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Effects of Barley Grain Particle Size on Ruminal Fermentation and Carcass Characteristics of Male Lambs Fed High Urea Diet

Research Article

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ABSTRACT

Two experiments were conducted to evaluate effects of barley grains particle size on ruminal pH and ammonia concentration of rams (experiment 1) and carcass characteristics (experiment 2) of male lambs fed high urea diet. Treatments in two experiments were (1: basal diet + whole barley grains, 2: basal diet + ground barley grains with a 5 mm screen, 3: basal diet + ground barley grains with a 3 mm screen and 4: basal diet + ground barley grains with a 1 mm screen). Basal diet (on a dry matter (DM) basis) consisted of 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt, 10 g/kg a vitamin-mineral premix and 600 g/kg of barley. In experiment 1, three 2-year old rams were fistulated for measuring ruminal pH and ruminal ammonia concentration. Ruminl pH was decreased by feeding ground barley grains through a 1 mm screen compared to feeding the whole barley grains ($P<0.05$). However, Ruminal ammonia concentrations were similar for all groups. In experiment 2, twenty four male lambs were used in a completely randomized design. Lambs were fed with the above mentioned diets for 90 days. Average daily gain, feed conversion ratio, average DM intake was significantly affected by treatments ($P<0.05$). Final body weight, cold carcass weight, dressing percentage, back fat thicknesses, carcass cuts (leg, shoulder, back and neck weights), internal organs (kidney, lungs, heart and gastrointestinal tract) weights were not significantly different between diets ($P>0.05$). Lambs fed diet containing ground barley with 3 mm of screen had ($P<0.05$) higher longissimus muscle area compared to lambs fed whole barley grain. Consumption of whole barley grains increased DM intake and pelvic and abdominal fats. As a conclusion, the consumption of ground barley grain with a 3 mm or a 5 mm screen is suggested for feeding lambs fed high urea diet.

KEY WORDS carcass, performance, processing, ruminal ammonia.

INTRODUCTION

Barley is an important feed grain for fattening of lambs in Iran as it is a readily available source of dietary energy. However, the endosperm of the barley kernel is surrounded by the pericarp overlain by a fibrous hull, which is extremely resistant to microbial degradation in the rumen. Processing makes the starch more accessible to microbes, and increases the rate and extent of starch degradation in the rumen. Although processing is essential to maximize the utilization of barley grain by sheep, extensive grain processing increases ruminal starch degradation, which often decreases feed intake in ruminants (McAllister *et al.* 1994; Allen, 2000). The price of sources of vegetable protein as oil seed meals in some countries is very high and non-protein nitrogen (NPN) is used to increase the dietary crude protein (CP). Urea can be used as a nitrogen source in ration to meet 25% of the total CP requirement of lambs (Stanto and Whittie, 2006). Moreover, Canpolat and Karabulut (2010) reported that supplementation of diet with urea had a positive effect on feedlot performance of lambs.

It has been reported that a synchronous supply of energy and nitrogen to the rumen enhance microbial CP synthesis (Sinclair *et al.* 1993; Trevaskis *et al.* 2001). Microbial protein can supply from 70% to 100% of amino acids requirements of ruminants (AFRC, 1992). Processing such as grinding generally increases ruminal degradable organic matter of grains for rumen bacteria for microbial crude protein synthesis.

Although the effect of processing of barley grain on feedlot performance of lambs has been evaluated in some studies (Economides *et al.* 1990; Petit, 2000; Voia *et al.* 2009), there is little information concerning the effects of barley grains particle size on performance of male lambs fed high urea diets. Therefore, the aim of this study was to evaluate the effects of feeding whole and ground barley grains on ruminal fermentation, growth and carcass characteristics of lambs fed high urea diet.

MATERIALS AND METHODS

Experiment 1

Three fistulated Mehraban rams aged 2 years and weighing 48 kg were used in change over design to determine rumen pH and ammonia concentration. Treatments were 1: basal diet + whole barley grains, 2: basal diet + ground barley grains through a 5 mm screen, 3: basal diet + ground barley grains through a 3 mm screen and 4: basal diet + ground barley grains through a 1 mm screen. The rams were fed with a basal diet on DM basis containing 365 g/kg corn silage, 600 g/kg barley, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt and 10 g/kg a vitamin-mineral premix. A 14-day period of adaptation to the diet was employed. The diet was formulated according to National Research Council (NRC, 1985) specifications to contain 124 g CP/kg of DM and fed twice daily at 07:00 and 15:00 h. Water was available *ad libitum*. Samples of rumen fluid were collected at 0 (before morning feeding) and 0.5, 2, 4 and 5 h after feeding. Samples of rumen fluid were strained through two layers of cheesecloth, and pH measured immediately with a pH meter (Metrohm, 744 Swiss). For determination of ammonia nitrogen (NH_3-N) in rumen fluid, 50 mL subsamples of strained rumen fluid were preserved by addition of 1 mL sulfuric acid 97% and stored at –20°C. Just before analysis, samples were thawed and analyzed for ammonia (Crooke and Simpson, 1971).

