Effects of Dietary Sea Buckthorn Pomace Supplementation on Growth Performance, Slaughter Performance, Meat Quality and Gastrointestinal Content pH in Finishing Sheep

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Abstract

This experiment aimed to investigate the effects of dietary seabuckthorn pomace (SBP) supplementation on growth performance, slaughter performance, meat quality, and pH of digestive tract contents in fattening sheep. Forty 4-month-old Dorper × Small-tailed Han crossbred male sheep with an initial body weight of approximately 22 kg were selected and randomly allocated into 4 groups using a completely randomized design. The SBP supplementation levels were 0 (control group), 7.8% (8SBP group), 16.0% (16SBP group), and 23.5% (24SBP group), with 10 sheep per group. The experimental period lasted for 80 days, consisting of a 10-day preliminary period followed by a 70-day formal trial period. The results showed that: the average daily gain and dry matter intake in the 16SBP and 24SBP groups were significantly higher than those in the control and 8SBP groups ($P<0.05$), while no significant differences were observed in feed conversion ratio among all groups ($P>0.05$); the final body weight in the 16SBP group was significantly higher than that in the control and 8SBP groups ($P<0.05$); the net meat weight in the 16SBP and 24SBP groups was significantly higher than that in the control group ($P<0.05$); the muscle GR value in the 24SBP group was significantly lower than that in the control and 8SBP groups ($P<0.05$); the muscle crude fat content in the 16SBP and 24SBP groups was significantly higher than that in the control and 8SBP groups ($P<0.05$); the muscle shear force in the 8SBP and 16SBP groups was significantly higher than that in the control group ($P<0.05$); no significant differences were found in muscle pH, meat color, water-holding capacity, or cooking loss among all groups ($P>0.05$); the pH of abomasal fluid and duodenal and jejunal contents decreased with increasing SBP supplementation levels, with the 24SBP group being significantly lower than the control group ($P<0.05$). In conclusion, di-

etary SBP supplementation can improve growth performance indicators such as average daily gain, dry matter intake, and net meat weight in fattening sheep, increase muscle crude fat content, and improve muscle tenderness and intestinal environment. SBP can be developed and applied as a novel feed resource for fattening sheep, and under the conditions of this experiment, the optimal dietary SBP supplementation level was 16%.

Full Text

Effects of Dietary Supplementation of Sea Buckthorn Pomace on Growth Performance, Slaughter Performance, Meat Quality, and pH of Digestive Tract Content of Fattening Sheep

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Abstract

This experiment investigated the effects of dietary supplementation of sea buckthorn pomace (SBP) on growth performance, slaughter performance, meat quality, and digestive tract content pH in fattening sheep. Forty Dorper × Small-tailed Han crossbred ram lambs (4 months old, approximately 22 kg body weight) were randomly allocated to four groups (n=10) according to SBP supplementation levels: 0% (control), 7.8% (8SBP), 16.0% (16SBP), and 23.5% (24SBP). The 80-day trial consisted of a 10-day pre-test period followed by a 70-day formal test period. Results showed that average daily gain (ADG) and dry matter intake (DMI) in the 16SBP and 24SBP groups were significantly higher than those in the control and 8SBP groups ($P<0.05$), with no significant differences in feed conversion ratio among all groups ($P>0.05$). Final body weight in the 16SBP group was significantly higher than in the control and 8SBP groups ($P<0.05$). Net meat weight in both the 16SBP and 24SBP groups was significantly greater than in the control group ($P<0.05$). The 24SBP group exhibited significantly lower muscle GR values compared to the control and 8SBP groups ($P<0.05$). Muscle ether extract (EE) content in the 16SBP and 24SBP groups was significantly higher than in the control and 8SBP groups ($P<0.05$), while muscle shear force in the 8SBP and 16SBP groups was significantly lower than in the control group ($P<0.05$). No significant differences were observed among groups in muscle pH, meat color, water holding capacity, or cooked meat rate ($P>0.05$). The pH of abomasal fluid and duodenal and jejunal contents decreased with increasing SBP supplementation, with the 24SBP group show-

ing significantly lower values than the control group (P<0.05). In conclusion, dietary SBP supplementation can improve growth performance indicators such as ADG, DMI, and net meat weight, increase muscle EE content, enhance muscle tenderness, and improve intestinal environment in fattening sheep. SBP can be developed as a novel feed resource for fattening sheep, with an optimal supplementation level of 16% under the conditions of this experiment.

