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Enhancing nutritional quality and antioxidant capacity of organic goat meat through sustainable sea-buckthorn and Russian olive leaf–based feeding systems

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RESEARCH

Abstract

As consumer demand for organic products increases, understanding how organic diet influences meat characteristics can provide an insight into enhancing the health benefits and sustainability of goat farming. This study explored an approach to produce premium organic goat meat enriched with superior nutritional qualities by incorporating sea-buckthorn (SBT) and Russian olive leaves (ROL) into the feeding regimen over a 6-month period. During the evening feeding period, four feeding regimes were administrated to the subjects MS (i) consisting of alfalfa hay and grass; MS (ii) consisting of SBT leaves; MS (iii) comprising of ROL; and MS (iv) involving a mixed ration of Russian olive and SBT leaves. These interventions were implemented to evaluate comparative nutritional efficacy under controlled circumstances. In the feed analysis, SBT leaves showed high crude protein content (19.02%) and dry matter (92.79%), while grass hay and alfalfa hay had higher ash content (10.01 and 9.19%) and fiber content (24.82%) in alfalfa hay. Fiber was lowest in SBT leaves (2.65%), highlighting their potential as a rich-feed protein source. Furthermore, the meat from different treatments were analyzed for physiochemical, antioxidant, and mineral content. Highly significant effects were observed for mass of carcass, and MS (i) scored maximum weight gain (3.73 kg), protein contents, fats, and ash. MS (iv) scored the maximum thiobarbituric acid reactive substance, DPPH, and phenolic of 67.52 µmol TE/g, 38.89 µmol MDA/g, and 50.60 mg GAE/g for different treatments while non-significant effects for moisture, fat, and ABTS were observed for different feeding systems. Based on the findings of the current study, it can be suggested that MS (iv) scored the highest rank among the management systems tested, while the meat obtained from the MS (iv) approach had good nutritional value, which could improve and fulfill nutritional requirements of the consumers.

Keywords: Goat meat, Feed management systems, Antioxidants, TBARS, Organic meat

Introduction

The increasing demand for organic goat meat is driven by its promising nutritional profile, ethical production, and association with consumer acceptance for sustainable healthy diets. Furthermore, goat meat is a rich source of high-quality macro- and micronutrients, while being low in fat and cholesterol, making it a lean and nutritious dietary option (Ahmad *et al.,* 2021; Hambaryan *et al.,* 2024). In addition, organic production systems further enhance their appeal by ensuring food safety, animal welfare, and environmental sustainability through the exclusion of synthetic chemicals, growth-promoting hormones, and GMOs (lu *et al.,* 2010). In spite of its valuable nutritional composition and emerging dietary trends, Western societies are trying to reduce and/or replace meat from human diets (Bohrer 2017, Muzaffar *et al.,* 2021). Therefore, researchers are finding innovative ways to maintain the interest on meat. One such approach involves incorporating naturally antioxidant-rich plants either into animal feed or directly onto the meat to enhance preservation and quality (Vlaicu and Untea, 2024).