Experiment 2

Twenty four Mehraban male lambs (7 to 8 months old) with an initial live weight of 39.5 ± 4.17 kg were used to determine the effects of barley grains particle size on feedlot performance and carcass characteristics of lambs.

The lambs were allotted randomly to 24 pens (140×120 cm). They were maintained at ambient temperature and natural day length and water was available *ad libitum*. The lambs were adapted to the diets for 2 weeks (to limit the risk of digestive upsets) followed by growth trial of 90 days. Lambs were fed 4 diets as follows 1: basal diet + whole barley grain, 2: basal diet + ground barley grains through a 5 mm screen, 3: basal diet + ground barley grains through a 3 mm screen, and 4: basal diet + ground barley grains through a 1 mm screen). Basal diet on DM basis containing 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt and 10 g/kg a vitamin-mineral premix. Chemical composition of the diets (on DM basis) was similar and contained 2.65 MJ ME per kg, 12.4% CP, 0.70% calcium and 0.28% phosphorus. The ME concentration of diet was calculated based on the digestible energy and acid detergent fiber content (Khalil *et al.* 1986). Vitamins and minerals were added to experimental diets to meet the requirements (NRC, 1985). Quarter of the total CP requirement of lambs was supplied by adding urea to the diet (Stanto and Whittie, 2006). The diets were fed as a totally mixed rations twice daily at 07:00 and 15:00 h in equal amounts to ensure 5% orts.

Amounts of feed offered and refused were recorded daily. At the beginning of experiment 2, lambs were weighed and lamb weights were recorded monthly before the 07:00 h feeding to monitor body weight change throughout the experiment. At the end of the experiment, the feed and water were removed for 18 h and then the lambs were weighed and slaughtered according to local practices (Zamiri and Izadifard, 1997). Cold carcass weight was determined after chilling hot carcass at 4 ˚C for 24 h. The cold carcass weight and live weight were used for determination of the dressing percentage. The abdominal and pelvic fats were removed and weighed. Fat depth over carcass was measured at the cross section of the 12^{th} and 13^{th} thoracic ribs at 4 points by caliper and the values were averaged as a measure of subcutaneous fat depth and then, longissimus muscle area were measured. The carcass was then split into the right and left sides, each side was cut into leg, shoulder, neck, brisket, flap and back joints (Farid, 1989) and each cut was weighed separately. Internal organs (kidney, liver, lungs, heart and gastrointestinal tract) were separated and weighed.

Rumen pH and ruminal ammonia concentration data were analyzed according to Proc Mixed as Repeated Measures of SAS (1996). Data for feedlot performance and carcass characteristics were analyzed as a completely randomized design according to the GLM procedure of SAS (1996) with the statistical model of:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:
Y_{ij}: dependent variable.
μ: overall mean.
T_i: screen size effect.
e_{ij}: residual error.

Least significant difference was used to compare means. Treatment differences were considered significant when (P<0.05).

RESULTS AND DISCUSSION

Experiment 1

Effects of barley particle size on rumen pH and ruminal ammonia concentration are presented in Table 1. Rumen pH was decreased by feeding ground barley grains through a 1 mm screen compared to feeding the whole barley grains. Our results are consistent with Tagawa *et al.* (2016), who reported that decreasing barley grains particle size in *in vitro* assay decreased fermentation pH. Grinding the cereals may increase availability and surface area of nutrients to rumen microbes compared with whole grains (Callison *et al.* 2001). Consequently, microbes could digest the nutrients more easily in ground grains and therefore rumen pH has the potential to decrease in ground vs. whole grains. Average ruminal NH_3-N concentration in rams fed whole barley grain was 14.08 mg/100 mL. This is relatively higher than rumen NH_3-N concentrations of 5 mg/100 mL reported by Satter and Slyter (1974) as a minimal concentration for optimum microbial protein synthesis. The relatively higher level of ruminal NH_3-N was probably due to the high proportion of non-protein nitrogen (urea) in the diet (10 g/kg), which is highly soluble in the rumen (Van Soest, 1994). The ruminal ammonia nitrogen concentrations were not affected by treatments.

