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Dietary Supplementation of Different Forms of Barley Grain in Mohgani Male Lambs Feeding: Impacts on Growth Performance, Nutrient Digestibility, Blood Metabolites, and Carcass Characteristics

Research Article

M. Kazemi[1*], O. Jangjou[2] and H. Saleh[2]

[1] Department of Animal Science, Faculty of Agriculture and Animal Science, University of Torbat-e Jam, Torbat-e Jam, Iran
[2] Department of Animal Science, Higher Education Complex of Saravan, Saravan, Iran

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*Correspondence E-mail: phd1388@gmail.com

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ABSTRACT

The effects of dietary supplementation of different forms of barley grain (whole, ground, steam flaking, tempering, and dry rolling) was investigated on growth performance, nutrient digestibility, blood parameters, and carcass characteristics of Mohgani male lambs. Thirty male lambs were allocated in a completely randomized design to five experimental diets containing different processing forms of barley grain (whole barley grain as control, ground, steam flaking, tempering, and dry rolling) for 90 days. Lambs were fed on barley in form of dry rolling exhibited the highest final body weight (54.96 kg, P=0.003), average daily gain (350 g/day, P=0.01), blood glucose (64.54 mg/dL, P=0.05), and warm carcass weight (23.12 kg, P=0.05) compared to the lambs fed on whole barley grain. Nutrient digestibility (dry matter, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber), urinary purine derivatives (allantoin, xanthine, and hypoxanthine), and internal organs weight (kidneys, lungs, and liver) were not affected by different forms of barley grain. Also, lambs fed on ground barley exhibited the highest blood urea nitrogen (14.84 mg/dL) among other experimental diets (P=0.04). Barley processing in the form of dry rolling had beneficial effects on the growth performance of male lambs, however, more scientific research is needed to study the other processing methods.

KEY WORDS dry rolling, ground, steam flaking, tempering, whole barley.

INTRODUCTION

Barley (*Hordeum vulgare*) is one of the important grains that is extensively used as a source of energy in ruminant nutrition (Paris, 2000; Taghizadeh and Zabihollah, 2008). The feed supply during a fattening period accounts for physically processing the feed. Barley starch has been shown to ferment rapidly in the rumen. The high digestibility rate of barley grain has raised concerns about acidosis, lameness, hepatic abscesses, and gastrointestinal abnormalities in ruminants (Yang *et al.* 2000). It is commonly thought that in the feed industries, barley grain processing can be used to adjust the digestion rate of its nutrients to prevent acidosis (Beauchemin *et al.* 2001). Different processing methods have been employed to equilibrate and improve the starch and protein digestibility of the barley (Boyles *et al.* 2000). Nicholson *et al.* (1971) reported that about 65 to 70% of the cost of raising livestock is related to feeding, so it is possible to increase feed efficiency by decreased organic matter digestibility when whole barley was fed to cattle compared to milled barley. Dry rolled barley increased organic matter digestibility by 42% and starch digestibility by 100% in steers (Toland, 1976). Mathison (1996) reported 37% higher starch digestibility for rolled

barley when compared with whole barley. Zinn *et al.* (1996) reported an increase in digestible energy by 3.5-3.7%, and an increase in net energy by 7-8%, for steam flaked versus dry rolled barley. Tempering, in which moisture is added to the grain, maintains the particle size of the grain by reducing its shattering and often reduces the rate of starch degradation compared with dry rolling or grinding (Dehghan-Banadaky *et al.* 2007). Feed intake, average daily gain, and feed efficiency were not affected when tempered rolled grain was fed to growing cattle (Wang *et al.* 2003). However, Bradshaw *et al.* (1996) reported a 5.4, 5.7, and 14.2% improvement in whole tract DM digestibility, gross energy digestibility, and barley digestible energy content, respectively, when tempered barley was fed to animals. Recent studies have focused on identifying barley grain processing methods that optimize feed efficiency and avoid subclinical and clinical acidosis (Ramsey *et al.* 2002; Dehghan-Banadaky *et al.* 2007). Although different physical processing methods including grinding, dry-rolling (Anele *et al.* 2014; Yang *et al.* 2014), and temper-rolling (Yang *et al.* 1996), have been evaluated, however studies on the nutritional and performance properties of processed barley grain in different methods are contradictory. Also, data about different processing methods of barley on carcass characteristics of small ruminants is scarce. Therefore, the present study was conducted to investigate the effects of different barley processing including whole, ground, steam flaking, tempering, and dry rolling, on growth performance, nutrient digestibility, blood parameters, and carcass characteristics of Moghani male lambs.