Antioxidants are incorporated either through animal feed or directly as additives in meat to improve its quality. This is often achieved through the application of synthetic antioxidants as dietary supplements (Nemati *et al.,* 2024). Notwithstanding their widespread use and efficacy, substantial concerns exist regarding the possible carcinogenic and toxicological effect of synthetic antioxidants. Previous studies have shown that synthetic antioxidants like BHA, PG, and TBHQ can exhibit genotoxic and cytotoxic effects (Carocho *et al.,* 2018; Esazadeh *et al.,* 2024; Kumar *et al.,* 2015). Different studies (Cuchillo-Hilario *et al.,* 2024; Fernandez-Lopez *et al.,* 2005; Ponnampalam *et al.,* 2024; Vlaicu *et al.,* 2024) suggest that natural compounds demonstrate significant potential in protecting human health and toning down foodborne illnesses. In addition, the incorporation of their natural antioxidant compound into animal feed signifies an effective and practical approach for improving animal health and meat quality as demonstrated by Alqahtani *et al.,* (2021) and Nieto *et al.* (2010). Natural compounds such as antioxidants particularly from plant sources have been considered to be highly effective in mitigating oxidative damage within the meat industry. Moreover, their efficiency stems from their capability to neutralize free radicals and donate hydrogen or electron atoms and chelate metal ions, which is accredited to their unique chemical structure (Das *et al.,* 2024). Seabuckthorn (SBT) leaves have shown significant promise as a dietary supplement in animal feed predominantly for their potential to enhance meat quality and nutritional values in livestock. This herbaceous plant documented for its rich composition of antioxidant polyphenols and various other bioactive compounds has been studied (Wang *et al.,* 2024; Munoz *et al.,* 2023; Qin *et al.,* 2020) for various applications in animal nutrition leading to enhanced health growth performance and meat quality (Wani *et al.,* 2026). The mechanism by which SBT leaves improve meat quality is often linked to their bioactive compounds, for instance similar to alfalfa leaves, SBT leaves could potentially improve meat quality by enhancing the antioxidant capacity of animal tissue and modulating lipid metabolism (Jin *et al.,* 2013). This leads to an increase in intermuscular fat, which contributes to flavor such as juiciness, and in the end improved fatty acid profile (Guo *et al.,* 2023). Russian olive oil (*Elaeagnus angustifolia*) seems to be a promising addition in animal feed ingredients, particularly for goats, because of its nutritional profile and potential to enhance meat quality. This plant is known for its resilience to various environmental stresses and contain macronutrients such as phosphorus, nitrogen, magnesium, potassium, and calcium in its dry foliage, making it a potentially beneficial ingredient for animal feed supplementation (Hamidpour *et al.,* 2017). The plant-based feedstuffs including olive cake and cactus has been incorporated in the feed of the goats which exhibited the better profile of the fatty acid contents, as the omega 3 fatty acids have been enhanced (El Otmani *et al.,* 2021; Paiva-Martins *et al.,* 2009; Innosa *et al.,* 2020; Obeidat *et al.,* 2023). Specifically concerning to goat meat quality dietary olive leaves addition as a meal in animal feed has shown better affects. A study by Jabalbarezi *et al.* (2020) showed that increasing meal (ROL) levels from 7.5 to 15% of diet did not significantly affect the total dry matter intake or growth rate, but specific impact on meat quality parameters warrant further comprehensive investigation. The synergistic accumulation of nutrition-dense, bioactively rich plant leaves in animal feed offer substantial potential to enhance the nutritional quality and antioxidant capacity of meat. This study aims to produce high-quality organic meat by including these enriched bioactive plant leaves in animal diets with subsequent evaluation of the meats' nutritional composition and antioxidant activities to further validate the efficacy of this emergent feeding approach.

Material and Methods

Procurement of meat

The Ishkomen Valley in the Ghizer district of Gilgit-Baltistan, Pakistan, provided the meat for the study. Each of the 24 goats we chose was about 6 months old. We thoroughly examined the goats before purchasing to make sure they had not been administered antibiotics or commercial feed items, hormones, or toxins. In addition, we divided the goats into four groups at random to investigate the effects of various management strategies on meat production. The configuration of these groups was comparable to that of our previous study (Faiz *et al.*, 2020). For 6 months, the goats were maintained on their own feeding schedules. The goats were carefully slaughtered at the end of this period, and their carcasses were separated into various anatomical parts, such as the ribs, back, neck, forelimb, and hindlimb. In order to preserve their quality and integrity for upcoming biochemical and nutritional tests, the acquired meat samples were also thereafter kept in a frozen environment. Figure 1 shows a summary of the experimental workflow.

Growth rate measurements

From the beginning until their humane slaughter 6 months later, the experimental goats were weighed monthly by the researchers. In addition, prior to the trial, we administered albendazole to the goats at the dosage recommended based on body weight. Throughout the trial, the goats were housed in groups rather than separate enclosures, given a regulated food, and had unrestricted access to water. In order to maintain consistency, measurements were taken early in the morning following an overnight fast, and their average weight was reported each month. The body weight of a goat was determined:

Growth Rate (%)=(Final weight (kg) − Initial weight/ Rearing period (days) × 100 (Eq. 1)

Physicochemical Tests

Proximate composition

The AOAC (2006) established standardized procedures for the proximate analysis of goat meat, which included measurements of moisture content, ash, fat, crude protein, and crude fiber. Similarly, we dried 5 g of beef samples in an oven at 105±2°C until the samples attained a constant weight in order to measure the moisture content. The Kjeldahl methodology, established by AOAC (2006), was used for evaluating crude protein. It entailed digesting samples (goat flesh) and then distilling and titrating the results to guarantee accuracy. In order to effectively extract and measure the lipids in goat meat samples, besides using the Soxhlet extraction technique with petroleum ether as the solvent within the boiling range (40–60°C), researchers burned 2 g of goat flesh samples in a muffle furnace set at 550 ± 20°C for 6–8 hours, or until a stable ash residue was obtained, in order to measure the amount of ash present. In addition, crude fiber was measured by sequentially digesting it with 1.25 % of NaOH and 1.25% H_2SO_4 followed by ignition at 550 ± 25°C to measure the indigestible residue, ensuring precise outcomes.

Determination of antioxidant activity

The DPPH (2,2,-diphenyly-1-picrylhydrzyl) free radical scavenging assay was used to evaluate the antioxidant activity of the beef sample (Merculieff *et al.*, 2014).

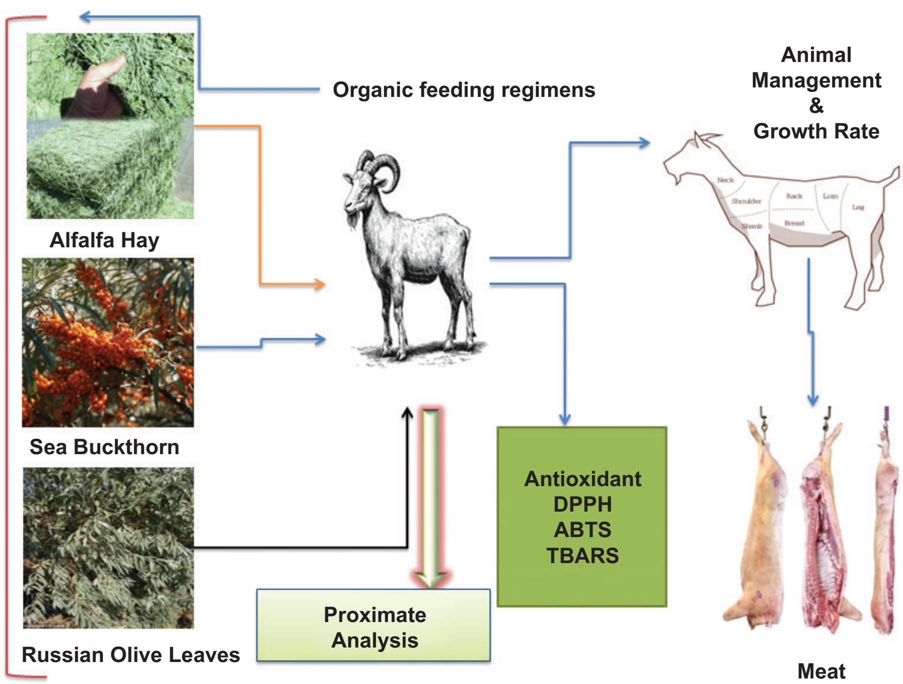

Figure 1. Summary of the experimental work.

Methanolic solution (DPPH) (1.9 mL) and 100 μL of meat extract were combined in a volumetric flask. For consistent homogenization, the mixture was agitated well before being incubated for 35 minutes at a regulated temperature of 37°C in a dark condition. Using a Cary 60 UV-Vis spectrophotometer, the absorbance of the solution was measured at 517 nm following incubation. The antioxidant activity of goat meat extracts was measured as the percentage of the DPPH radical.

$$\text{Antioxidant capacity (\% inhibition)} = \frac{\text{Ao(DPPH without extract)} - \text{A1(DPPH with extract)}}{\text{Ao}} \times 100 \quad \text{(Eq. 2)}$$

Determination of ABTS

Following the procedure described by Qwele *et al.* (2013), researchers used the ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) radical scavenging assay to evaluate the antioxidant activity of meat samples. To produce $ABTS^{\bullet+}$ radicals, scientists prepared two stock solutions (2.4 mM and 7 mM potassium persulfate) in equal volumes and kept them at room temperature in darkness for 1 day. Before analysis, we diluted the resulting solutions with ethanol to achieve an absorbance of 0.7 ± 0.2 at 734 nm, using ethanol as the blank reference. We then measured the absorbance of the goat meat samples and calculated the percentage (%) inhibition of ABTS radicals using the provided formula.

$$\text{Inhibition \%} = 1 - \left[\frac{\text{Absorbance of smaple}}{\text{Absorbance of control}}\right] \times 100 \quad \text{(Eq. 3)}$$

Determination of thiobarbituric acid reactive substance (TBARS)

To evaluate the lipid oxidation of the goat meat sample, we conducted the TBARS assays following the method by Hussain *et al.,* (2021). Briefly, we blended 10 g of minced meat with 30 mL of 7.5% trichloroacetic acid (TCA) at 15,000 rpm for 30 seconds at 20°C. After filtering the mixture, we further added 5 mL of 0.02 M thiobarbituric acid (TBA) to the filtrate, sealed the mixture in tubes, and heated it to 100^0C for 35 minutes. The samples were then cooled to 20^0C. We measured absorbance at 532 nm using an Ultraspec 3000 spectrophotometer (Pharmica, Bio-Tech, UK) with a blank prepared using distilled water and TBA reagent as reference. TBARS (mg MDA/kg meat) values, expressed as milligram monoaldehyde (MDA^{-kg}) of goat meat, were quantified using a tetraethoxypropane (TEP) standard curve. For consistency, the same samples were subjected to both fluorescence and TBARS tests.

Data Analysis

Randomized complete design (RCD) was used to examine the data and assess sample parameter variances. SPSS (version 16, IBM Corporation NY, USA) means and standard deviations were calculated and a one-way ANOVA was carried out. The Tukey post-hoc test with a significance level of $P<0.05$ was used to evaluate meaningful differences between means.

Results

Feed composition

Statistical analysis revealed that crude protein, ash, and crude fiber exhibited statistically significant ($p<0.05$) variations across grass hay, alfalfa, ROL, and SBT leaves. In contrast, dry matter exhibited no significant variations at the $p>0.05$ level among all tested feed samples (Figure 2). Alfalfa hay and grass hay had higher ash content (9.19 and 10.01%, respectively) as compared to ROL (5.34%) and SBT leaves (4.11%). In addition, crude protein was maximum in SBT leaves (19.02 %) and minimum in ROL (12.67%). Fiber content was observed to be higher in alfalfa hay (24.82 %) and lower in SBT (2.65%). Maximum value for dry matter (92.79%) was observed in SBT leaves, and minimum values were found in alfalfa hay (88.56%).

Effect of formulated feed on growth rate of animals

Table 1 presents mean values of weight gain from initial body weight to slaughter weight of animals fed on different feeds. The statistical values for growth rate of goats were highly significant ($p<0.05$) among all management systems, namely, MS (i), MS (ii), MS (iii), and MS (iv). The highest weight gain was observed in lambs fed under the MS (i) regimen, while the lowest weight gain was recorded in those receiving the MS (iii) feeding protocols.

Carcass weight

The carcass mass of goats exhibited statistically significant differences ($p<0.05$) for all the management systems. Table 2 shows the weight of the carcass at the time of slaughter (slaughter weight) with hot carcass weight (meat after dressing) and weight of body parts. Moreover, the differences in slaughter weight were attributed to the variations in goats' preslaughter weight. However, maximum carcass weight was observed in the group which was fed under MS (i).

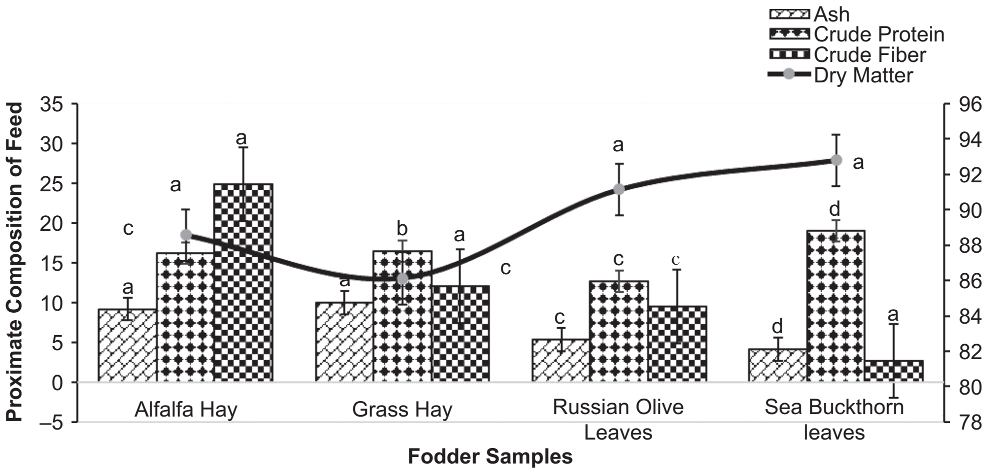

Figure 2. Proximate composition of alfalfa, hay grass, Russian Olives leaves, and sea buckthorn leaves. Mean values are shown with markers, bars represents Std± (n=3), and different letters a–b indicate significant differences between management systems, *p<0.05*.

Table 1. Growth rate during 6 months of organic feeding.

Management system	MS (i)	MS (ii)	MS (iii)	MS (iv)
Initial weight (Kg)	12.04±0.01[h]	12.57±0.02[h]	12.43±0.01[h]	12.50±0.01[h]
First month	12.85±0.01[g]	12.94±0.01[g]	12.7267±0.01[g]	12.83±0.02[g]
Second month	13.63±0.01[f]	13.32±0.02[f]	13.08±0.01[f]	13.20±0.02[f]
Third month	14.12±0.02[e]	13.76±0.02[e]	13.47±0.01[e]	13.62±0.01[e]
Fourth month	14.74±0.01[d]	14.14±0.02[d]	13.83±0.02[d]	14.04±0.01[d]
Fifth month	15.21±0.01[c]	14.68±0.01[c]	14.18±0.01[c]	14.43±0.02[c]
Sixth month	15.78±0.01[b]	15.21±0.01[b]	14.82±0.02[c]	15.02±0.01[c]
Total weight gain	3.74±0.01[a]	2.62±0.02[a]	2.39±0.01[a]	2.52±0.01[a]

All values are expressed as the mean ± standard deviation. Statistically significant differences are denoted by means of distinct letters.

Table 2. Effect of organic fodder on the weight of body parts of growing goats.

Body parts	MS (i)	MS (ii)	MS (iii)	MS (iv)
Weight during slaughter	15.78±0.01[a]	15.21±0.01[d]	14.82±0.01[b]	15.02±0.01[c]
Hot carcass weight	7.64±0.01[a]	7.16±0.02[d]	6.63±0.02[b]	6.89±0.02[c]
Fore limb	1.44±0.01[a]	1.34±0.01[b]	1.31±0.01[b]	1.33±0.02[bc]
Hind limb	1.89±0.02[a]	1.75±0.02[d]	1.63±0.01[b]	1.69±0.01[c]
Back	1.68±0.01[a]	1.56±0,01[d]	1.42±0.01[b]	1.50±0.01[c]
Neck	1.34±0.01[a]	1.27±0,02[d]	1.11±0.01[b]	1.18±0.02[c]
Ribs	1.29±0.02[a]	1.24±0.02[d]	1.16±0.02[b]	1.21±0.01[c]
Total weight gain	3.73±0.01[a]	2.64±0.02[a]	2.39±0.01[a]	2.52±0.01[a]

All values are expressed as the mean ± standard deviation. Statistically significant differences are denoted by means of distinct letters.

Physicochemical properties of goat meat

Goat meat supplemented with organic fodders exhibited statistically significant differences at $p<0.05$ in fat, protein, and pH, whereas moisture and ash showed statistically negligible variations at $p<0.05$. The proximate composition of goat meat is shown in Figure 3. The pH (6.13, 5.66, 5.36, 5.52) and fat (19.74, 18.13, 17.86, 25.00%, respectively) content of the meat was decreasing as organic fodder containing more antioxidants retards the fat in meat samples. Moreover, the protein (19.91, 22.37, 25.01, and 23.70%) and ash content (1.96, 2.21, 2.43, and 2.33%, respectively) in meat increased as fodder containing antioxidants were supplied. The maximum value was shown in ROL-fed meat as compared to SBT leaves and control fed meats. Moreover, moisture showed the random changes as control has minimum value (63.00%), whereas the maximum moisture (63.65%) content was calculated in a meat sample fed with SBT leaves.

Antioxidant potential of goat meat

The impact of extending animal diets with SBT leaves (*Hippophae rhamnoides* L.) and olive tree leaves (*Olea europaea* L.), which involves Russian olive in broader understanding of the *Elaeagnaceae* family, on the bioactive summary of meat, markedly in meat goats, is an area of mounting scientific interest because of the rich phytochemical content of these plants (García *et al.,* 2019; Saracila *et al.,* 2022; Wang *et al.,* 2022). The values for antioxidants and TBARS of the goat meat fed on the natural feed sources is shown in Figures 4 and 5. ABTS, DPPH, and phenolic values showed that the goat fed

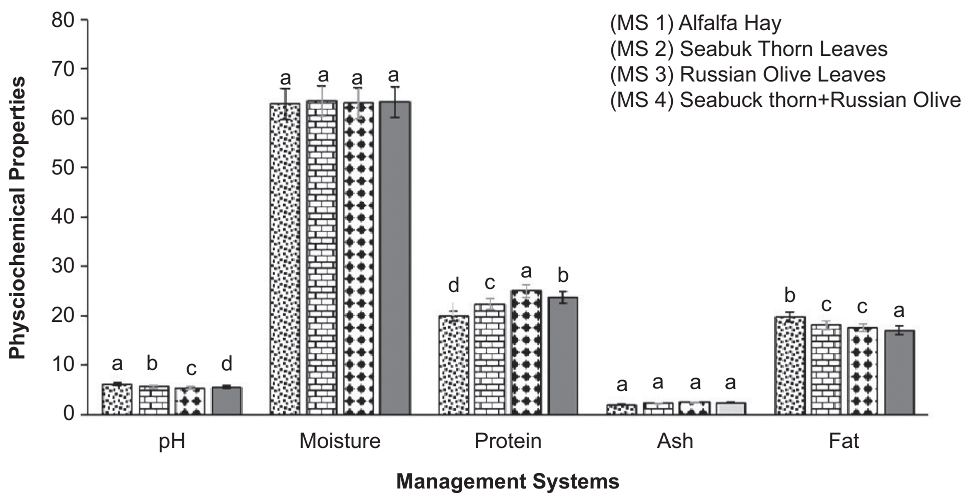

Figure 3. Physicochemical characteristics of goat meat across diverse management systems. Mean values are shown with markers, bars represents Std± (n=3), and different letters a–b indicate significant differences between management systems, *p<0.05*.

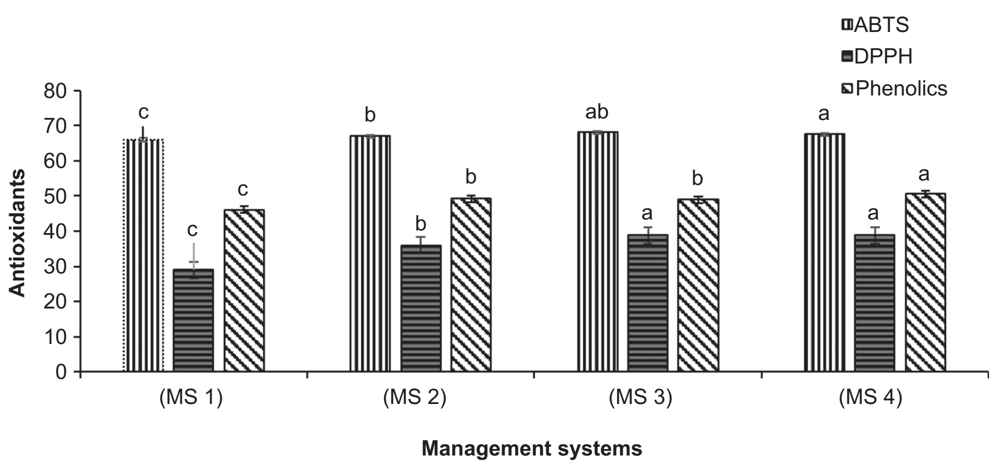

Figure 4. Comparative antioxidant profiles of goat meat across different management systems. Mean values are shown with markers, bars represents Std± (n=3), and different letters a–b indicate significant differences between management systems, *p<0.05.*