This result is supported by Ebrahimi-Mahmoudabad and Taghinejad-Roudbaneh (2015), who reported that decreasing barley grain particle size had not significant effect on maximum potential degradability of CP. The concentrations of ammonia nitrogen in rumen fluid depend on the source and amount of the degradable protein in rumen (Reynal *et al.* 2007). Vanhatalo *et al.* (2003) found a numerical increase in rumen NH_3-N concentration with abomasal infusion of casein in comparison with water infusion (control group).

Experiment 2

Effects of barley grains particle size on performance of lambs are presented in Table 2. Treatments had not significant effects on final body weight of lambs. Moreover, Salo *et al.* (2016) reported that final body weight of lambs was not affected by barley grain processing.

However, average DM intake, average daily gain (ADG) and feed conversion ratio (FCR) (kg DM to kg live weight gain) of lambs were affected by treatments (P<0.05). Our results are in agreement with other studies (Economides *et al.* 1990; Petit, 2000).

There were differences among treatments for average DM intake. Average DM intake of lambs receiving ground barley grains was on average 1.39 kg and was lower than lambs feeding whole barley grains. This finding is supported by result of experiment 1 and is consistent with the traditional belief that finely ground grains produce dust and depress DM intake (Mathison, 1996).

Lower ruminal pH of lambs fed ground barley grain compared to lambs fed whole barley grain decreases cellulolytic bacteria count (Russell and Wilson, 1996), resulting in decreased DM intake of lambs fed ground barley grain with 1 mm screen.

Overall, feeding lambs with ground barley grain with a 1 mm screen decreased ADG of lambs compared to lambs fed whole barley grain. Our results are not consistent with Sormunen-Cristian (2013) and Salo *et al.* (2016). Salo *et al.* (2016) reported that feeding malted and cracked barley grain had no positive effect on ADG of Highland lambs. However, Voia *et al.* (2009) reported that total weight gain and ADG of ground barley-fed lambs was higher than whole barley–fed lambs. The higher ADG lambs fed whole barley could be due the higher DM intake on this diet compared to ground barley-fed lambs.

The FCR of the lambs ranged from 8.95 to 11.59 and these values were considerably higher than those reported by Petit (2000) and Sormunen-Cristian (2013), probably due to the higher initial weight of the lambs used in the present study. Lambs fed ground barley grain with 5 mm screen had better (P<0.05) FCR than lambs fed ground barley grain with 1 mm screen. However, Crane *et al.* (2014) reported that FCR of feedlot lambs was not affected by corn particle size. The lowest cost of feed per kg live weight was achieved on the diet based on ground barley with 5 mm screen.

There were no differences between the treatments in terms of the cold carcass weights and dressing percentage (Table 3). The dressing percentage in our study was similar to those obtained by Fozooni and Zamiri (2007). Similar results were reported by Crane *et al.* (2014) and Salo *et al.* (2016). Carcass weight and dressing percentage of Highland sheep were not affected by processing of barley grain (Salo *et al.* 2016).

Lambs fed diet containing ground barley with a 3 mm of screen had (P<0.05) higher longissimus muscle area compared to lambs fed whole barley grain. The pattern of fat deposition and increase in longissimus area was altered by changing screen size.

Table 1 Effects of barley grain particle size on rumen pH and ruminal ammonia concentration

Items	Basal diet* + whole barley grain	Basal diet + ground barley with a 5 mm screen	Basal diet + ground barley with a 3 mm screen	Basal diet + ground barley with a 1 mm screen	SEM
Average pH	6.21[a]	6.17[ab]	6.15[ab]	6.05[b]	0.06
Average NH_3-N (mg/dL)	14.08	13.98	13.87	13.74	0.23

* Basal diet on DM basis consisted of 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt, 10 g/kg a vitamin-mineral premix and 600 g/kg barley.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 2 Effects of barley grains particle size on performance of male lambs

Items	Basal diet* + whole barley grain	Basal diet + ground barley with a 5 mm screen	Basal diet + ground barley with a 3 mm screen	Basal diet + ground barley with a 1 mm screen	SEM
Final body weight (kg)	54.3	54.9	52.3	51.5	1.77
Average dry matter intake (kg)	1.46[a]	1.41[ab]	1.39[ab]	1.39[b]	0.023
Average daily gain (g)	165.7[a]	163.9[a]	141.7[ab]	121.3[b]	12.48
Feed conversion ratio	9.19[ab]	8.95[b]	10.16[ab]	11.59[a]	0.901
Cost of feed for kg live weight (Rial)	65610[bc]	63903[c]	72542[b]	82753[a]	534.1