Keywords: sea buckthorn pomace; fattening sheep; growth performance; slaughter performance; meat quality; digestive tract content

Sea buckthorn pomace is a byproduct of sea buckthorn processing that is widely used as a roughage source for ruminants, containing both medicinal components and abundant nutrients. Sea buckthorn (*Hippophae rhamnoides*), belonging to the Elaeagnaceae family, is primarily distributed in high-altitude regions of northwestern China. It thrives in barren lands with strong adaptability, and its fruits, stems, and leaves possess substantial nutritional and medicinal value [1]. Kagliwal et al. [2] extracted antioxidant substances from dehydrated sea buckthorn pulp and seeds using supercritical carbon dioxide, demonstrating that these components contain substantial amounts of vitamin E, vitamin C, carotenoids, and flavonoids. Liu et al. [3] conducted toxicological tests on sea buckthorn pomace and branches, concluding that sea buckthorn leaves and processing residues are nutritionally rich, safe for long-term animal feeding without cumulative toxicity, promote animal growth performance to varying degrees, improve feed utilization, reduce cholesterol, and enhance immune organ development. This study investigated the effects of different dietary SBP supplementation levels on growth performance, slaughter performance, meat quality, and digestive tract content pH in Dorper × Small-tailed Han crossbred ram lambs to provide a theoretical basis for the development and application of SBP in sheep production.

1.1 Experimental Time and Location

The experiment was conducted from July to October 2017 at the Xianghe Lingshang Experimental Base in Youyu County, Shuozhou City, Shanxi Province. The trial lasted 80 days, comprising a 10-day pre-test period and a 70-day formal test period.

1.2 Experimental Design and Diet

Forty healthy Dorper × Small-tailed Han crossbred ram lambs (4 months old, initial body weight 22.2$±$0.92 kg) were randomly assigned to four groups (n=10) based on SBP supplementation levels: 0% (control), 7.8% (8SBP), 16.0% (16SBP), and 23.5% (24SBP). Each lamb was housed individually. Experimental diets were formulated according to NRC (2007) nutrient requirements for 20 kg ram lambs with a target daily gain of 300 g/d, using oat straw and potato seedlings as roughage sources. All diets were processed as total mixed pellets. Diet composition and nutrient levels are presented in Table 1 .

Nutrient levels in diets and SBP were determined according to *Feed Analysis and Feed Quality Detection Technology* [4]. Dry matter (DM) content was measured by oven-drying at 105°C to constant weight, crude protein (CP) by Kjeldahl nitrogen analysis, and ether extract (EE) by ether reflux extraction. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed using the Van Soest method [5], and gross energy by oxygen bomb calorimetry. Non-fibrous carbohydrate (NFC) was calculated as: NFC (%) = 1 - (NDF + CP + EE + crude ash) [6].

Nutrient levels of SBP (DM basis) are shown in Table 2 .

1.3 Feeding Management

Prior to the experiment, the flock underwent quarantine inspection. During the pre-test period, lambs were dewormed and vaccinated, with regular disinfection to maintain clean housing conditions. Lambs were fed at 08:00 and 16:00 daily with ad libitum access to feed and water.

1.4 Sample Collection and Measurement

1.4.1 Growth Performance All lambs were fast-weighed on day 1 of the formal test period to determine initial body weight (IW), with subsequent fasting weights recorded every two weeks. On the final day of the formal test period, feed and water were withdrawn at 20:00 for 12 hours, and lambs were fast-weighed the following morning at 08:00 to determine final body weight (FW). Feed intake and refusals were accurately recorded to calculate individual DMI, ADG, and feed conversion ratio.

1.4.2 Slaughter Performance After final weighing, lambs were slaughtered following pre-slaughter weighing. Heads, hooves, viscera, and skins were removed, and organ weights were recorded. Carcasses were separated into bone and meat, with bone weight and net meat weight recorded. Muscle, visceral, and testicular samples were immediately collected and weighed.

1.4.3 Meat Quality Carcass weight = pre-slaughter live weight - weight of head, hooves, and tail;
Dressing percentage = 100 × carcass weight / pre-slaughter live weight;
Net meat weight = carcass weight - bone weight;
Net meat percentage = 100 × net meat weight / carcass weight;
Meat-to-bone ratio = bone weight / net meat weight.

The left *Longissimus dorsi* muscle was collected at slaughter to determine pH, GR value, meat color, water loss rate, cooked meat rate, shear force, and routine nutrients. pH was measured 1 hour post-collection (pH_1) and after 24-hour chilling at 4°C (pH_{24}). GR value, representing carcass fat thickness, was measured at 11 cm from the dorsal midline between the 12th and 13th ribs. Meat color was assessed using a CM-5 spectrophotometer to determine lightness (L*),* *redness (a*), and yellowness (b*) values at 1 hour (L_1 , a_1 , b_1*) and after 24-hour chilling at 4°C (L_{24} , a_{24} , b_{24} *), with three measurements averaged per sample. Water loss rate and shear force were determined using a TMS-PRO texture analyzer. Cooked meat rate was measured by heating approximately 50 g meat samples in an 80°C water bath for 30 minutes, cooling to room temperature, and reweighing. Routine nutrients were analyzed in freeze-dried muscle samples stored at -20°C. Moisture content was calculated after 72 hours of freeze-drying. CP, EE, and crude ash contents were determined according to* Feed Analysis and Feed Quality Detection Technology* [4].

