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RESEARCH TITLE

Effect of Physical Processing of Barley Grains on Growth Efficiency and Performance in Afshari Breed Fattening Lambs

Hassan Fallah Hassan*[1], Amir Davar Forouzandeh[1]

[1], International Faculty, Isfahan (Khorasgan) Branch, Islamic Azad University, Iran

*Corresponding Author: hasanfalahhasanfalah448@gmail.com

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Abstract

This study aimed to evaluate the effect of five different barley grain processing methods (whole grain, mash, flaked or rolled, water soaked, and milled) on the growth performance, nutrient digestibility, and blood biochemical parameters in Afshari breed fattening lambs. Forty male lambs, aged 90 days with an average body weight of 32±1 kg, were assigned to five dietary treatments with eight lambs per treatment. The experimental results indicated that the processing methods had no significant impact on body weight, total body weight gain, daily weight gain, feed intake, or feed conversion ratio (P>0.05). Likewise, nutrient digestibility (dry matter, organic matter, crude protein, ash, and ether extract) was unaffected by the barley grain processing methods (P>0.05). Regarding blood biochemical parameters, serum glucose concentrations did not differ significantly between treatments (P>0.05), but barley processing methods did affect serum cholesterol and triglyceride levels. Lambs fed a mash-based diet showed the highest cholesterol and triglyceride levels, although no significant differences were found among the other treatments. In conclusion, the physical processing of barley grains did not improve lambs' performance or nutrient digestibility, suggesting that further research and alternative processing methods are required to enhance growth performance in fattening lambs.

Key Words: Barley Grain, Digestibility, Flaking, Milling, Performance, Processing.

عنوان البحث

أثر المعالجة الفيزيائية لحبوب الشعير على كفاءة النمو والأداء في حملان سلالة أفشاري للتسمين

المستخلص

هدفت هذه الدراسة إلى تقييم تأثير خمس طرق معالجة مختلفة لحبوب الشعير (الحبوب الكاملة، المهروس، المفلطح أو المدحرج، المنقوع في الماء، والمطحون) على الأداء النمو، وهضم العناصر الغذائية، وبعض المعايير الكيميائية الحيوية في دم حملان سلالة أفشاري للتسمين. تم استخدام 40 خروفاً من الذكور، بعمر 90 يوماً ووزن جسم متوسط قدره 32±1 كجم، تم تقسيمها إلى خمسة معالجات غذائية مع 8 حملان في كل مجموعة. أظهرت نتائج التجربة أن طرق المعالجة لم تؤثر بشكل كبير على الوزن الجسماني، إجمالي زيادة الوزن، الزيادة اليومية في الوزن، تناول العلف، أو نسبة تحويل العلف إلى وزن .(P>0.05) كما أن هضم المواد الغذائية (المادة الجافة، المواد العضوية، البروتين الخام، الرماد، والمستخلص الإيثر) لم يتأثر بطرق معالجة حبوب الشعير .(P>0.05) فيما يخص المعايير الكيميائية الحيوية في الدم، لم تختلف تركيزات الجلوكوز في الدم بشكل كبير بين المعالجات(P>0.05) ، لكن طرق معالجة الشعير أثرت على مستويات الكوليسترول والشحوم الثلاثية في الدم. أظهرت الحملان التي تناولت النظام الغذائي المعتمد على المهروس أعلى مستويات من الكوليسترول والشحوم الثلاثية، ولكن لم تكن هناك اختلافات معنوية بين المعالجات الأخرى. في الختام، لم تحسن المعالجة الفيزيائية لحبوب الشعير أداء الحملان أو هضم العناصر الغذائية، مما يشير إلى ضرورة إجراء مزيد من البحث وتجربة طرق معالجة بديلة لتحسين أداء النمو في حملان التسمين.

الكلمات المفتاحية: حبوب الشعير، الهضم، المفلحة، الطحن، الأداء، المعالجة.