* Basal diet on DM basis consisted of 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt, 10 g/kg a vitamin-mineral premix and 600 g/kg barley.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 3 Effects of barley grains particle size on carcass characteristics of male lambs

Items	Basal diet* + whole barley grain	Basal diet + ground barley with a 5 mm screen	Basal diet + ground barley with a 3 mm screen	Basal diet + ground barley with a 1 mm screen	SEM
Cold carcass weight (kg)	27.64	27.92	26.92	26.1	0.813
Dressing percentage (%)	50.90	50.86	51.47	50.68	1.07
Longissimus muscle area (cm^{2})	14.7[b]	15.9[ab]	16.4[a]	16.2[ab]	0.543
Leg weight (kg)	6.68	6.62	6.64	6.26	0.285
Shoulder weight (kg)	4.38	4.63	4.43	4.16	0.163
Back weight (kg)	5.59	5.40	5.23	5.14	0.147
Brisket weight (kg)	3.35[a]	3.32[ab]	3.29[ab]	3.14[b]	0.123
Neck weight (kg)	1.25	1.20	1.30	1.22	0.051
Flap weight (kg)	1.41[b]	1.81[a]	1.50[ab]	1.43[b]	0.107
Head weight (kg)	2.75	2.65	2.65	2.69	0.064
Back fat thickness (cm)	0.600	0.505	0.512	0.498	0.063
Abdominal fat (kg)	0.890[a]	0.785[ab]	0.535[b]	0.527[b]	0.901
Pelvic fat (kg)	0.205[a]	0.197[ab]	0.120[b]	0.138[ab]	0.023
Kidney fat (kg)	0.178	0.192	0.145	0.168	0.019

* Basal diet on DM basis consisted of 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt, 10 g/kg a vitamin-mineral premix and 600 g/kg barley.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Feeding ground barley grain with a 3 mm screen could provide the energy and protein needs in synchronization, which may stimulate the microbial growth in the rumen (Witt *et al.* 1999). Crane *et al.* (2014) reported that feeding ground corn grain increased loin eye area of feedlot lambs fed high crude protein diet. The improved microbial growth in the rumen led to improving of longissimus muscle area. Treatments had no significant effect on leg, shoulder, back and neck weights of lambs (P>0.05). There was no difference in back fat thickness and kidney fat of lambs fed whole and ground barley grains as previously reported by Petit (2000). Moreover, Crane *et al.* (2014) reported that grinding of corn grain had not significant effect on dressing percentage and fat depth of feedlot lambs. Lambs fed whole barley grain also had higher abdominal and pelvic fats, which is in line with results of Sormunen-Cristian (2013) who, reported that lambs receiving whole barley grains had a higher kidney fat than those receiving crushed or ground barley grains. Feeding whole compared to ground barley decreases synchronization of energy and protein in rumen and increases acetate: propionate ratio, overall resulting in increased abdominal and pelvic fats (Ørskov *et al.* 1974).

Effects of barley grains particle size on internal organs of lambs are shown in Table 4. Kidney, heart, lungs and gastrointestinal tract weights of lambs were not affected by treatments (P>0.05). However, liver weight of lambs was statistically different among treatments. The highest liver weight was obtained from lambs fed whole barley grains. While data on the effects of grain particle size on internal organs of lambs is limited, there is high correlation between live body weight and internal organs weights (Abegaz *et al.* 1996).

Table 4 Effects of barley grains particle size on internal organs weights (kg) of male lambs

Organs weights	Basal diet* + whole barley grain	Basal diet + ground barley with a 5 mm screen	Basal diet + ground barley with a 3 mm screen	Basal diet + ground barley with a 1 mm screen	SEM
Kidney	0.138	0.132	0.127	0.133	0.004
Liver	0.783[b]	0.862[a]	0.665[b]	0.672[b]	0.037
Heart	0.227	0.223	0.210	0.212	0.007
Lungs	0.577	0.568	0.608	0.570	0.024
Gastrointestinal tract	2.60	2.58	2.55	2.42	0.047

* Basal diet on DM basis consisted of 365 g/kg corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt, 10 g/kg a vitamin-mineral premix and 600 g/kg barley.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

According to the non -significant effect of barley particle size on live body weight, this result is predictable.

CONCLUSION

Barley grain particle size affects the performance of young feedlot lambs. Grinding the grains to pass through 5 and 3 mm sieves reduced feed cost of gain, abdominal and pelvic fat deposition. Our results suggest ground barley grain with a 5 mm or a 3 mm screen for feeding 7-8 months lambs fed high urea diet. Further research on particle size effects on ruminal nutrient degradability and microbial crude protein synthesis is needed.

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