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Growth performance and carcass characteristics of finishing male lambs fed barberry pomace-containing diets

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ABSTRACT

Barberry (*Berberis vulgaris*) fruits contain bioactive compounds with antimicrobial, antioxidant and hepatoprotective effects. The inclusion of barberry pomace (BP) in finishing diets could potentially enhance growth performance and carcass characteristics of sheep. To test this hypothesis, 21 male Balouchi lambs (24.5 ± 4 kg initial live weight; 5 ± 0.6 months of age) were randomly assigned to three BP-containing experimental diets to determine their effects on feed intake, live weight gain and carcass characteristics. The experimental diets were formulated to meet nutrient requirements for a targeted daily weight gain of 200 g as follows: (1) control diet (BP0), (2) control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP (BP75), (3) control diet in which 15% of alfalfa hay and wheat straw were replaced with BP (BP150). Lambs were fed the experimental diets for 75 days during which feed intake and live weight changes were recorded. At the end of the feeding period, lambs were fasted for 16 h, weighed and then slaughtered in order to determine carcass characteristics. Experimental diets had no effect on feed intake and growth performance of lambs. Similarly, diets had no effect ($p > 0.05$) on weight of carcass, commercial cuts (neck, shoulder, loin, leg, fat-tail, brisket, flank) and non-carcass components (head, skin, feet, lung and trachea, heart, liver, spleen, gastro-intestinal, kidney, bladder and testicles) but linearly increased ($p < 0.05$) warm and cold dressing percentage as well as heart weight. These results do not support the hypothesis that feeding BP-containing diets enhances growth performance and carcass characteristics of male Balouchi lambs. However, inclusion of BP had no negative effects on animal performance and carcass characteristics.

KEYWORDS
Barberry pomace; fattening lambs; growth performance; carcass characteristics

Introduction

Sheep production is one of the main sources of red meat in Iran but the sustainability of this enterprise is threatened by high feed and chemotherapeutic drug costs. It is, therefore, imperative that local, readily available, environmentally friendly and less expensive feedstuffs with nutraceutical properties be identified and evaluated. Such feed resources may boost growth performance and enhance the quality of animal products through the action of bioactive compounds. One such potential feed resource is the BP (pulp and leaves), a by-product from the extraction of juice from barberry fruits. Barberry (*Berberis vulgaris* L.) is a native shrub that grows in the south-east of Iran, the largest producer of seedless barberry worldwide.[1] The shrub occupies more than 15,000 ha, producing more than 9200 tons of dried fruit, annually. The industrial juice extraction process from barberry fruits generates large amounts of BP at the rate of 400 kg per ton of barberry fruits processed.[2] The current practice of disposing barberry pomace in landfills and by burning poses an environmental challenge both in terms of soil, air and water pollution. It is, therefore, imperative that the potential of this by-product as an animal feed resource be evaluated as this would increase the value of BP waste by converting it into animal products for human consumption. The pomace is known to contain bioactive compounds such as flavonoids, anthocyanins, vitamins, phenolic compounds and carotenoid pigments with potential

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beneficial nutritional effects.[3] These compounds have the potential to enhance the growth performance and carcass characteristics of sheep if the pomace is used as a feed supplement. Indeed, studies with rats confirm that BP has antimicrobial, antioxidant, antidiabetic, hepatoprotective, and antihypertensive effects.[4] When a barberry leaf meal was added to diets of lactating goats at 34% inclusion level, the total antioxidant capacity of plasma was enhanced.[5] Scientific information on the use of barberry in animal feeding is generally limited to barberry leaves[5] while no studies have been carried out using the by-product of barberry juice extraction, whose disposal is an environmental nuisance. Therefore, the aim of this study was to evaluate the effect of partial replacement of forage ingredients in a finishing diet with BP on feed intake, growth performance and carcass characteristics and non-carcass components in male Balouchi lambs. The study tested the hypothesis that partially replacing the forage component of finishing lamb diets with BP will enhance growth performance and carcass characteristics of male Balouchi lambs.

Materials and methods

Feed ingredients

Fresh barberry pomace (Ghaen sershk factory, Ghaen, Iran), obtained from ripe berries harvested in October and November 2016, was sun-dried (35 °C and 0% humidity) to a constant weight. The pomace was then ground through a 1 mm screen (Wiley mill, Standard Model 3, Arthur H. Thomas Co., Philadelphia, USA) for chemical analyses. Alfalfa was harvested at the bud stage, sun-dried in the field and stored pending milling and incorporation in lamb diets. After harvesting of wheat grain at maturity, the remaining wheat straw was shredded using a threshing machine and also incorporated into lamb diets.

