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Effects of feeding whole and ground barley grains on its ruminal dry matter and crude protein degradability and performance of male lambs

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Abstract

Two experiments were conducted to evaluate effects of feeding whole and ground barley grains in diet containing high urea on its ruminal dry matter (DM) and crude protein (CP) degradability and performance of male lambs fed barley-based diet. Barley grains were ground with hammer mill fitted with 5, 3 and 1 mm screens. DM and CP ruminal degradabilities of whole and ground barley grains were determined by nylon bag technique. Whole barley grains were not degraded up to 48 h incubation in the rumen. Water soluble fraction of DM and CP of barley increased as screen size decreased. Effective rumen degradation (ERD) of DM and CP increased as screen size decreased. In experiment 2, twenty four male lambs were used. Lambs were fed with 4 diets (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) in a completely randomized design for 90 days. At the end of experiment, lambs were weighed after 18 hours water and feed deprivation and then were slaughtered. Average daily gain (ADG), feed conversion ratio (FCR), DM intake significantly affected by treatments. Consumption of whole barley grains increased dry matter intake and pelvic and abdominal fats. The results of this experiment showed that consumption of whole barley grains in diets of feedlot 7-8-month lambs with an initial live weight 40 kg can be recommended.

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Introduction

Processing of cereal grains is practiced with the purpose of ensuring better utilization of the diets. In dairy cows, processed barley has increased milk production and enhanced ruminal nitrogen efficiency (NRC, 2001). According to Sormunen-Cristian (2013), processing (crushing and grinding) of barley and oat had no positive effect on the feedlot performance of lambs. Processing increases the price of whole grain and consequently the feeding cost. Moreover, processed grain also creates more dust, resulting in less pleasant working condition. On the other hand, whole barley grain are not efficiently digested by sheep and therefore grains are usually processed prior to feeding to breach the hull and pericarp, thereby promoting access of ruminal micro-organisms to endosperm (McAllister *et al.,* 1994).

The price of oil seed meals in some countries is very high and non-protein nitrogen (NPN) is used to increase the CP level of the rations. 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, Canbolat and Karabulut (2010) reported that supplementation of urea to diet had a positive effect on feedlot performance of lambs. Therefore, we added urea to diets to meet approximately 24% of total CP requirement 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). Barley grain is the primary constituent of rations of growing-fattening lambs in Iran. Processing such as grinding generally increases ruminal degradable organic matter of barley for rumen bacteria for microbial crude protein synthesis.
There is little information concerning the effects of feeding whole and ground barley grains on the performance and carcass quality of male lambs fed high urea diet. Therefore, the aim of this study was to evaluate the effects of feeding whole and ground barley grains in diet containing high urea on its ruminal degradability, feedlot performance, carcass characteristics and chemical composition of LD muscle of lambs.

Materials and methods

Experiment

Animal and diet

Three ruminally fistulated rams weighing 48 kg were used. Rams were fed of on DM basis a total mixed ration containing 365 g/kg of 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 was included for adaptation to the diet. Water was available ad libitum. The diet was formulated according to sheep National Research Council (NRC, 1985) guidelines to contain 124 g CP/kg of DM and was fed twice daily at 07:00 and 15:00 h.

In situ ruminal degradability

Rumen degradability of DM and CP of unprocessed or processed barley grain was determined using the nylon bag technique according to Michalet-Doreauand and Ould-Bah (1992). Nylon bags (8 cm × 15 cm; 45 μm pore size) were filled with approximately 3 g sample (size: bag surface area of 12.5 mg/cm²). Barley grains were ground with hammer mill fitted with 5, 3 and 1 mm screens. Duplicate bags were incubated in the rumen for 0, 2, 4, 8, 16, 24 and 48 h. All bags were simultaneously placed in the rumen just before the rams were offered their first meal (i.e., 07:00 h). After retrieval from the rumen, bags were thoroughly washed with tap water until the rinsing water was clear. The same procedure was applied to two bags per treatment to obtain the 0 h value. The residues were dried and analyzed for DM and CP to determine degradation kinetics of whole and ground barley grains. Digestion kinetics of DM or CP was determined according to the equation of Ørskov & McDonald (1979). Effective rumen degradability (ERD) of DM and CP was calculated as:
$ERD = a + [b \times c/(c+k)]$.