1. Introduction

Despite scientific and economic progress, the provision of food, especially animal protein, remains one of the major challenges in the world today. In Iran, sheep farming is an important way to fulfil the growing need for red meat, especially as the population grows and food demand increases. Fattening projects play an important role not only in protein production, but also in preserving pastures and reducing unemployment. Carbohydrates, mainly starch, are the main energy component of ruminant diets and make up about 75 per cent of plant dry matter. Cereals such as barley and maize are a major source of starch in animal nutrition, and the extent to which they are utilised depends on the type of animal and the processing method. Improving the utilisation of starchy grains, particularly barley, is important to increase the efficiency of meat production and maximise the use of available feed resources. Barley is a perennial plant in the Nigellaceae family and ranks fourth globally in terms of area under cultivation. It varies between arable and wild varieties, and is mainly cultivated for cereal and fodder production, especially in semi-arid regions due to its ability to tolerate drought. Barley is characterised by its ease of cultivation and its ability to grow in cold environments and short growing periods, making it suitable as a food source for animals. After wheat, it is the second most important agricultural crop in Iran and can be used as a substitute for maize in feed. Barley is rich in protein (typically 11-12%), some amino acids, important vitamins such as B vitamins, and fatty acids important for ruminant nutrition. Its energy content is correlated with grain density and inversely with fibre, and it contains beta-glucans which may increase in dry conditions.

2. The Use of Barley Grains in Ruminant Nutrition

Barley is considered one of the oldest domesticated crops and is used in feeding goats, sheep, and cattle, whether for milk or meat production [1]. Barley grains are among the common cereals in ruminant diets, characterized by their thick fibrous hull and high content of beta-glucan and starch. Barley surpasses corn in its protein content and certain essential amino acids such as methionine and lysine. It also contains high levels of vitamin A and potassium, with calcium content up to five times that of oats [2]. Barley is cultivated as an economical and readily available energy source in regions such as the western United States and Canada [3]. In Iran, barley is widely used as a main ingredient in most concentrated ruminant feed formulations. It is considered a good energy source due to its starch being 80–90% digestible in the rumen, compared to 50–70% for corn [4]. The hull makes up approximately 10–14% of the barley grain's weight. It contains about 13.3 MJ/kg of metabolizable energy (on a dry matter basis) and crude protein ranging from 6–16%, with an average of 12%. Ground barley is used at a rate of 50% in fattening systems for cows and ewes [5]. Barley is an important source of energy and protein in ruminant diets and is considered a more affordable alternative to corn. The presence of barley in feed increases both the quantity and quality of milk and meat. In some countries, barley is the main ingredient in feed formulations for beef cattle, with a nutritional value approximately 90% of corn for cattle and 85–100% for sheep and goats [6].

2.1 Use of Barley Grains in Feeding Cattle and Sheep

Barley grains are easily digestible and absorbable, making them suitable for feeding cattle and sheep, as they help produce high-quality meat, butter, and cheese. Due to their hard outer husk, it is recommended to feed barley in ground or powdered form [7]. Barley is the primary energy source in ruminant diets in many parts of the world. Despite its relatively low protein content, its widespread use makes it an important protein source in animal feed. However, the high ruminal degradability of its protein reduces its nutritional value and may lead to reproductive issues in pregnant or high-producing cows [8]. In Europe, Iran, and most parts of the world, barley is the main cereal used in animal feed, making up about 50% of feed grains in the United States. It contains a high percentage of starch (60–70% of the grain's weight) and is thus mainly used as an energy source in cattle diets. It also contains more protein compared to some other cereals, along with important vitamins and minerals [9]. To ensure effective use of barley in cattle diets, it must be processed and introduced gradually, as it ferments rapidly in the rumen [10]. In poultry and pig nutrition, barley is rarely used due to its high fiber content (5–6%) and lower energy value. However, in dairy cows, this fiber helps maintain or increase milk fat content and improves rumen function, making barley a suitable energy- and fiber-rich feed for milk production [11].

2.2 Growth Performance

This study was conducted to evaluate the potential benefits of different barley grain processing methods (whole grains, ground barley, rolled barley, soaked barley, and coarsely ground barley) on growth performance in castrated lambs of both sexes separately. Contrary to the researchers' expectations, barley processing methods did not have a significant effect on body weight, weight gain, feed intake, or feed conversion ratio in either sex during the different experimental periods: the middle period (days 1 to 30), the final period (days 31 to 60), and the entire period (days 1 to 60). Similar results were reported in other studies, which showed no improvement in sheep performance as a result of grain processing [12].