Diet formulation

Three barberry pomace-containing diets were formulated to meet nutrient requirements for a targeted daily weight gain of 200 g in sheep[6] as follows: (1) Control lamb finishing diet (BP0), (2) Control diet in which 7.5% of alfalfa hay and wheat straw was replaced with BP (BP75), (3) Control diet in which 15% of alfalfa hay and wheat straw was replaced with BP (BP150) (Table 1). In order to reduce differences in physical form of experimental diets and to prevent feed selection by animals, the forage components of the diet (alfalfa hay and straw wheat) were chopped to 30 mm and then mixed with the rest of the diet ingredients.

Table 1. Ingredient composition (g/kg as fed) of barberry pomace-containing diets.

	Diets[a]		
Ingredients	BP0	BP75	BP150
Alfalfa hay	200	153	106
Wheat straw	100	72	44
Barberry pomace[b]	0	75	150
Barley grain, ground	380	380	380
Corn grain, ground	130	130	130
Soybean meal	100	100	100
Wheat bran	60	60	60
Minerals and vitamins supplement[c]	10	10	10
Sodium bicarbonate	5	5	5
Salt	5	5	5
Calcium carbonate	10	10	10

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.
[b]Barberry pomace containing (on a dry matter basis): 99.2 g/kg crude protein, 23.6 g/kg ether extract, 41.5 g/kg ash, 509.6 g/kg neutral detergent fiber, 444.8 g/kg acid detergent fiber, 67.6 g/kg total phenols, 30.5 g/kg total tannins, 11.8 g/kg condensed tannins, and 18.7 g/kg hydrolyzable tannins.
[c]Supplement containing vitamin A (250,000 IU/kg), vitamin D (50,000 IU/kg) and vitamin E (1650 IU/kg), manganese (2.25 g/kg), calcium (125 g/kg), zinc (7.6 g/kg), phosphorus (20 g/kg), magnesium (20.2 g/kg), sodium (186 g/kg), iron (1.20 g/kg), sulfur (3 g/kg), copper (1.2 g/kg), cobalt (12 mg/kg), iodine (55 mg/kg) and selenium(10 mg/kg).

Chemical analyses

Samples of the experimental diets were ground (1 mm screen) and chemically characterized. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using a Fibertec System 1010 (FOSS Analytical AB, Sweden) according to Van Soest et al.[7] The NDF was assayed without heat-stable α-amylase and sodium sulfite. Both NDF and ADF were expressed inclusive of residual ash. Crude protein (CP, method number: 968.06), organic matter (OM, method number: 942.05), ether extract (EE, method number: 963.15), calcium (method number: 927.02), and phosphorus (method number: 964.06) were determined according to the procedures of AOAC.[8] Total phenolic compounds and total tannins were analyzed as described by Makkar et al.[9] Condensed tannins were estimated using the butanol–HCl method of Porter et al.[10] Hydrolyzable tannins were calculated as the difference between total tannins and condensed tannins Barman et al.[11]

Feeding trial

Twenty-one male Balouchi lambs (24.5 ± 4 kg initial live weight; 5 ± 0.6 months of age) were purchased in July of 2017 and housed at the Goat and Sheep

Research Station at the University of Birjand, Iran. Before the experiment started, lambs were drenched with 1 mL of Azantole 10% mixed with 7 L of water to reduce internal parasites while Albendazole 2.5% (Damloran Pharmaceutical Co., Iran) was applied against external parasites. Lambs were also vaccinated against enterotoxaemia (3 mL per lamb; Razi Vaccine and Serum Research Institute, Karaj, Alborz, Iran). The 21 lambs, which were the experimental units, were then randomly assigned to the three dietary treatments in a completely randomized design. Lambs were housed individually in stalls with floor area dimensions of 1.3 m × 1.1 m each and adapted to dietary treatments for 15 days, during which a pre-experimental diet (alfalfa hay alone) was gradually replaced with the dietary treatments described in section 2.2 above. On day 16, lambs were fed *ad libitum* (targeting a minimum of 10% orts) with experimental diets in two equal rations at 0800 h and 1600 h in a 75-day feeding trial. Lambs had free access to fresh water. Before each morning feeding, feed bunks were cleaned and refusals weighed and recorded for each lamb to determine dry matter intake (DMI). The live weight of each lamb was recorded before feeding every 15 days at 0900 h in order to calculate the average daily weight gain (ADG). The ADG was calculated as the difference between the final weight and initial weight within each period divided by the number of days in that period. The animals used in this experiment were cared for according to the guidelines of the Iranian Council of Animal Care (Approval No: 19293).[12]

Carcass traits

At the end of the feeding trial, the lambs were humanely slaughtered in the abattoir after 16 h of fasting using the Halal method.[13] The carcasses were weighed immediately to obtain the hot carcass weight (HCW) and again after storage at 4 °C for 24 h to obtain cold carcass weight (CCW). The difference between HCW and CCW was used as a measure of refrigeration loss (carcass shrinkage). Hot and cold carcass dressing percentages were both calculated as proportions of live weight at slaughter as described by Zimerman et al.[14] Head, feet and skin weights were recorded. Carcasses were eviscerated and internal organs were removed for measurements. Non-carcass components (heart, fat around the aorta, liver, spleen, kidney, kidney fat, testes, lungs and trachea, bladder, digestive tract and offal) were weighed immediately after slaughter. The intestines were emptied and weighed while the reticulo-rumen was separated from the omasum and abomasum and all compartments were emptied, washed and weighed. Carcass composition was determined from the left half of the carcass. The eye muscle surface area between the 12th and 13th ribs was traced on an acetate paper and then measured using a digital planimeter. Back fat thickness at the 12th rib was measured using a Vernier caliper. The right side of each carcass was dissected into six cuts (neck, shoulder, brisket, loin, flank, legs and tail) according to Kashan et al.[15] and weighed separately. The individual cuts were then dissected into lean meat, bone and trimmings, which were also weighed separately.

Statistical analyses

Average daily gain, feed intake and carcass characteristics data were analyzed as a completely random design using GLM procedure[16] according to the following model:

$$Y_{ij} = \mu + T_i + \varepsilon_{ij},$$

where Y_{ij} is the dependent variable; μ is the overall mean; T_i is the diet effect; and ε_{ij} is the residual error. The Tukey's multiple comparison of means test was used to separate means where dietary effects were found to be statistically significant. Linear and quadratic polynomial contrasts were used to examine responses of measurements to different barberry pomace levels.For all parameters, significant differences were declared at $p \leq 0.05$.

Results

The ingredient and chemical composition of the three experimental diets are shown in Tables 1 and 2,

Table 2. Chemical composition (g/kg DM, unless otherwise stated) of barberry pomace (BP)-containing diets.

	Diets[a]		
	BP0	BP75	BP150
Metabolizable energy (Mcal/kg DM)	2.56	2.56	2.56
Dry matter (g/kg)	914	914.8	915.6
Crude protein	140	140	140
Neutral detergent fiber	308.8	307.7	306.6
Ash	69.4	65.1	60.8
Calcium	9.2	8.8	8.4
Phosphorus	4.7	4.5	4.4
Ca: P ratio	19.6	19.6	19.1
Total phenols	13.1	36.7	50.9
Total tannins	9.6	18.3	24.4
Condensed tannins	2.3	6.6	10.8

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.

respectively. The crude protein, NDF, ADF, ash, total phenolics, total tannins and condensed tannin content of BP was 99.2, 509.6, 444.8, 41.5, 67.6, 35 and 11.8 g/kg DM, respectively. Experimental diets did not affect ($p > 0.05$) feed intake (DMI), total weight gain and ADG (Table 3). However, there was a linear (L, $p < 0.05$) increase in warm and cold dressing percentages in response to incremental levels of dietary BP. In addition, inclusion of BP in Balouchi sheep reduced carcass shrinkage (Q, $p < 0.05$) upon refrigeration (Table 4). The eye muscle area and back fat thickness were also not affected by partially replacing alfalfa hay and wheat straw with BP. The effect of dietary treatments on carcass cuts is shown in Table 5. Including BP in lamb diets had no effect on shoulder, neck, brisket, leg, flank and fat-tail weights. There were no significant dietary differences with respect to the weights of most of the internal organs (Table 6). However, heart size increased linearly (L, $p < 0.05$) as BP inclusion levels increased.

Discussion

Barberry pomace-containing diets promoted similar DMI and final live weight as the commercial control diet. In agreement with these observations, Ghavipanje et al.[5] reported that inclusion barberry leaf at 34% of dietary DM did not significantly affect initial and final body weight of lactating goats. In a related study, Shakeri[17] reported that replacing alfalfa hay with a pistachio by-product (similar to BP in terms of protein and phenolic content) at 10 and 20% had no effect on DMI, final body weight, ADG and FCR of Kermanian male lambs. Similarly, Norouzian and Ghiasi[18] and Valizadeh et al.[19] found that feeding a pistachio by-product had no effect on DMI, daily gain and feed conversion ratio (FCR) in Balouchi lambs. In contrast to findings in the present study, Ghavipanje et al.[5] showed that dietary barberry leaf increased DMI in lactating crossbred goats. Nevertheless, it appears that the anti-nutritional factors such as tannins that are present in BP do not reduce feed intake and lamb growth. There is a general agreement that condensed tannins at low and moderate levels (2–4%) may improve growth

Table 3. Effect of replacing alfalfa hay and wheat straw in a finishing diet with barberry pomace on feed intake and growth performance of male baluochi lambs.

	Diet[a]				*p*-Value	
Parameters	BP0	BP75	BP150	SEM[d]	Linear	Quadratic
Initial weight (kg)	24.00	24.786	23.929	0.79	0.95	0.41
Final weight (kg)	46.079	46.157	46.586	1.781	0.84	0.94
Weight gain (kg)	22.079	21.371	22.657	1.29	0.75	0.54
ADG[b] (g/day)	0.245	0.237	0.251	0.014	0.75	0.54
DMI[c] (g/day)	1599.49	1595.49	1640.50	61.71	0.64	0.75

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.
[b]ADG: average daily gain.
[c]DMI: dry matter intake.
[d]SEM: standard error of mean.

Table 5. Effect of replacing alfalfa hay and wheat straw in a finishing diet with barberry pomace (BP) on size of carcass cuts (kg) of male baluochi lambs.

	Diets[a]				*p*-Value	
Carcass cut	BP0	BP75	BP150	SEM[b]	Linear	Quadratic
Tail Fat	3.634	3.763	3.576	0.140	0.77	0.37
Neck	1.333	1.420	1.377	0.040	0.45	0.21
Shoulder	2.824	3.140	3.103	0.148	0.2	0.34
Brisket	1.689	1.407	1.596	0.105	0.54	0.08
Flank	2.606	2.417	2.624	0.151	0.93	0.3
Loin	3.316	3.440	3.566	0.149	0.25	0.99
Leg	5.658	5.705	5.804	0.219	0.64	0.92

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.
[b]SEM: standard error of mean.

Table 4. Effect of replacing alfalfa hay and wheat straw in a finishing diet with barberry pomace (BP) on carcass traits of male baluochi lambs.

	Diets[a]				*p*-Value	
Carcass traits	BP0	BP75	BP150	SEM[b]	Linear	Quadratic
Hot carcass weight (kg)	22.056	22.135	22.564	0.874	0.69	0.87
Cold carcass weight (kg)	21.297	21.571	21.894	0.810	0.61	0.98
Warm dressing percentage	48.317	48.385	49.0	0.163	0.0084	0.19
Cold dressing percentage	46.698	47.168	47.551	0.157	0.0012	0.82
Shrinkage (% of warm carcass)	3.347	2.510	2.960	0.241	0.27	0.04
Back fat (cm)	0.216	0.218	0.222	0.026	0.21	0.74
Eye muscle area (cm^2)	13.046	13.054	13.150	0.562	0.44	0.92
Carcass composition (kg)						
Lean	13.046	13.054	13.150	0.590	0.90	0.95
Bone	4.183	4.184	4.184	0.189	0.99	0.99

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.
[b]SEM: standard error of mean.

Table 6. Effect of replacing alfalfa hay and wheat straw in a finishing diet with barberry pomace on size of offals (kg) in male baluochi lambs.

	Diets[a]				*p*-Value	
Offals	Control	BP75	BP150	SEM[b]	Linear	Quadratic
Skin	4.515	4.630	4.782	0.117	0.12	0.9
Head	2.122	2.091	2.173	0.063	0.58	0.48
Feet	0.976	0.908	0.946	0.033	0.54	0.22
Liver	0.769	0.756	0.869	0.046	0.14	0.28
Lung & trachea	0.480	0.498	0.481	0.017	0.99	0.43
Heart	0.142	0.154	0.161	0.004	0.0078	0.62
Heart fat	0.051	0.045	0.050	0.007	0.91	0.49
Kidneys	0.117	0.124	0.129	0.006	0.15	0.86
Kidney Fat	0.081	0.076	0.069	0.004	0.09	0.91
Bladder	0.046	0.039	0.041	0.004	0.41	0.39
Testicles	0.306	0.350	0.361	0.028	0.19	0.65
Spleen	0.055	0.061	0.059	0.002	0.38	0.25
Full forestomach	4.314	4.457	4.434	0.349	0.81	0.85
Empty forestomach	1.814	1.824	1.693	0.151	0.58	0.71
Omasum	0.167	0.162	0.165	0.004	0.71	0.48
Abomasum	0.276	0.274	0.276	0.002	0.94	0.42
Empty small intestine	0.767	0.768	0.735	0.029	0.46	0.64
Intestinal fat	0.580	0.570	0.547	0.025	0.36	0.85