Where: 'a' is the washout fraction, 'b' the potentially degradable fraction, 'c' the constant rate of disappearance of b, t the time of incubation (h).

Estimated ruminal outflow rates (k) of 2, 5 and 8%/h were used.

Chemical analyses

The DM content of feed samples, LD muscle samples and nylon bag residues was determined at 55°C for 48 h. The N in feeds, LD muscle samples and residues after rumen incubation was determined according to AOAC (1995). Ash was determined by burning duplicate 2 g samples at 500°C for 5 h in a muffle furnace (AOAC, 1995). Total fat content of LD muscle was determined according to AOAC (1995). ADF was determined by the method of Van Soest *et al.* (1991).

Experiment 2

Feedlot trial

Twenty four Mehraban male lambs (7–8-month-old) with an initial live weight (mean ± SD) of 39.5±4.17 kg were used to determine the effects of whole and ground barley grains on feedlot performance and carcass characteristics of lambs. The lambs were allotted randomly to 24 pens (140×120 cm) and water was available in plastic buckets. They were maintained at ambient temperature and natural day length and pens were cleaned weekly. 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 with 4 diets (1: basal diet+whole barley grain, 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 consisted of 365 g/kg of DM corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt and 10 g/kg a vitamin-mineral premix to which was added 600 g/kg of barley in the appropriate form. The diet consisted of (DM basis) 2.65 Mcal metabolizable energy (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 or exceed the requirements (NRC, 1985). The diets were fed as a totally mixed rations twice daily at 0800 and 1600 h in amounts to ensure 5% orts.

Amounts of feed offered and refused were recorded daily. At the initial of experiment 2, lambs were weighed and lamb weights were recorded monthly before the 0800 h feeding to monitor body weight change throughout the experiment. At the end of 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). Hot carcass weight was determined immediately after slaughter. Cold carcass weight was determined after keeping at 4 °C for 24 h. The cold carcass weight and live weight were used for determination of the dressing percentage. The fat-tail and abdominal and pelvic fats were removed and weighed. Fat depth over carcass was measured at the cross section of the 12th and 13th thoracic ribs at 4 points and the values were averaged as a measure of subcutaneous fat depth. The right LD muscle was ground twice and mixed thoroughly before sampling for chemical analysis. Samples (approximately 200 g) were taken for determining of chemical composition of LD muscle. The samples were kept at -20 °C until analysis for chemical composition.

Statistical analyses

degradability data were analyzed as a completely randomized block design according to the general linear models (GLM) procedure of SAS (1996) with the statistical model $Y_{ijk}=\mu+T_i+B_j+e_{ijk}$. Data for feedlot performance, carcass characteristics and chemical composition of LD muscle 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_{ijk} and Y_{ij} are dependent variable, μ is overall mean, T_i is screen size effect, B_j is animal effect and e_{ijk} and e_{ij} are residual error. Least significant difference was used to compare means. Treatment differences were considered significant when $P<0.05$.

Results and discussion

Effects of grinding on DM and CP degradability parameters of barley are presented in Table 1. Whole barley grains were not degraded up to 48 h incubation in the rumen. When the grinding screen aperture decreased, the washout fractions of DM and CP decreased and potentially degradable fraction of DM and CP increased. Our results are consistent with Cerneau and Michalet-Doreau (1991), who reported that the increase in grinding fineness (from 6 to 0.8 mm screen grinding) led to an increase in degradation of starch, organic matter and CP of barley. Therefore, grinding induced more rapidly transformed starch granules into less-organized, amorphous, and easily hydrolysable state. The higher degradation is also due to increased water absorption capacity, which ensures better enzyme diffusion within the starch granules. Moreover, higher solubilization of protein matrix surrounding the starch granule may make it more accessible to amylolytic activity. However, grinding increases surface area per unit weight of sample and the surface area accessible for microbial attachment. This generally results in increased digestion rate (Nocek, 1988).