MATERIALS AND METHODS

Barley grain processing

Barley was steamed by high pressure for about 5 min before passing through a roller mill (30-cm diameter, 19 grooves per 2.40 cm). The steamed barley was dried immediately in a horizontal drier after passing through the roller mill. Grinding was done with an industrial hammer mill to reduce the particle size of barley grain. Tempering is achieved by raising the moisture content of the barley to 200-250 g/kg by adding water for 24 h. Dry-rolled grains were prepared by passing barley grain through rollers adjusted so that kernels were coarsely broken to obtain for barley a density of 0.45 kg/L dry rolled barley.

Animals, experimental diets, and nutrition management

In this experiment, thirty Moghani male lambs (23±2.5 kg of body weight, three months) were used in a completely randomized design with five treatments and six replicates. Before the beginning of the experiment, lambs were fed with a commercial concentrate and alfalfa hay (50:50) as a total mixed ration (TMR). The lambs with similar weight and age were selected from single-bearing ewes. Treatments were 1) Whole barley (control), 2) Steam flaking barley, 3) Tempered barley, 4) Ground barley, and 5) Dry rolled barley. The experimental diets were balanced based on NRC (2007) and fed to animals for 90 days following a 14 days adaptation. Before the adaptation period, animals were treated against external and internal parasites and vaccinated against enterotoxaemia. Each animal was kept in an individual pen with a concrete floor (2×2 m^2) throughout the experimental period except when digestibility experiments and urinary collection were done that they were kept in an individual metabolic cage (1.5×1.5 m^2). The animal welfare and experimental protocols were performed according to the Iranian Council of Animal Care (1995). The lambs were fed two times a day (7:00 a.m. and 7:00 p.m.) with a TMR ration, and they had access to fresh and clean water. Total offered feed was weighed every day for each lamb, and residuals were weighed the next day for dry matter intake determination.

Also, lambs were weighed at the beginning of the experiment and every 15 days for average daily gain calculation. The feed conversion ratio was determined by dividing feed intake by weight gain.

Determination of the chemical composition of feed

The amounts of dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fiber (NDF), and acid detergent fiber (ADF) were measured according to the protocol suggested by AOAC (2005). The ingredients and chemical composition of experimental diets are presented in Table 1.

Nutrient digestibility, microbial protein, and blood metabolites determination

On the 73rd day of the experiment, each lamb was moved to an individual metabolic cage. Seven days were considered for adaptation to the new place. On the 80rd day of the experiment, total feces was collected every day in the bags for seven consecutive days. The bags containing feces were emptied and weighed on the following day. The feces related to each animal were mixed entirely by hand, and a 10% sub-sample was taken and stored at –15 ˚C for nutrient digestibility analysis. The offered feed and residual were determined throughout the digestion experiment. The nutrient digestibility was determined according to the protocol described by Van Keulen and Young (1977).

On the 85rd day, ten ml of blood were collected three hours after morning feeding from the jugular vein and divided into two-part. One part (5 mL) was moved to a heparinized tube for cell count analysis (cell counter, Celltac α, Nihon Kohden, Japan).

Table 1 Ingredients and chemical composition of the experimental diets

Ingredients (% of DM)	Barley grain type				
	Whole	Ground	Steam flaking	Tempering	Dry rolling
Alfalfa hay	15.2	15.2	15.2	15.2	15.2
Wheat straw	15.2	15.2	15.2	15.2	15.2
Barley grain	20.3	20.3	20.3	20.3	20.3
Corn grain	20.3	20.3	20.3	20.3	20.3
Cottonseed meal	5.07	5.07	5.07	5.07	5.07
Soybean meal	5.07	5.07	5.07	5.07	5.07
Sugar beet pulp	4.61	4.61	4.61	4.61	4.61
Wheat bran	9.02	9.02	9.02	9.02	9.02
Salt	1.22	1.22	1.22	1.22	1.22
Sodium bicarbonate	1.0	1.0	1.0	1.0	1.0
Calcium carbonate	1.0	1.0	1.0	1.0	1.0
Mineral-vitamin supplement[1]	2.01	2.01	2.01	2.01	2.01
Chemical composition					
Metabolizable energy (Mcal/kg DM)	2.18	2.18	2.18	2.18	2.18
Crude protein (%)	14.3	14.3	14.3	14.3	14.3
Ether extract (%)	2.5	2.5	2.5	2.5	2.5
Neutral detergent fiber (%)	37	37	37	37	37
Ash (%)	10.4	10.4	10.4	10.4	10.4
Calcium (%)	0.72	0.72	0.72	0.72	0.72
Phosphorus (%)	0.40	0.40	0.40	0.40	0.40

[1] Each kilogram of vitamin–mineral premix contained: vitamin A: 50000 IU; vitamin D_3: 10000 IU; vitamin E: 1000 IU; Ca: 196 g; P: 96 g; Na: 71 g; Mg: 19 g; Fe: 3 g; Cu: 0.3 g; Mn: 2 g; Zn: 3 g; Co: 0.1 g; I: 0.1 g and Se: 0.001 g.