[a]Diets: BP0 = control lamb finishing diet; BP75 = control diet in which 7.5% of alfalfa hay and wheat straw were replaced with BP; BP150 = control diet in which 15% of alfalfa hay and wheat straw were replaced with BP.
[b]SEM: standard error of mean.

performance, wool growth, milk production, and ovulation rate while controlling internal parasites and preventing bloat.[20–22] However, Mlambo et al.[23] did not find a direct relationship between level of condensed tannins and their effect on animal performance when tannin-rich *D. cinerea* fruits were offered to goats. The same authors[24] instead propose a structure-activity, rather than a concentration-activity, relationship when it comes to the biological activity of condensed tannins. The level of condensed tannins (11.8 g/kg DM) in the BP used in this experiment was higher than the values reported by Ghavipanje et al.[5] Dietary barberry pomace did not improve weight gain beyond what was observed in the control sheep, a result that was unexpected. However, BP-containing diets promoted similar weight gains as the commercial control diet, which costs 10% more to formulate. This result indicates that BP, when fed in appropriate proportions, is an important source of nutrients for sheep.

The yield of most of the edible offal components did not change when Balouchi lambs were fed BP-containing diets. Dressing percentage is an important parameter in the assessment of meat-producing animals since it determines the amount of meat available. Warm dressing percentage and cold dressing percentage increased in response to incremental levels of BP inclusion. These parameters were similar to those reported by SoltaniNezhad et al.[25] when they fed sheep with pistachio by-products (PBP). In contrast, Norouzian and Ghiasi[18] and Valizadeh et al.[19] found that up to 30% inclusion of PBP in diets of fattening lambs had no effect on dressing percentage. According to SoltaniNezhad et al.[25] and Hirut et al.[26], dressing percentage of sheep generally ranges between 40% and 50%, which is corroborated by the findings in the current study. In general, the higher dressing percentage in BP150 lambs was associated with higher hot and cold carcass weight. The average warm dressing percentage of lambs in this study was 48.57%, which is consistent with the value reported by Dabiri[27] for indigenous Iranian lamb breeds.

A quadratic response was observed for carcass refrigeration losses in response to increasing dietary BP levels. Chilling loss is the weight difference upon cooling of the carcass and it depends on several factors such as humidity and chemical reactions in the muscle. More-O'Ferral et al.[28] suggested that higher carcass shrinkage indicates poorer water holding capacity of the muscle, which is of commercial significance. The average shrinkage found in this study was 2.94%, which is lower than the values reported by SoltaniNezhad et al.[25] in Kermani lambs reared on PBP. Shrinkage is inversely related to carcass fat content since the fat layer provides protection to carcasses during the cooling period, reducing losses. However, no dietary differences ($p > 0.05$) were observed in terms of back fat and eye muscle area. The values of back fat thickness in Kermani lambs fed on PBP as reported by SoltaniNezhad et al.[25] were similar to those observed in this study.

In the current study, the size of the heart increased (L, $p < 0.05$) with BP inclusion level (Table 6). Fitwil and Tadesse[29] reported that live weight and nutritional status of the animals can affect the size of carcass offals. However, Valizadeh et al.[19] reported that weights of the internal organs were not affected by feeding 30% PBP to Balouchi lambs. As seen in Table 5, there were no dietary differences in terms of tail fat, neck, shoulder, brisket, flank, loin and leg sizes. This similarity in size of carcass cuts can be attributed to the similar initial weight, ADG and slaughter weight among the lambs (Table 5). Similarly, Valizadeh et al.[19] and SoltaniNezhad et al.[25] did not observe any changes in the carcass characteristics of lambs fed diets supplemented with PBP silage.

Conclusions

The results reported in this study do not support the hypothesis that feeding BP-containing diets enhance growth performance and carcass characteristics of male Balouchi lambs. However, replacing 15% of alfalfa hay and wheat straw in lamb finishing diets with BP had no negative effect on animal performance and carcass characteristics. It is, therefore concluded that BP can be used as an alternative, less expensive forage source for male Blauochi lambs. The use of BP for this purpose represents an ingenious waste-reduction and valorization strategy that contributes to food security and environmental stewardship.

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Disclosure statement

The researchers declare that they are no conflict of interests relating to the execution and publication of this study.

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