In another experiment studying the effect of processing ground versus rolled barley in lamb diets, processing had no significant effect on weight gain; however, the final weight of lambs fed rolled barley was significantly higher than those fed ground barley [13]. This partially agrees with the present study's results, whereas lactic acid treatment of barley improved total dry matter digestibility and feed efficiency in Holstein calves, but did not affect feed intake or daily weight gain [14].

In contrast to the current findings, [15] showed that grinding or steam rolling barley changed kernel density, which affected rumen fill and feed intake rates in lambs. Studies [16] reported that using ground or rolled barley increased daily growth rates and final weights of lambs compared to whole barley. Similarly, [17] noted that organic acid treatments (soaking in lactic and citric acid) improved performance through increased final weight, growth rate, and feed conversion efficiency.

Additionally, studies [18–21] demonstrated that feeding rolled barley led to significant increases in lamb final weight compared to ground barley. In a similar study, [22] found that feeding ground wheat instead of whole wheat resulted in increased lamb weights.

Moreover, [23,24] indicated that physical processing of corn grains (grinding or steam rolling) improved growth performance in lambs, with steam rolling showing superior efficiency. This is attributed to partial starch gelatinization during steam rolling, which reduces rapid ruminal fermentation, leading to better synchronization of energy and nitrogen availability for microbial growth, thus improving energy utilization efficiency and growth.

In another study, [25] reported that different barley processing methods (grinding, rolling, pelleting) improved daily weight gain, dry matter intake, and feed conversion efficiency, although there were no significant differences in final weight compared to whole barley. Steam or grinding treatments did not affect daily growth rates in calves.

Lower dry matter intake observed with ground barley may be due to excessive grinding producing fine dust that reduces palatability despite improved digestibility. Conversely, some studies suggest that over-processing may accelerate ruminal fermentation, reducing feed intake [26].

Opposing the current results, [27] found that feeding steam-rolled barley with high-protein diets (24%) improved feed intake, growth rate, weight gain, and volatile fatty acid concentration in the rumen compared to calves fed whole barley.

[28] reported that calves fed steam-rolled corn had higher ruminal fatty acid concentrations than those fed steam-rolled barley, while growth performance, feed efficiency, and some blood parameters were unaffected by grain processing.

3. Experimental Location

This study was conducted at the Research Station of the Faculty of Agriculture, Islamic Azad University, Khorasgan Branch, located in the village of Khatounabad. The facilities for raising lambs were individual pens, each measuring 1.2 × 1.5 meters, separated by metal bars and mesh to prevent mixing between animals.

3.1 Experimental Management

The study was carried out using a completely randomized design on 40 lambs (20 of each sex) with an average age of 90 days and an average weight of 32 ± 1 kg. The experiment lasted for 80 days, including a 20-day adaptation period and a 60-day main trial period. Lambs were housed individually, with access to designated feed and water containers, salt, and ad libitum feeding. The floor was covered with straw. Animals were vaccinated during the adaptation period. Prior to adaptation, lambs fasted for 36 hours to empty their digestive tracts, then were weighed and randomly assigned to treatment groups with approximately equal weights. Identification tags were placed on each pen for easy management. Feed was offered three times daily (8 AM, 4 PM, and 12 midnight), and thoroughly mixed to ensure consistent availability. Feed refusals were collected and weighed daily to adjust feed quantity.

3.2 Experimental Diets

The experimental diets included:

1. Control diet with whole unground barley grains
2. Control diet with ground barley
3. Diet with barley flour
4. Diet with dehulled or flaked barley
5. Diet with soaked barley

All diets were formulated to be isocaloric and isonitrogenous, minimizing differences in nutrient content such as protein levels, cell wall components, concentrate-to-forage ratio, and energy. The ingredients included alfalfa, wheat straw, and concentrate mixtures composed of ground barley, soybean meal, wheat bran, vitamin and mineral supplements, and vegetable oil. The only difference between treatments was the method of barley processing.