Table 1 Effects of grinding on rumen degradation parameters of dry matter and crude protein of barley

	Ground barley with a 5 mm screen	Ground barley with a 3 mm screen	Ground barley with a 1 mm screen	SEM
Dry matter				
a (g/kg)	355.3[b]	395.3[a]	412.5[a]	5.87
b (g/kg)	493.1[a]	464.0[b]	453.7[b]	4.07
a+b (g/kg)	848.4[b]	859.4[ab]	866.2[ab]	8.27
c (per h)	0.268[b]	0.282[ab]	0.295[a]	0.0058
Effective rumen degradation (g/kg)				
0.02/h	806.7[b]	828.6[ab]	837.3[a]	8.09
0.05/h	770.7[b]	789.3[ab]	800.3[a]	8.17
0.08/h	734.8[b]	756.6[ab]	769.2[a]	8.01
Crude protein				
a(g/kg)	203.7[b]	210.2[ab]	221.7[a]	5.45
b(g/kg)	655.2[a]	644.7[a]	635.3[b]	4.28
a+b(g/kg)	858.8[a]	857.0[a]	854.8[a]	7.35
c (per h)	0.150[b]	0.162[a]	0.166[a]	0.0030
Effective rumen degradation (g/kg)				
0.02/h	766.6[a]	783.7[a]	788.6[a]	8.54
0.05/h	695.0[a]	702.3[a]	709.7[a]	6.36
0.08/h	631.0[a]	641.1[a]	650.2[a]	6.18

[a, b] Means in the same row with different letters are different ($P<0.05$).

a, the washout fraction; *b*, the potentially degradable fraction

SEM, standard error of mean.

Maximum potential degradability (a+b) of DM and CP were not affected ($P>0.05$) by grinding. Maximum potential degradability (a+b) of DM and CP were 848 and 859 g/kg for ground barley grain with a 5 mm screen, respectively, indicating barley grain is a readily available source of dietary energy and protein. Degradability parameters of DM are in consistent with Ghorbani and Hadj-Hussaini (2002). However, the washout fraction of DM was lower than the value reported by Sadeghi and Shawrang (2007). Factors that influence the extent and rate of ruminal digestion of in situ studies are differences in pore size of bags, the variety of grain, the ratio of sample weight: bag surface area, particle size and washing technique used in the studies (Vanzant *et al.,* 1998; Ghorbani and Hadj-Hussaini, 2002).

ERD of DM increased as grinding screen decreased ($P<0.05$). ERD value of DM of ground barley grain was similar to that obtained by Ghorbani and Hadj-

Hussaini (2002) and lower than that reported by Sadeghi and Shawrang (2007). Ghorbani and Hadj-Hussaini (2002) reported that the ERD for barley DM of 10 different cultivars ranged from 75.4 to 79.5% h^{-1} at rumen outflow rate of 8% h^{-1}. The value of 840 g/kg was reported by Sadeghi and Shawrang (2007) for ERD of DM at rumen outflow rate of 0.08 h^{-1}. As the rate of degradation of DM and CP increases, the amount of organic matter being made available to rumen bacteria becomes larger.

Table 2. Effects of feeding whole and ground barley grains on performance of male lambs.

	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	P value Whole vs ground	SEM
Initial body weight (kg)	39.4[a]	40.2[a]	39.6[a]	40.6[a]	0.702	1.62
Final body weight (kg)	54.3[a]	54.9[a]	52.3[a]	51.5[a]	0.495	1.77
Total weight gain (kg)	14.9[a]	14.8[a]	12.8[ab]	10.9[b]	0.145	1.12
Average daily gain (g)	165.7[a]	163.9[a]	141.7[ab]	121.3[b]	0.145	12.48
Total dry matter intake (kg)	131.2[a]	127.1[ab]	125.2[ab]	124.7[b]	0.022	2.02
Average dry matter intake (kg)	1.46[a]	1.41[ab]	1.39[ab]	1.39[b]	0.022	0.023
Feed conversion ratio	9.19[ab]	8.95[b]	10.16[ab]	11.59[a]	0.301	0.901
Hot carcass weight (kg)	28.47[a]	28.95[a]	27.83[a]	27.13[a]	0.619	0.843
Cold carcass weight (kg)	27.64[a]	27.92[a]	26.92[a]	26.1[a]	0.492	0.813
Dressing percentage (%)	50.90[a]	50.86[a]	51.47[a]	50.68[a]	0.968	1.07
Fat-tail weight (kg)	4.80[a]	4.94[a]	4.55[a]	4.78[a]	0.921	0.381
Back fat thickness (cm)	0.600[a]	0.505[a]	0.512[a]	0.498[a]	0.182	0.063
Abdominal fat (kg)	0.890[a]	0.785[ab]	0.535[b]	0.527[b]	0.054	0.901
Pelvic fat (kg)	0.205[a]	0.197[ab]	0.120[b]	0.138[ab]	0.111	0.023

[a, b] Means in the same row with different letters are different (P<0.05).

SEM, standard error of mean

*Basal diet consisted of 365 g/kg of DM corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt and 10 g/kg .

Effects of feeding whole and ground barley grains on performance of lambs are presented in Table 2. ADG, total weight gain, DM intake and FCR (kg DM to kg live weight gain) of lambs were affected by treatments (P<0.05). Final body weight was not different between treatments (P>0.05).

The body weight gain of lambs ranged from 10.9 to 14.9 kg. The highest body weight gain was obtained for lambs fed whole barley grains and ground barley grains with a 5 mm screen. The lowest total increase in body weight gain was obtained from lambs fed diet containing ground barley with 1mm screen. ADG of lambs ranged 121.3 to 165.7 g, which is in agreement with Fozooni and Zamiri (2007). Overall, processing had no effect on total body weight gain and ADG. Our results are in consistent with Sormunen-Cristian (2013), who reported that processing (crushing and grinding) of barley and oat had no positive effect on the feedlot performance of lambs. However, Voia *et al.* (2009) reported that total weight gain and ADG of ground barley-fed lambs tented to be higher than whole barley–fed lambs. The improved performance of whole barley-fed lambs was associated with their higher DM intake compared to ground barley-fed lambs. Moreover, the higher ADG and total body weight gain is likely to be mostly attributable to improved digestibility of diet.

The total DM intake of lambs receiving ground barley grains was on average 125.7 kg and 5.5 kg lower than those receiving whole barley grains. DM intake of lambs fed whole barley grains was significantly higher than lambs fed ground barley grains, which could be supported by degradability data and explained by the fact that DM and starch are more ruminally degradable in ground barley than whole barley grain (Cerneau and Michalet-Doreau, 1991). This might lead to a lower ruminal pH with ground barley than with whole barley based diet, resulting in a lower cellulolytic bacteria count and decreased DM intake (Askar *et al.,* 2006). Moreover, grinding results in a significant amount of dust, which reduces feed intake. 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 the higher initial weight of the lambs used in the present study. Feeding whole barley grain and ground barley grain with a 5 mm screen have provided the synchronization of energy and protein, which may have stimulated the microbial growth in the rumen (Witt *et al.,* 1999). The improved microbial growth in the rumen led to improving of FCR.

Table 3. Effects of feeding whole and ground barley grains on chemical composition of *longissimus dorsi* muscle of male lambs.

	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	P value Whole vs ground	SEM
Moisture (%)	57.62[a]	58.73[a]	58.40[a]	58.60[a]	0.092	0.492
Crude fat (%)	22.41[a]	21.93[a]	21.98[a]	21.62[a]	0.107	0.301
Crude protein (%)	17.88[a]	18.23[a]	18.45[a]	18.26[a]	0.157	0.427
Ash (%)	0.616	0.619[a]	0.632[a]	0.624[a]	0.499	0.012

SEM, standard error of mean

*Basal diet consisted of 365 g/kg of DM corn silage, 10 g/kg limestone, 10 g/kg urea, 5 g/kg salt and 10 g/kg a vitamin-mineral premix to which was added 600 g/kg of barley in the appropriate form.

There were no differences between the treatments in terms of the hot and cold carcass weights (P>0.05). The dressing percentage ranged 50.78% to 51.47%. Treatments had no significant effect on dressing percentage (P>0.05). The dressing percentage in the our study was similar to those obtained by Fozooni and Zamiri (2007). There was no difference in back fat thickness of lambs fed whole and ground barley grains as previously reported by Petit (2000). Lambs fed whole barley grain had also higher abdominal and pelvic fats, which is in line with results of Sormunen-Cristian (2013). Sormunen-Cristian (2013) reported that lambs receiving whole barley grains had a higher kidney fat than those receiving crushed or ground barley grains. Therefore, in agreement with other studies (Economides *et al.,* 1990; Petit, 2000; Sormunen-Cristian, 2013) it was suggested that barley should be fed as whole grain for lambs. Moreover, feeding whole barley grain is efficient for synchronous supply of energy and nitrogen to the rumen bacteria.

Effects of feeding whole and ground barley grains on chemical analysis of LD muscle samples are shown in Table 3. Treatments had no effect on chemical composition of LD muscle of lambs (P>0.05). Overall, moisture content of LD muscle of whole barley-fed lambs tended (P<0.092) to be lower than those fed ground barley grains. Moisture content of LD muscle in present study is consistent with those reported by Matsushita *et al.* (2010) and is lower in comparison with other study (Yousefi *et al.,* 2012). Yousefi *et al.* (2012) reported that moisture content of LD muscle of Chall lambs (10-12 months) was 761 g/kg. The decrease in moisture content of LD muscle observed in the present study seems to be related to increasing slaughtering age of sheep, increasing fat content of meat (Stankov *et al.*, 2002) and increasing level of nutrition (Fozooni and Zamiri, 2007). There was a tendency for the moisture content of LD muscle to be lower in lambs fed whole barley compared with those fed ground barley grains, which is in consistent with findings of Stankov *et al.* (2002). Stankov *et al.* (2002) reported that the decrease in moisture content of meat resulted from increasing fat content of meat.

The protein content of LD muscle of whole barley-fed lambs was 178.8 g/kg, which was close to results of Tariq *et al.* (2013). The CP content of LD muscle of lambs was lower than value reported by Yousefi *et al.* (2012) and was higher than value reported by Matsushita *et al.* (2010). The values of 208.3 g/kg and 145.5 g/kg for CP of LD muscle were reported by Yousefi *et al.* (2012) and Matsushita *et al.* (2010), respectively. The CP content of LD muscle is affected by slaughtering age, breed, level of nutrition and rearing system (Khaldari, 2008).

The results of fat contents obtained in the present study were close to those reported by Matsushita *et al.* (2010), who obtained the LD muscle fat content of 25.28% for 40 kg lambs. The fat content of LD muscle was high in present study. The increase in fat content of LD muscle lambs is related to increasing slaughtering age (Tariq *et al.,* 2013). Tariq *et al.* (2013) showed that the older animal had higher meat fat content. Fat content of LD muscle of lambs was similar among treatments although fat content of LD muscle of lambs tended ($P<0.107$) to be increased by feeding whole barley grains compared to ground barley grains. Feeding whole compared to ground barley decreases rate of DM ruminal fermentation (as supported by DM degradability data in present study) and increases acetate: propionate ratio, overall resulting in increased LD muscle fat (Ørskov *et al.,* 1974).

The average ash content of LD muscle was 0.623% for all groups. Treatments had no significant effect on ash content of LD muscle. Ash content of LD muscle is in line with study of Matsushita *et al.* (2010) and was lower than other studies (Yousefi, *et al.,* 2012; Tariq *et al.,* 2013). This difference probably was due to breed, sacrifice age and level of nutrition (Khaldari, 2008; Yousefi *et al.,* 2012).

Conclusion

Feeding ground barley to lambs did not improve the performance of the lambs. Moreover, processing the grain increases the cost of the diet. It was concluded that feeding whole grain to 7 - 8 months old lambs can be recommended. Moreover, if grain fed to lambs is ground using a hammer mill, then the size of the screen should not be less than 5 mm.

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