1.4.4 Digestive Tract Content pH Rumen fluid, abomasal fluid, and duodenal, jejunal, and ileal contents were collected at slaughter for pH measurement using a pH meter.

1.5 Statistical Analysis

Data were initially processed using Excel 2007 and subsequently analyzed using SAS 9.2 software with a Mixed model. Differences were considered significant at $P<0.05$.

2.1 Effects of Dietary SBP Supplementation on Growth Performance of Fattening Sheep

As shown in Table 3 , initial body weight did not differ significantly among groups ($P>0.05$). Final body weight in the 16SBP group was significantly higher than in the control and 8SBP groups ($P<0.05$), with the greatest weight gain observed in this group, while the 8SBP group did not differ significantly from the control group ($P>0.05$). Average daily gain and DMI in both the 16SBP and 24SBP groups were significantly higher than those in the control and 8SBP groups ($P<0.05$), with no significant difference between the 8SBP and control groups ($P>0.05$). Feed conversion ratio did not differ significantly among all groups ($P>0.05$).

2.2 Effects of Dietary SBP Supplementation on Slaughter Performance of Fattening Sheep

Table 4 shows that pre-slaughter body weight in the 16SBP group was significantly higher than in the control group ($P<0.05$). Net meat weight in both the 16SBP and 24SBP groups was significantly greater than in the control group ($P<0.05$), with the 16SBP group achieving the highest net meat weight. The 24SBP group exhibited significantly lower muscle GR values compared to the control and 8SBP groups ($P<0.05$). No significant differences were observed among groups in carcass weight, dressing percentage, net meat percentage, bone weight, or meat-to-bone ratio ($P>0.05$).

2.3 Effects of Dietary SBP Supplementation on Muscle Nutrient Content and Meat Quality of Fattening Sheep

Table 5 demonstrates that muscle moisture, CP, and crude ash contents did not differ significantly between treatment and control groups (P>0.05). Muscle EE content increased with SBP supplementation level, with the 16SBP and 24SBP groups showing significantly higher values than the control and 8SBP groups (P<0.05).

As presented in Table 6 , no significant differences were detected among groups in muscle pH_1 or pH_{24} (P>0.05). Similarly, L_1 *and* a_1 values did not differ significantly among groups (P>0.05). After 24-hour chilling, L_{24} , a_{24} , and b^*_{24} values numerically increased but remained statistically similar across groups (P>0.05). Water holding capacity and cooked meat rate did not differ significantly among groups (P>0.05), though treatment groups showed numerically higher values than the control group. Muscle shear force in the 8SBP and 16SBP groups was significantly lower than in the control group (P<0.05), while the 24SBP group did not differ significantly from the control group (P>0.05).

2.4 Effects of Dietary SBP Supplementation on Digestive Tract Content pH of Fattening Sheep

Table 7 reveals that rumen fluid pH tended to decrease with increasing SBP supplementation, though differences among groups were not significant (P>0.05). Abomasal fluid pH decreased significantly with SBP supplementation (P<0.05). Duodenal content pH in the 16SBP and 24SBP groups was significantly lower than in the control group (P<0.05), while jejunal content pH in the 24SBP group was significantly lower than in the control group (P<0.05). Ileal content pH did not differ significantly among groups (P>0.05).

3.1 Effects of Dietary SBP Supplementation on Growth Performance of Fattening Sheep

Unconventional feed resources such as pomace have been widely utilized in animal production. According to incomplete statistics, China' s total pomace feed resources amount to approximately 160 million tons [7], with fruit pomace accounting for one-third. Fruit pomace contains substantial digestible protein and carbohydrates, making it a valuable feed resource rich in bioactive compounds that can enhance animal immunity. Yang et al. [8] reported that fermented apple pomace supplementation increased calf ADG by 14.14%. Lu et al. [9] investigated the effects of grape pomace on lamb growth and slaughter performance, determining optimal supplementation levels and demonstrating that increasing grape pomace levels significantly improved feed intake, daily gain, and carcass fat content while gradually decreasing apparent digestibility of CP, NDF, and ADF. In the present study, final body weight, DMI, and ADG were higher in treatment groups than in the control group, likely because SBP' s distinctive fruity aroma and acidic compounds stimulated olfactory senses and increased feed intake. Additionally, SBP supplementation reduced the proportion of roughage (oat straw and potato seedlings) in the diet, altering dietary physical properties and reducing the proportion of poorly digestible potato seedlings, which facilitated rumen degradation and further enhanced feed intake.

3.2 Effects of Dietary SBP Supplementation on Slaughter Performance of Fattening Sheep

Slaughter performance directly reflects animal economic value, with carcass weight, dressing percentage, and net meat percentage being key profit determinants [10]. