels, etc.) might be the possible cause for the variation of results observed on digestion or performance of cattle. The degree of steam processing in barley grains is not well defined, however reduced bulk density of barley by steam rolling to 70% or less of whole barley (<0.45 kg/L) have a positive effect in lactating cows (Beauchemin *et al*. 1997). Although processing improves the utilization of nutrients in barley grain, extensive processing increases ruminal starch

degradation, which often decreases feed intake in ruminants (Allen, 2000). Therefore, the objective of barley grain processing should be to optimize the digestibility rather than maximizing the digestibility. In the present experiment, the densities of processed barley relative to the original grain were 71, 61 y 41% for DRB, SFBM and SFBT, respectively.

CONCLUSION

Steam flaking improves the feed value of barley for lactating cows compared with dry rolled corn. This improvement can be attributed to enhanced ruminal and total tract OM fermentation, increased ruminal protein efficiency, and decreased ruminal methane energy loss. Steam flaking increased the estimated ME of barley by 8% over dry rolled barley. However, flaking barley too thinly depress feed intake and will increase the potential for acidosis. The optimal flake density for barley fed to lactating dairy cattle is around of 0.39 kg/L.

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