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Performance, Rumen Fluid pH, and Blood Metabolites of Lambs Fed on Whole or Ground Barley Grain

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ABSTRACT

The objective of this study was to assess the effect of feeding whole or ground barley grain on Awassi lambs. Twenty-six lambs (17.5 ± 1.28 kg) were randomly assigned to one of two treatments (13 lambs/treatment) on whole or ground barley grain. Lambs were housed individually and fed twice daily for 47 days. Initial body weight (BW) was not different when the experiment was started, as well as for the BW at the end of the experiment. At the same time, total weight gain (TWG) and the average daily gain (ADG) were significantly higher for lambs fed a diet containing ground barley grain than lambs fed a diet containing whole barley grain. The digestibility of dry matter, crude protein, neutral detergent fiber, and acid detergent fiber was greater in ground barley than in whole barley treatment. Nitrogen intake and nitrogen in the urine were similar in both lamb groups. At the same time, fecal N was greater in the group of lambs fed whole barley grain in their diet, but less amount and percentage of N retained in the body for the same group of lambs (whole grain). Blood Urea N was not affected by the dietary treatment, while blood glucose was higher in lambs fed ground barley grain compared to lambs fed a diet containing whole barley grain. In conclusion, feeding ground barley contained diet had a significant improvement in intake, digestibility, and N retention, without any negative effects on ruminal pH.

Keywords: Awassi lambs, Barley grain, Feed intake, Digestibility, Growth performance.

INTRODUCTION

Barley is an energy-rich cereal grain with a thick fiber coat and with high level of starch. Grinding has been practiced widely to ensure proper mixing and digestion of barley. Sheep production in Jordan focuses on the final product of lambs for consumers which is the meat; therefore, maximizing sheep production and increasing the body weight gain of lambs has a unique importance in the animal industry (Omar *et al.*, 2012). Since the feeding cost is about 70% of the total production cost, minimizing the extra cost of feeding sheep is required. Using whole barley will lower the cost of gain since no processing cost is required, whereas grinding increases the surface area of the barley in the concentrate diet fed to the lambs, which maximizes contact with the ruminal microbes and their enzymes.

The world's barley production is around 30 % of corn production, but the protein, methionine, lysine, cysteine, and tryptophan percentages in barley were higher when compared with corn (Nikkhah *et al.*, 2004). Compared to

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other cereal grains, the starch in barley ferments rapidly, which requires a higher degree of control and management when added to high-concentrate finishing diets (Owens *et al.,* 1998) to avoid animal losses from ruminal acidosis. Cereal grain grinding has been practiced widely to ensure proper mixing and digestion. Although ruminant animals are highly able to consume whole grains such as barley and maize, processing cereal grains such as grinding increases the utilization and efficiency of edible products improves their nutritional value, and increases their efficiency and digestibility (Lesmeister & Heinrichs, 2004). Using early-weaned lambs, Orskov *et al.,* (1974) demonstrated that whole barley had greater digestion coefficients than ground barley. Later, Kaiser (1999) asserted that barley should be treated before feeding it to ruminants. Additionally, grain processing increased the starch's susceptibility to microbial attack when provided in high-concentrate finishing diets, which in turn enhanced the utilization of cereal grains (Caetano *et al.,*2019).

Therefore, this experiment was designed and performed to study the effect of feeding whole or ground barley grain on nutrient intake, nutrient digestibility, N retention, and blood metabolites of Awassi lambs fed a finishing diet.

Materials and Methods

All methods in this study were permitted by the Jordan University of Science and Technology Institutional Animal Care and Use Committee. The study was conducted at the Agricultural Research and Training Unit (ARTU) at Jordan University of Science and Technology (JUST).

Animals and experimental methods

In a complete randomized design, twenty-six Awassi ram lambs (17.5 ± 1.28 kg initial body weight, 2 to 3 months of age, and thirteen lambs per group) were randomly allocated to one of two dietary treatments (whole or ground barley grain). Both treatments have a similar diet composition, which is formulated based on the N.R.C. (2007) to meet the growing Awassi lamb's requirements. Both diets include barley (58%), soybean meal (15%), wheat straw (25%), limestone (1%), salt (0.9%, and vitamin-mineral premix (0.1%). The chemical composition of the diet (DM basis) was 90.1% DM, 16.5% crude protein (CP), 33.1% neutral detergent fiber (NDF), and 15.3% acid detergent fiber (ADF) (Any information on the amount of energy in the diet). All lambs were treated for internal parasites at the start of the study. Seven days of adaptation were allowed before the experimental period. Diets were presented *ad libitum* to the animals throughout the study which lasted for 47 days after adaptation. In shaded individual pens (1.5 × 0.75 m) lambs were housed separately and fed twice daily (two equal meals at 09:00 and 14:00 h). Pens were cleaned weekly or as needed to stay dry and clean.