Table 1: Feed Ingredients of Experimental Diets (Based on Dry Matter)

	Barley processing method				
Feedstuff	Barley flour	Soaked barley	Rolled (or flaked) barley	Ground barley	**Whole barley**
Chopped alfalfa	29/85	29/85	29/85	29/85	**29/85**
Wheat straw	10/00	10/00	10/00	10/00	**10/00**
Barley	25/45	25/45	25/45	25/45	**25/45**
Soybean meal	7/45	7/45	7/45	7/45	**7/45**
Wheat bran	21/50	21/50	21/50	21/50	**21/50**
Vegetable oil	3/75	3/75	3/75	3/75	**3/75**
Vitamin supplement	1/00	1/00	1/00	1/00	**1/00**
Mineral supplement	1/00	1/00	1/00	1/00	**1/00**
Total	100	100	100	100	**100**
Forage ratio in the diet (%)	39/85	39/85	39/85	39/85	**39/85**
Concentrate ratio in the diet (%)	60/15	60/15	60/15	60/15	**60/15**
Metabolizable energy (Mcal/kg)	2/5	2/5	2/5	2/5	**2/5**
Metabolizable energy (Mcal/kg)	14/0	14/0	14/0	14/0	**14/0**
Neutral detergent fiber (NDF, %)	65/12	70/46	63/10	57/78	**64/54**
Acid detergent fiber (ADF, %)	**63/46**	**68/71**	**52/14**	**55/46**	**61/11**

3.3. Barley Processing Methods

3-3-1: Germination (Sprouting) Method

In this method, barley grains are soaked in water for 24 hours, then drained and spread on a cotton sack, covered with another cotton sack. To ensure proper germination, the grains are sprayed with water twice daily to prevent the sacks from drying out. To avoid mold, the grains are turned over three times a day. After approximately three days, the grains fully sprout, then are exposed to sunlight to dry completely before being incorporated into the feed ration.

3-3-2: Soaking Method

The required amount of barley for the ration is first weighed and divided into three portions for morning, evening, and nighttime meals. The portions are placed in separate containers, and water is added until the grains are fully submerged. After 24 hours of soaking, the grains are drained using a mesh bag, then thoroughly mixed with the feed and offered to the lambs.

3-3-3: Steam-Flaking Method

This process is carried out in a feed factory. Barley grains are transferred to a special chamber and exposed to steam for 30 minutes. Then, the grains are passed through a device with two counter-rotating rollers that press and flatten the grains. The resulting steam-flaked barley is immediately transferred to a cooling system to remove excess moisture, then packed into bags and transported to the farm.

Due to the importance of this method, the flaking level was set to achieve a

Processing Index = 0.65, calculated using the formula:

Processing Index = (Bulk density of processed grain / Bulk density of raw grain) × 100 = 0.65

4. Effect of Experimental Diets on Lamb Performance (Materials and Methods)

4.1 Diet Formulation and Feeding Strategy:

1. The base ration was formulated according to the NRC (2007) standards to meet:
   i. Maintenance requirements.
   ii. A target daily weight gain of 200 grams.
   iii. Target age: 3 to 7 months.
2. Feed composition (dry matter, ash, crude protein, ether extract, organic matter) was analyzed using standard procedures.

4.2 Feeding:

1. Feed was offered ad libitum in three meals at 8:00 AM, 4:00 PM, and 12:00 AM.
2. At all times, 10% feed was left in the feeder to ensure continuous availability.
3. Clean water was always available.
4. Feed refusals were collected and weighed daily before the morning meal.

4.3 Feed Intake Measurement:

1. The amount of feed offered was weighed daily for each animal.
2. Refusals were collected and weighed.
3. Feed intake was calculated as the difference between feed offered and refused.
4. Samples of feed and refusals were dried at 60°C until weight was constant, then stored for analysis.

4.4 Chemical Analysis of Feed:

1. Dry matter: Oven-dried until weight stabilization.
2. Ash: Combusted in an electric furnace.
3. Crude protein: Determined using the Kjeldahl method.
4. Ether extract (fat): Measured using the Soxhlet method.
5. Organic matter: Calculated as dry matter minus ash.
6. NDF (neutral detergent fiber): Measured using a neutral detergent solution per Mertens (2002).

4.5 Growth Performance Evaluation:

1. The following indicators were measured:
   i. Initial weight.
   ii. Mid-trial weight (Day 30).

   iii. Final weight (Day 60).
   iv. Weight gain during each phase.
   v. Average daily gain (ADG).
   vi. Feed conversion ratio (FCR = body weight gain / feed intake).
2. Lambs were weighed after 16 hours of fasting at the beginning and end of the trial.
3. Body weights were recorded every 14 days.

4.6 Digestibility Assessment:

1. Acid-insoluble ash (AIA) was used as an internal marker.
2. By measuring AIA concentration in feed and feces, the apparent digestibility of:
   i. Dry matter (DM),
   ii. Crude protein (CP),
   iii. NDF,
   iv. Ash,
   v. Organic matter (OM) was calculated.

4.7 Statistical Analysis:

1. Design: Completely Randomized Design (CRD)
2. Factors: 5 barley processing methods × 2 lamb sexes
3. Software: SAS version 9.4
4. Procedure: GLM (General Linear Model)
5. Mean comparison: Duncan's Multiple Range Test at a 5% significance level.

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

   Y_{ij} = Sightings

   μ = mean

   T_j = Effect of treatment type (bush type).

   e_{ij} = Random error.

5. Results and Discussion

5.1 Results – Effect of Barley Processing Type on Body Weight in Lambs

Table (4-1): Effect of Barley Processing Type on Body Weight (kg) in Fattening Lambs (Males and Females)

Barley Processing Type	Initial Weight	Mid-Trial Weight	Final Weight
Whole barley (unprocessed)	32.3	41.7	47.9
Ground barley (flour)	32.8	41.6	47.6
Flaked barley (rolled/flattened)	32.8	44.2	51.5
Soaked barley	33.1	42.9	49.8
Coarsely ground barley	33.0	42.8	49.4
SEM (Standard Error of Mean)	0.99	1.10	1.43
P-value	0.98	0.43	0.32

Means that do not share the same letter in a given column are significantly different at P < 0.05.

Analysis of the Effect of Barley Processing Type and Lamb Sex on Productive Performance During Different Fattening Periods

The effects of barley grain processing type and lamb sex on growth performance were evaluated over the following periods:

- **First period (Day 1 to 30):** Mid-stage
- **Second period (Day 31 to 60):** End of fattening
- **Overall period (Day 1 to 60):** Total fattening duration

The assessed parameters included:

- **Body weight:** Table (4-1)
- **Total and daily weight gain:** Table (4-2)
- **Feed intake (daily and periodic) and feed conversion ratio (FCR):** Table (4-3)

Based on the analysis of these tables, **no statistically significant differences (P > 0.05)** were observed among the experimental treatments (barley processing type and lamb sex) in any of the following performance indicators:

- Body weight
- Total and daily weight gain
- Feed intake
- Feed conversion ratio (FCR)

Although some numerical differences were noted among the groups, these differences did not reach statistical significance, indicating that the different barley processing methods and the sex of the lambs had no significant impact on productive performance during the fattening period. However, some of these differences may be biologically relevant and warrant further investigation in future studies with larger sample sizes or under different conditions.

Table 4-2: Effect of Barley Processing Type on Lamb Weight Gain (kg and g)

Barley Processing Type	**Weight Gain (kg)**		**Average Daily Gain (g)**		
	Mid-period (1–30)	Total Period (1–60)	Mid-period (1–30)	Final-period (31–60)	Total Period (1–60)
Whole Barley	9.37	15.56	206	222	216
Ground Barley	8.75	14.75	192	214	206
Steam-Flaked Barley	11.50	18.75	257	258	260
Soaked Barley	9.81	16.62	219	244	232
Coarsely Ground Barley	9.81	16.37	219	236	227
SEM	0.79	1.315	17.5	19.5	18.2
P-Value	0.18	0.29	0.13	0.54	0.31

Note: There were no statistically significant differences (P > 0.05) among the treatments. However, **steam-flaked barley numerically resulted in the best performance** in terms of both daily and total weight gain.

Table 4-3: Effect of Barley Processing Type on Feed Intake (kg) and Feed Conversion Ratio (FCR)

Barley Processing Type	Feed Intake – 1st Half (kg)	Total As-Fed Intake (kg)	Total Dry Matter Intake (kg)	Daily Intake (kg/day)	Feed Conversion Ratio (FCR)
				First Half	Total
Whole Barley	48.9	88.9	75.5	1.09	1.23
Ground Barley	50.1	88.8	75.4	1.11	1.23
Steam-Flaked Barley	54.1	96.4	81.9	1.20	1.34
Soaked Barley	51.4	93.9	79.8	1.14	1.30
Coarsely Ground Barley	49.4	96.1	81.7	1.10	1.33
SEM	1.63	3.12	2.65	0.036	0.043
P-Value	0.18	0.24	0.24	0.39	0.53

Although numerical differences were observed in feed intake and feed conversion efficiency, these differences were not statistically significant ($P > 0.05$). However, steam-flaked barley (Perak) showed the best feed conversion efficiency, indicating lower feed intake per kilogram of body weight gain.

Table 4-4: Effect of Barley Processing Type on Apparent Digestibility Coefficients in Fattening Lambs (%)

Barley Processing Type	Crude Protein	Protein (90%)	Dry Matter	NDF (Fiber)	Ash	Organic Matter
Whole Barley	83.0	70.6	78.5	42.0	9.61	71.7
Ground Barley (Fine Flour)	82.9	70.5	78.5	42.7	9.24	72.0
Flaked Barley (Steam-Flaked)	83.2	70.7	79.2	40.4	8.16	74.6
Soaked Barley	82.1	69.8	77.8	45.3	8.65	73.8
Coarsely Ground Barley	82.2	69.9	77.8	43.0	9.21	70.6
SEM	0.45	0.39	0.48	1.03	0.462	86.14
P-Value	0.34	0.34	0.21	**0.03**	0.68	1.17

There were no statistically significant differences ($P > 0.05$) among the treatments for most of the digestibility parameters, indicating that the type of barley processing did not have a clear effect on the digestion of essential nutrients. The only exception was neutral detergent fiber (NDF), which showed a significant difference ($P = 0.03$), suggesting that the processing method influenced fiber digestibility an expected outcome due to the changes in the physical structure of the grains.

Table 4-5: Effect of Barley Processing Method on Blood Biochemical Parameters in Lambs (mg/dL)

Barley Processing Method	Glucose (Mean / End) (mg/dL)	Triglycerides (Mean / End) (mg/dL)	Cholesterol (Mean / End) (mg/dL)
Whole Barley	54.4 / 52.4	11.03^{ab} / 11.7^{ab}	44.4^{b} / 47.1^{b}
Ground Barley	61.1 / 57.2	13.1^{a} / 13.7^{a}	58.4^{a} / 60.3^{a}
Rolled Barley (Flaked)	57.7 / 54.4	8.5^{b} / 8.9^{b}	47.4^{b} / 49.0^{b}
Soaked Barley	61.4 / 57.9	9.5^{b} / 9.9^{b}	48.9^{b} / 50.0^{b}
Coarsely Ground Barley	57.9 / 55.5	8.7^{b} / 9.5^{b}	44.9^{b} / 46.1^{b}
SEM	2.82 / 2.68	1.08 / 1.08	2.02 / 2.18
P-Value	0.40 / 0.61	0.03 / 0.03	0.002 / 0.005

The means that do not share the same letter in a column indicate a statistically significant difference at the probability level ($P < 0.05$).

6. Conclusion

The present study's results indicated that applying different barley processing methods to castrated lambs of both sexes resulted in the following:

1. Experimental processing methods had no significant effect on body weight, total or daily weight gain, periodic or daily feed intake, nor on feed conversion ratio.
2. Digestibility of nitrogen-free extract, dry matter, organic matter, crude protein, ash, and crude fat were not affected by processing methods.
3. Serum glucose concentrations were unaffected by processing treatments, and neither lamb sex nor the interaction between barley processing type and sex significantly influenced serum cholesterol or triglyceride concentrations. However, barley processing type did affect serum cholesterol and triglyceride levels.
4. The highest serum cholesterol and triglyceride concentrations were observed in lambs fed diets containing barley flour, with no significant differences among lambs fed whole barley, rolled, soaked, or ground barley.

Overall, barley processing did not improve performance or digestibility of feed components in castrated male and female lambs. Further studies are recommended, employing alternative processing methods to achieve a tangible impact of barley processing on castrated lamb performance.

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