The other part (5 mL) was used for blood biochemistry analysis (A15, Biosystem, Spain) by centrifugation at 3000 × g for 10 min.

Estimation of microbial protein

Urinary purine derivatives excretion predicts rumen microbial protein synthesis in lambs. On the 80rd day of the experiment, total urine was collected and recorded daily by a tray embedded under each animal that was connective to a polyethylene reservoir for seven consecutive days. Urine volume was recorded daily and collected into the polyethylene containers containing 10 mL of 10% H_2SO_4 to decrease the pH to below 3 for preventing PD destruction by bacteria, and 1% daily aliquot was pooled over the 7-day period per lamb. For prevention of precipitation of PD, especially uric acid in the preserved urine (Chen and Gomez, 1992), 10 mL of daily collected urine was sampled, diluted with 40 mL distilled water, and then preserved for further analysis. Purine derivatives in urine, including allantoin, xanthine, and hypoxanthine, were determined following the procedures described by Chen and Gomes (1992). Uric acid in the urine was determined by a quantitative enzymatic colorimetric method using a commercial kit (Stanbio Uric Acid Liquicolor Kit, Boerne, TX). Estimation of microbial N was performed based on the equation of Chen and Gomes (1992).

Carcass traits

At the end of the experimental period, the lambs were slaughtered after 16 h fasting in a small slaughterhouse. After whole bleeding, the lambs were skinned. The internal organs such as kidneys, lungs, heart, and liver were separated and weighed.

After that, the weights of the warm carcass, skin, and head were recorded. The internal fat content was wholly separated and weighed.

Statistical analysis

The lambs were allocated randomly to each experimental diet. All *in vivo* data were analyzed in a completely randomized design using the procedure of SAS (SAS, 2002) with the following model:

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

Where:
Y_{ij}: value of each observation.
μ: overall mean.
T_i: treatment effect.
e_{ij}: experimental error.

The statistical difference between the treatments was calculated based on the Duncan test at $P < 0.05$.

RESULTS AND DISCUSSION

The effect of the experimental diets on dry matter intake, daily weight gain, feed conversion ratio, and nutrient digestibility are presented in Table 2. Dry matter intake, initial body weight, average daily gain, and feed conversion ratio were not affected by the different forms of barley; however, final body weight (P=0.003) and average daily gain (P=0.04) was highest in lambs fed on dry rolling barley. Nutrient digestibility (DM, OM, CP, NDF, and ADF) were not affected by different forms of barley feeding (P<0.05).

The effects of the experimental treatments on blood metabolites and hematology parameters of lambs fed on different forms of barley are presented in Table 3. Blood metabolites (except glucose, P=0.05 and blood urea nitrogen (BUN), P=0.04) and hematology parameters weren't affected by the experimental diets.

The effects of the treatments on urinary derivatives and microbial nitrogen supply in lambs are presented in Table 4. The urinary derivatives (allantoin, uric acid, xanthine, and hypoxanthine) and microbial nitrogen supply were not affected by different forms of barley.

The effects of the experimental diets on the carcass weight and internal organs of lambs fed different forms of barley are presented in Table 5. Except for warm carcass weight (P=0.05), other organ weights were not affected by different forms of barley feeding (P>0.05).

Grinding is a processing method that increases the surface area available for microbial attachment, and the rate of starch degradation in the rumen varies inversely with the particle size of the grain (Galyean *et al*. 1981). In contrast with the present results, Mathison (1996) reported that steers fed ground barley in an all concentrate diet gained 0.09 kg/d less body weight with reduced feed efficiency compared with that fed rolled barley.