The experimental diets were presented as a total mixed ration with water offered as free access all through the experiment. Daily feed refusals were collected, weighed, and stored at -20°C for chemical analysis throughout the study. Dietary DM intake and nutrient intake were measured by the difference between the offered nutrients in feed and refusals nutrients (after analyzing diets and refusals for the chemical composition). Lamb's weights were recorded at the beginning of the experiment and subsequent weights were recorded before the morning feeding every three weeks throughout the study. The difference between the final and the initial BW of the lambs was calculated to find total the gain. Dividing total gain by the duration of the study to calculate the average daily gain (ADG).

After 47 days of the feeding period, from both groups, ten lambs were randomly selected (five lambs/group) and housed separately in metabolism crates (1.05 × 0.80 m) to evaluate N retention and nutrient digestibility. After five days of adaptation, lambs were kept in the crates for five days of collection where feed intake and refusals were

recorded and sampled for pending analysis. In plastic bottles, urine was gathered, weighed, and recorded, and then 5 % was saved for N retention evaluation. Each bottle had 50 mL of 6 *N* HCl added before the urine sample to avoid ammonia losses. Urine samples for each lamb were combined and one sample was analyzed. Daily fecal production was gathered, weighed up, and recorded, and then 10 % was saved for analyses. Daily collected fecal samples were combined for each lamb, and one sample was analyzed. Fecal samples were dried in a forced-air oven, at 55ºC to reach a steady weight, then air equilibrized, and ground to pass by a 1 mm sieve and kept for more analysis.

Laboratory procedures

Feed and refusal samples (composited) were dried in a forced-air oven, at 55ºC to reach a constant weight, then air equilibrated, and ground to pass by a 1 mm sieve (Brabender OHG Kulturstrase, Duisburg, Germany) and kept for analysis. Following different procedures, diets, and refusals were analyzed for DM (100°C in the air-forced oven for 24 h), CP (Kjeldahl procedure), and EE (Soxtec procedure, SXTEC SYSTEM HT 1043 Extraction Unit, TECATOR, Box 70, Hoganas, Sweden). Using the ANKOM^{2000} fiber analyzer apparatus (ANKOM Technology Cooperation, Fairport, NY) all feed and fecal samples were analyzed for NDF and ADF according to the modified procedure described by Soest et al. (1991). The analyses for NDF and ADF were completed using sodium sulfite and a high-temperature stable alpha-amylase and expressed with the content of ash residual.

On days 0, 21, 42, and 63 blood samples were drawn at 8:00 h (before morning feeding) in plain vacutainers from the jugular vein, then centrifuged one hour after collection at 3000 r/m for 15 min. Serum samples were separated directly and then stored at - 20 ºC till the day of analysis. All serum samples were analyzed for the concentrations of glucose and urea N according to the manufacturer's specifications using commercial kits (BioSystems, S. A. Costa Brava, Barcelona, Spain) with a spectrophotometer (JENWAY 6105 UV/Vis, Model 6105, Janeway LTD Felsted, Dunmow ESSEX CM6 3LB, UK).

On the last day of the study, using a syringe with a G14 needle, 5 mL of rumen fluid was gathered from the ventral sac of the rumen at 0, 2, and 4 h post feeding, to evaluate rumen fluid pH.

Statistical analysis

All data were tested using the MIXED procedure of SAS (version 8.1, 2000, SAS Inst. Inc., Cary, NC) with the lamb as the random variable. For analyzing differences in body weight gain, initial body weight was used as a covariate. For performance data, treatment was the fixed effect. However, treatment, day, and their interaction were considered fixed effects, and lamb nested within treatment was a random effect with the day as a repeated effect for the serum and rumen fluid data. No day × treatment interactions were found; therefore, the main treatment effects are considered. To identify significant differences amongst means; means LSD of the MIXED procedures of SAS were used. Significant differences were detected at ($p < 0.05$).