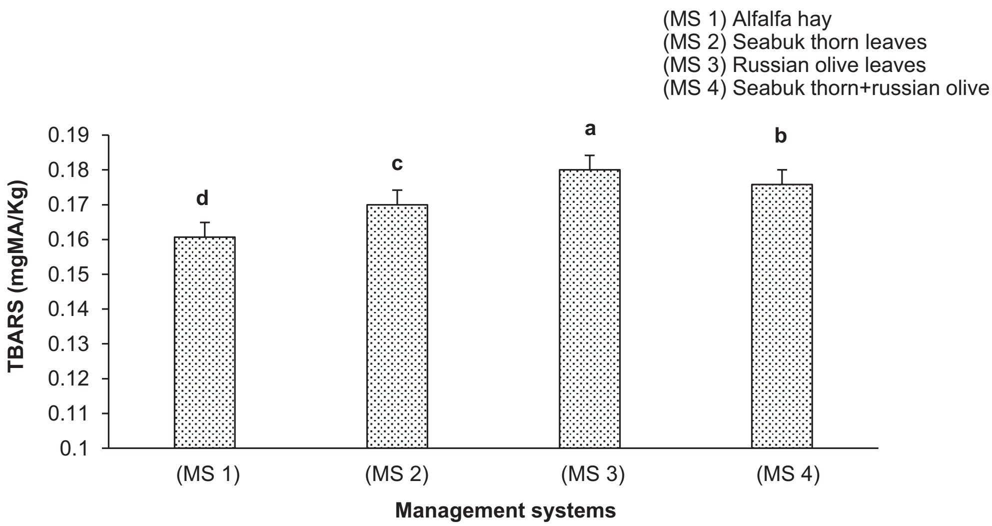

Figure 5. TBARS Analysis of goat meat from various management systems. Mean values are shown with markers, bars represents Std± (n=3), and different letters a–b indicate significant differences between management systems, *p<0.05.*

under MS (iv) had greater values of 67.52 μmol TE/g, 38.89 μmol MDA/g, and 50.60 mg GAE/g. While minimum values of 65.9 μmol TE/g 6, 28.97 μmol MDA/g, and 46.08 mg GAE/g were observed in the animals fed on control feed (alfalfa and grass hay).

Discussion

The study assessed the effects of organic feeding regimens on feed composition, growth rate, carcass trait, and meat quality considering the following proximate analysis physicochemical analysis, antioxidant properties, TBARS, and ABTS. Significant amounts of macro- and micronutrients, such as protein, lipids, vitamins, and minerals, found in SBT leaves serve as an excellent source of protein for animal feed (Hu and Guo 2006). According to Ghabru *et al.* (2018), SBT leaves were a valuable source of protein for animal feed because of their crude protein concentration, which ranged from 23.0% to 43.0% on a dry matter basis. The growth rate of broilers was found to be significantly impacted by the high levels of bioactive compounds and protein (20.7%), amino acids (methionine, lysine, and cysteine), minerals (Mg, Ca, and K), esterified sterols, folic acid, and isoprenols in SBT leaves (Christaki, 2012). The crude fiber content of SBT varied from 20.3% to 26.2%, depending on the region where the leaves were collected (Gradt *et al.,* 2017). Significant differences in growth rate additionally demonstrated how dietary management strategies affect growth performance, emphasizing the advantages of MS(i) over MS(iii) in terms of optimizing weight gain results. Because of severe weather and organic farming practices, the total weight gain climbed gradually. Another explanation for the lower weight gain could be because of the higher antioxidant content and weight gain process by destroying fat molecules. Goats raised in Baluchistan ranges showed comparable weight gain (Munir *et al.,* 2007). Researchers discovered that the wintertime decrease in the forage's nutritional value and dormant plants were the causes of the delayed weight gain. Similar weather conditions prevail when the winter temperature falls down to −20°C, which might be the reason for the slow weight gain in the goats in the winter season.

Similarly, other researchers (Zhang *et al.,* 2016) also noticed that seasonal variation and temperature had significant effects on the weight gain of the animals. They observed that Ewes kept in the shaded places in warm temperature WS (Warm Shed) had higher live weights than the animals in the traditional shades. Melaku and Betsha (2008) demonstrated that dietary supplementation with wheat bran and peanut cake significantly enhances weight gain in goats. The supplemented animals (goats) not only gained maximum body weight but also displayed higher proportions of offal and increased bone density as compared to nonsupplemented counterparts, which in few cases experienced weight loss. These findings underscore how targeted dietary strategies can enhance carcass composition and growth performance in ruminants. Johnson *et al.* (2010) reported that grain supplementation produces an additional 4 kg over the predicted end weight of 36 kg, demonstrating the benefits of energy-dense supplementation interventions. In contrast, different feeding groups in our study showing lower carcass weight may reflect the influence of bioactive plant compounds presents in both SBT and ROL which may alter nutrients partitioning and tissue deposition