In agreement with our study, the physical processing of barley grain did not affect DM and OM digestibility (Sadri *et al*. 2007). Also, in the study of Tothi *et al*. (2003), expanded barley grain did not affect starch digestibility rather than diets containing ground barley. Although it is reported that grain processing can affect the rate, extent, and site of protein, fiber, and starch digestion (Mathison, 1996), however, we found no significant effect on nutrient digestibility. In the present study, we used tempering barley which is reported that reduces the risk of rumen acidosis (Anderson and Schroeder, 2010). We found no significant effect on nutrient digestibility however, Tolland (1976) reported that dry rolling improved the OM digestibility of barley from 525 to 852 g/kg compared to whole grain in beef steers. In the study of Goonewardene *et al*. (1998), steers fed rolled barley had higher average daily gain (ADG) compared to cattle fed whole barley, although dry matter intake (DMI) was not affected. It is reported that steam-rolling is often preferred over dry-rolling because it is easier to control the resulting kernel thickness and minimize the number of fines (Yang *et al*. 2000). Similar to the present study, Yang *et al*. (2000) found that in lactating dairy cows fed different forms of barley grain, there was no influence on the ruminal digestibility of organic matter (OM). Steam-processed grains or dry-rolled grains can differ widely in the degree of processing, so the results of the current study and previous ones are not always readily comparable.

Although we did not observe any change in blood plasma (except BUN and glucose) due to the use of different forms of barley grain among lambs, blood glucose concentrations were increased in response to feeding ground barley relative to ground sorghum (57 *vs*. 55 mg/dL; P<0.01) in the results of Nikkhah *et al*. (2004). Mean blood glucose concentrations in all animals were within the normal range reported for Moghani male lambs by Azizi-Shotorkhoft *et al*. (2013).

Table 2 The effect of the experimental diets on dry matter intake, daily weight gain, feed conversion ratio, and nutrient digestibility

Item	Barley grain type					SEM	P-value
	Whole	Ground	Steam flaking	Tempering	Dry rolling		
Dry matter intake (kg)	1.46	1.31	1.40	1.35	1.42	0.04	0.21
Initial body weight (kg)	23.5	23.4	23.3	23.5	23.4	0.78	0.99
Final body weight (kg)	46.2^{b}	47.7^{b}	47.9^{b}	50.0^{b}	55.0^{a}	1.37	0.003
Average daily gain (g/day)	252^{b}	270^{b}	272^{b}	294^{ab}	350^{a}	0.01	0.01
Feed conversion ratio	5.87	4.87	5.17	4.82	4.10	0.39	0.07
Nutrient digestibility							
DM	70.2	71.2	72.0	73.3	73.5	1.66	0.58
OM	70.9	72.7	72.8	73.2	74.0	1.76	0.80
CP	69.2	70.2	70.7	72.4	72.6	2.54	0.85
NDF	61.7	63.5	63.7	64.5	64.7	1.19	0.45
ADF	63	65.2	65.7	66.2	66.4	1.22	0.32

DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber and ADF: acid detergent fiber.
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 the experimental treatments on blood metabolites and hematology parameters of lambs fed on different forms of barley

Item	Barley grain type					SEM	P-value
	Whole	Ground	Steam flaking	Tempering	Dry rolling		
Metabolites							
Glucose (mg/dL)	58.5^{b}	61.0^{ab}	62.0^{ab}	62.0^{ab}	64.5^{a}	0.72	0.05
Triglycerides (mg/dL)	28.4	29.9	29.5	29.4	29.6	0.34	0.73
Cholesterol (mg/dL)	59.6	59.5	60.0	61.5	61.3	0.80	0.80
BUN (mg/dL)	13.4^{b}	14.8^{a}	13.7^{b}	13.6^{b}	13.6^{b}	0.18	0.04
Albumin (g/dL)	3.54	3.37	3.23	3.72	3.60	0.08	0.24
Creatinine (mg/dL)	0.93	0.96	0.99	0.93	0.94	0.02	0.88
AST (U/L)	100	103	97	98	102	1.30	0.61
ALT (U/L)	25.7	27.5	28.0	27.2	27.9	0.44	0.53
Hematology							
Hemoglobin (g/dL)	11.1	11.0	11.1	11.0	10.9	0.19	0.90
Hematocrit (%)	35.2	34.3	35.2	35.2	35.4	0.16	0.19
RBC ($\times 10^{6}$/µL)	12.3	12.4	11.4	12.1	11.6	0.16	0.15
WBC (cell/µL)	8450	8525	8762	8710	8480	50.7	0.18
MCH (pg)	10.6	10.9	11.4	11.8	11.5	0.18	0.19
MCV (fL)	36.7	37.0	37.1	36.6	37.3	0.19	0.87

BUN: blood urea nitrogen; AST: aspartate aminotransferase; ALT: alanine aminotransferase; RBC: red blood cells; WBC: white blood cells; MCH: mean corpuscular hemoglobin; MCV: mean corpuscular volume.
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 4 Effects of the experimental diets on urinary derivatives and microbial nitrogen supply in lambs

Item	Barley grain type					SEM	P-value
	Whole	Ground	Steam flaking	Tempering	Dry rolling		
Allantoin (mmol/L)	6.30	5.97	5.62	5.82	5.62	0.57	0.91
Uric acid (mmol/L)	2.85	2.57	2.53	2.62	2.85	0.34	0.94
X + h (mg/dL)	0.92	0.85	0.83	0.88	0.85	0.05	0.74
Total purine derivatives (mmol/L)	10.1	9.40	8.99	9.33	9.32	0.70	0.86
Microbial N supply (g/day)	7.10	6.94	6.21	6.81	6.46	0.58	0.81

X + h: xanthine + hypoxanthine.
SEM: standard error of the means.

Table 5 Effects of the experimental diets on the weight of carcass and internal organs fed on different forms of barley grain

Item	Barley grain type					SEM	P-value
	Whole	Ground	Steam flaking	Tempering	Dry rolling		
Warm carcass weight (kg)	20.3^{b}	21.6^{ab}	21.6^{ab}	21.8^{ab}	23.1^{a}	0.40	0.05
Liver weight (kg)	0.74	0.72	0.76	0.73	0.74	0.05	0.98
Abdominal fat (kg)	0.19	0.21	0.23	0.22	0.23	0.01	0.46
Whole gastrointestinal (kg)	7.72	7.83	7.75	7.55	7.61	0.25	0.93
Empty gastrointestinal (kg)	2.66	2.75	2.81	2.83	3.08	0.17	0.51
Shoulder weight (kg)	1.59	1.64	1.65	1.70	1.72	0.23	0.99
Thigh weight (kg)	2.1	2.07	2.11	2.14	2.16	0.09	0.97
Skin (kg)	4.86	4.82	4.90	4.93	4.98	0.03	0.77
Head (kg)	2.68	2.70	2.81	2.68	2.85	0.04	0.33
Liver (kg)	0.74	0.72	0.75	0.73	0.76	0.02	0.98
Lungs (kg)	0.55	0.56	0.56	0.57	0.58	0.004	0.29
Kidneys (kg)	0.16	0.15	0.16	0.16	0.16	0.002	0.89

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.

The level of ammonia nitrogen increases when nitrogen production exceeds the production of volatile fatty acids in the rumen. Excess ruminal ammonia is transported into the liver, converted back to urea, and finally returned to the rumen through the saliva flow. As a result of these metabolic transactions, BUN is highly correlated with ruminal ammonia nitrogen (Hennessy and Nolan, 1988).

Therefore, the lower concentrations of BUN for grinding than for other processing methods (whole barley, steam flaking, tempering, and dry rolling) in the present study might be attributed to lower ruminal ammonia nitrogen concentration.

We found no difference between urinary derivatives and microbial nitrogen supply in lambs fed on the different

physical forms of barley. Similar to the study of Gozho *et al*. (2008), we found no significant difference for purine derivatives when lambs were fed diets containing different barley processing. Tosta *et al*. (2019) also showed no significant difference in purine derivatives excretion between cows fed rolled, pelleted, or flaked oat compared to barley. In ruminants, the urinary excretion of purine derivatives (PD) reflects the absorption of microbial purines and can be used as an index of microbial protein supply. We also found no significant effect of microbial nitrogen supply between treatments.

Data about the effect of barley with different processing methods on carcass characteristics of lambs is scarce. We found that lambs fed on the ground, steam flaking, tempering, or dry rolling barley had higher whole carcass weight than the lambs fed on the whole barley. Dry rolling is achieved by passing grain kernels between rotating rollers to break the pericarp and expose the endosperm to microbial degradation in the rumen.

Roller mills provide a more uniform particle size distribution, producing fewer fine particles than grinding. Therefore, the increase in carcass weight in lambs fed with rolled barley than the whole barley is related to the simultaneous use of energy and protein by ruminal microorganisms.

CONCLUSION

Several processing techniques can be used to slow the degradation rate in the rumen and thus provide more bypass CP and starch to the small intestine. In the present study, barley processing had no significant effect on the digestibility of dietary nutrients; however, the final body weight and carcass weight were significantly higher in lambs fed on dry rolled barley than whole barley. In general, processing barley grains, especially by dry rolling, can improve performance of small ruminants.

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