Results

Growth performance

Parameters measured reflecting Awassi lamb's growth performance that was affected by barley grain processing (whole vs ground grain) are listed in Table 1. The initial body weight for lambs was not different when the experiment was started ($p > 0.05$), as well as the final body weight at the end of the experiment ($p > 0.05$). However, total gain (Final body weight – Initial body weight) was significantly higher for a lambs-fed diet containing ground barley grain compared to a lambs-fed diet containing whole barley grain (8.1 kg vs. 10.8 kg). The average daily gain (total gain/days on feed) was also

significantly higher for a lambs-fed diet containing ground barley grain compared to a lambs-fed diet containing whole barley grain (171 g/d vs. 230 g/d; $p < 0.05$). The feed conversion ratio (FCR) was not affected by the treatment diets fed to lambs ($p > 0.05$).

Nutrient intake and digestibility, Nitrogen balance, and rumen fluid pH

This research was performed and conducted to evaluate the effect of feeding whole or ground barley grain to Awassi lambs. The results indicate no effect of barley processing in the diet on the amount of daily dry matter intake (Table 1) and N intake (Table 2; $p > 0.05$).

Table 1. Effect of barley grain processing (whole vs ground grain) on nutrient intakes and growth performance of Awassi lambs.

	Treatment[1]		
Item	**Whole**	**Ground**	**SE**
DM Intake (g/d)	903	992	53.0
Initial BW, kg	16.9	18.0	1.28
Final BW, kg	25.0	28.8	1.74
Total gain, kg	8.1[a]	10.8[b]	0.84
ADG, g/d	171[a]	230[b]	17.8
Feed to Gain ratio	5.39	4.50	0.37

[1]Diets were: Whole (n = 13) and Ground (n = 13) barley grain

[a, b] Means within the same row with different letters are significantly different ($p < 0.05$)

Table 2. Effect of barley grain processing (whole vs ground grain) on N balance of Awassi lambs.

	Treatment[1]		
Item	**Whole**	**Ground**	**SE**
N intake, g/d	31.0	33.1	0.97
N in feces, g/d	8.4[b]	6.3[a]	0.49
N in urine, g/d	7.9	5.9	1.56
Retained, g/d	14.7[a]	20.9[b]	1.61
Retention, %	47.5[a]	63.0b	5.41

[1]Diets were: Whole (n = 5) and Ground (n = 5) barley grain.

[a, b] Means within the same row with different letters are significantly different ($p < 0.05$)

Dry matter digestibility results, and the digestibility results of CP, NDF, and ADF were summarized in Table3.

Table 3. Effect of barley grain processing (whole vs ground grain) on digestibility of nutrients and rumen fluid pH of Awassi lambs.

	Treatment[1]		
Item	**Whole**	**Ground**	**SE**
Dry matter	71.3[a]	80.7[b]	1.77
Crude protein	72.7[a]	79.5[b]	2.09
Neutral detergent fiber	55.6[a]	66.6[b]	3.07
Acid detergent fiber	53.4[a]	66.3b	2.99
Rumen fluid pH	6.37	6.67	0.119

[1]Diets were: Whole (n = 5) and Ground (n = 5) barley grain. For pH (n = 13).

a, b Means within the same row with different letters are significantly different ($p < 0.05$)

which was greater in ground barley treatment than in whole barley treatment ($p < 0.05$). Rumen pH was similar in both groups (Whole or Ground) and was not affected by the processing of barley grain ($p > 0.05$). Nitrogen balance data (Table 2) shows a similar intake of N in both lamb groups and urine N as well ($p > 0.05$), while showing greater fecal N in the group of lambs fed whole barley grain in their diet ($p < 0.05$). The results also show less amount and percentage of N retained in the body for the same group of lambs (whole grain; $p < 0.05$).

Blood

The effect of barley grain processing (whole vs ground grain) on blood metabolites is listed in Table 4.

Table 4: Effect of barley grain processing (whole vs ground grain) on blood metabolites of Awassi lambs.

	Diets[1]		
Item	Whole	Ground	SEM
Urea N (mg/dL)	23.45	23.36	1.627
Glucose (mg/dL)	50.20[a]	56.58[b]	2.055

[1]Diets were: Whole (n = 13) and Ground (n = 13) barley grain

[a, b] Means within the same row with different letters are significantly different ($p < 0.05$)

Blood Urea N was not affected by the experiment diets ($p > 0.05$), while blood glucose was higher in lambs fed a diet containing ground barley grain compared to lambs fed a diet containing whole barley grain ($p < 0.05$).