In support, Yusuf *et al.* (2014) observed that inclusion of *Androghraphis paniculata significantly (p<0.05) improved* weight gain, feed efficiency, live weight, and feed intake of the goats. Analogously, Oman *et al.* (1999) observed that feedlot-finished goats attained higher carcass weight, increased lean meat yield and lower bone proportions, and enhanced fat content compared to the animals raised on natural pasture. Together, these outcomes suggest the role of optimized feeding strategies in producing high-quality meat carcasses, ultimately meeting market demands and supporting sustainable livestock systems. These outcomes highlight the significant role of intensive feeding systems in improving meat quality and overall carcass composition in goats, compared to less controlled nutritional intake linked to grazing on natural pastures. Another comparable study was performed by Ayeb *et al.* (2016) to check the chemical and tissue composition of goats in different feeding systems in the arid land. The estimation showed higher fat content in animals fed on grass hay compared to the dried olive leaves and *stipa tanacissima* leaves. The effects of different feed on pH, protein, and mineral contents of the different meat cuts remained nonsignificant. In addition, Ijaz *et al.* (2020) demonstrated that the color of DFD (dark, firm, and dry) is influenced not only by pH but also by factors such as water-holding capacity, shear force, and glycolytic potential. In another study, Alexandre *et al.* (2009) noted less sores for meat color, less amount of lipid contents in the shoulder, less pH of the carcass in animals reared in free grazing system as compared to the meat obtained through the indoor system. The quality of forage influences the quality of the meat and carcass. Moreover, The TBARS values were significantly below 0.9 mg MA/k, which is considered the critical threshold for lipid oxidation in meat products (Moawad *et al.,* 2013). Consequently, the elevated DPPH scavenging activity observed in the meat extract from goat supplemented with ROL can be attributed to its strong hydrogen-donating capacity.

Addition of citrus waste in meat increases the antioxidant activity of meat, as reported by (Faiz *et al.,* 2017). Moreover, Qwele *et al.* (2013) showed in their result that the DPPH, ABTS, and phenolic content were increased as goats were fed on high antioxidant containing feed, namely, *moringa oleifera* leaves. Serpen *et al.* (2012) show the result as the DPPH and ABTS in meat were increased with an increase in the supplementation of organic fodder. Das *et al.* (2012) reported the lowest TBARS number (0.53 mg malonaldehyde/kg sample) in samples treated with *moringa oleifera* leaves extract and also found delayed lipid peroxidation in patties prepared from goat meat. (Hussain *et al.* (2020) reported that the inclusion of Chinese cinnamon powder significantly ($p<0.05$) reduced both TBARS and TVC in all treated samples. This suggests that Chinese cinnamon possess strong antimicrobial and anti-oxidative properties, which may contribute to the preservation of meat quality by mitigating lipid oxidation and microbial growth. Ergezer *et al.* (2018) further investigated TBARS levels in raw beef patties and found values higher than those observed in this current study.

Conclusion

The current study highlights the diverse flora that is conducive to supporting goat farming using organic feeding strategies. All the fodder samples used as feed for the experimental goats had a higher nutritional profile, which was reflected in the meat quality. The composition of fodder was analyzed, and the weight gain was also observed. After 6 months, the goats were slaughtered and the properties of meat were analyzed. The meat samples of the carcass of goats under four different management systems showed better results for physicochemical, antioxidants, and mineral composition. Higher growth rate was observed in Management system 1 MS (i). The other management systems MS (ii), MS (iii), and MS (iv) had low growth rates with high content of antioxidants. The higher content of antioxidants and lower weight gain is because of higher phytochemical content in feed of MS (ii), MS (iii), and MS (iv). Another reason behind the low weight gain is the harsh climatic conditions and heavy snowfall. While all grazing and feeding systems positively influenced the nutritional quality of goat meat, their impacts vary concerning specific outcomes. For antioxidant enrichment, MS (iv) appears to be the most effective system. In contrast, for optional weight gain, MS (i) demonstrates superior performance, though its effectiveness depends on resource availability and management conditions.

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Data Availability

The data of this study are available within the manuscript.

Ethical Approval

Research ethics from Karakoram International University Compliance Committee at Gilgit gave the ethics number (EC/2018'213/25) approval for the animal study.

Authors Contributions

All authors made equal contributions to the final work's analysis, review, and presentation.

Conflict of Interest

This study has no conflict of interest with other authors.

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