Discussion

While conducting this study, we hypothesize that feeding lambs fattening diets containing ground vs. whole barley grain would improve growth performance, nutrient digestibility, and feed efficiency. To prevent any additional influence on the study's findings, experimental diets were created to have the same nutritional and chemical content (on the same DM status) other than grinding the barley in the diet containing ground barley grain.

Grinding barley increases the surface area of the barley in the concentrated diet fed to the lambs, which boosts the interaction with the ruminal microbes and their enzymes. As well as grinding is important to ensure proper mixing of the diet. Although ruminant animals are highly able to utilize whole grains such as barley, processing cereal grains (for instance grinding) increases the utilization and proficiency of edible products improves their nutritional value, and increases their efficiency and digestibility (Yoon *et al.,* 1986).

No advantage of processing barley is indicated by some researchers when compared to feeding whole barley in ruminant diets (Erickson *et al.,* 1989; Morgan *et al.,* 1991; Orskov, 1979). At the same time, others approved the benefits of feeding processed barley to ruminant animals (Yoon *et al.,* 1986).

Our results indicated no effect of barley processing on daily dry matter intake nor feed conversion ratio (FCR) which agreed with (Erickson *et al.,* 1989). Total gain and ADG were higher for lambs fed a diet containing ground barley grain compared to lambs fed a diet containing whole barley grain, which did not agree with the author who reported no advantage in the performance of lamb when fed barley ground vs. whole; feed intake, average daily gain, and feed efficiency, were the same for the treatments of whole barley vs. ground barley (Erickson *et al.,* 1989). Our results show no significant differences in final body weight between treatments, but numerically the final body weight in the ground barley group was 28.8 kg while 25 kg for the whole barley group, this ended in significant differences in total gain between groups. Total gain was greater when animals fed a diet containing ground barley compared to the animals fed a diet containing whole barley grain, and since the average daily gain was expressed as total gain/days on feed, it also shows the same trend as total gain. Gallo *et al.,* (2016) found that increasing the particle size of ground grain decreases the rate of starch degradation. Dehghan-Banadaky *et al.,*. (2007) also found that the processing of barley-like cracking increases the availability of starch, and such processing results in high starch degradability in the rumen and the provision of the energy required for the growth of fattening animals.

Processing cereal grains such as grinding, increases the utilization and efficiency of edible products improves their nutritional value, and increases their efficiency and digestibility (Lesmeister & Heinrichs, 2004; Orskov *et al.,* 1974). The digestibility results of DM, CP, NDF, and ADF in the current study were greater in ground barley treatment than in whole barley treatment. Ghorbani *et al.,* (2002) reported less dry matter digestibility than found in dairy cattle studies using diets containing large particle sizes of barley when compared with diets containing fine particle sizes of barley. Similar results were reported by Sano *et al.,* (2018) in sheep who found a lower nutrient digestibility for the group treated with a diet containing ground barley grain compared with the other group treated with a diet containing whole barley grain.

Nitrogen balance data shows a similar intake of N in both lamb groups and similar urine N as well. At the same time, greater fecal N was found in the group of lambs fed whole barley grain in their diet, and as a result, less amount and percentage of N retained in the body for the

same group of lambs (whole grain). Lower fecal N in the group of lambs fed ground barley grain in their diet with similar intake N and similar urine N results in a smaller amount and percentage of N retained in the body for this group of animals fed ground barley grain in their diet. When whole barley rather than processed barley was fed, rumen pH increased. This would be expected to control and eliminate the problem related to fiber digestion and intake found when supplementing roughages with concentrate (Orscov & Fraser, 1975). Grinding barley grain (which is extremely fermentable) to a fine particle size would improve rumen fermentation level, and influence rumen pH (Yang *et al.,* 2000) and then the animal is highly susceptible to acidosis (Ebrahimi, 2020). This was not the case in our results of rumen pH, which were found to be numerically greater when the barley fed ground to the animals, but significantly they were the same in both groups (Whole or Ground) and were not affected by the processing of barley grain, this means processing of the barley and starch availability in the rumen did not affect rumen pH negatively. Due to the rapid degradation and fermentation of barley starch, the opposite is expected to happen, a drop of rumen pH, but since the barley included in the diet is less than 35% regardless of the method of processing, this was not the case. Rapid degradation and fermentation of barley starch with barley overfed will cause a drop in pH and result in ruminal acidosis (Nikkhah, 2012).

Blood glucose was higher in lambs fed a diet containing ground barley grain compared to lambs fed a diet containing whole barley grain, and this might be explained by the high availability of starch in the rumen from the ground barley, rapid degradation, and fermentation of barley starch, as starch fermented, high concentration of propionic acid appears in the rumen which is the main source of blood glucose through the glucogenic process of the energy metabolism. These results did not agree with the findings of Sano *et al.,* (2018) who found that the blood glucose concentration was not affected among diets (diet containing ground barley grain compared with diet containing whole barley grain). Despite this fact, our result agreed with the findings of (Nikkhah *et al.,* 2004) who fed ground barley to midlactation dairy cows. High blood glucose level might be the factor responsible for low protein turnover (even that was not expressed in blood Urea-N results) and increased N retention consequently, which is presented in the results of our current study.

Conclusion

Feeding diets containing ground barley to Awassi lamb during the finishing period have had a significant improvement in feed intake, average daily gain, nutrient digestibility, and N retention, without any negative effects on ruminal pH. More research studies are needed to validate the results obtained here so can the feed mill take their decisions on grinding the grains or not when mixing the diets of livestock.

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Conflict of interest:

The authors declare that they have no conflict of interest.

Ethics approval

The Institutional Animal Care and Use Committee at Jordan University of Science and Technology approved the techniques and procedures followed in this study.

Consent to participate

Not applicable.

Consent for publication

The authors declare that this study has never been published anywhere else.

Authors' contributions

FAAL: running the study, analyzing the collected samples, writing, reviewing, and editing.

BSO: writing & editing, data curation; formal analysis, methodology, supervision.

MAA: writing, reviewing, and editing.

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الأداء ودرجة الحموضة سائل الكرش ومستقلبات الدم للحملان التي تغذت على حبوب الشعير الكاملة أو المطحونة

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ملخص

هدفت هذه الدراسة إلى تقييم تأثير تغذية الحملان العواسي على حبوب الشعير الكاملة أو المطحونة. تم تخصيص ستة وعشرين حملًا (متوسط أوزانها 17.5 كجم) وزِّعت بشكل عشوائي إلى مجموعتين (13 حملًا / معاملة): على حبوب الشعير الكاملة أو المطحونة. تم إيواء الحملان بشكل فردي وإطعامها مرتين يوميًا لمدة 47 يومًا. لم يختلف وزن الجسم (BW في بداية التجربة عن نهايتها. وفي نفس الوقت كانت الزيادة الكلية TWG ومعدل الزيادة اليومية ADG أعلى معنويا في الحملان التي تغذت على حبوب الشعير المطحونة منهما في الحملان التي تغذت على حبوب الشعير الكاملة. كانت قابلية هضم المادة الجافة والبروتين الخام والألياف المنظفة المحايدة NDF و ADF أكبر في المجموعة المغذاة على الشعير المطحون مقارنة بالمجموعة المغذاة على الشعير الكامل. تم ادخال كميات متماثلة من النايتروجين في كل من المجموعتين كما تم اخراج كميات متماثلة من النايتروجين في البول أيضًا، في حين أنه تم إخراج كمية أكبر من النايتروجين عن طريق الروث في مجموعة الحملان التي تغذت على حبوب الشعير الكاملة، ولكن كمية ونسبة أقل من النايتروجين المحتفظ بها في الجسم لنفس المجموعة من الحملان (الحبوب الكاملة). لم يتأثر النيتروجين في يوريا الدم BUN بالمعاملة الغذائية، بينما كان مستوى الجلوكوز في الدم أعلى في الحملان التي تغذت على حبوب الشعير المطحونة مقارنة بالحملان التي تغذت على حبوب الشعير الكاملة. في الخلاصة دلت هذه التجربة على أن لتغذية الحملان على عليقة محتوية على الشعير المطحون تأثيرا إيجابيا ملحوظًا في استهلاك العلف والهضم، وحفظ النيتروجين، دون أي آثار سلبية على درجة الحموضة في الكرش.

الكلمات الدالة: حبوب الشعير، الحملان العواسي، استهلاك العلف، أداء النمو، قابلية الهضم.

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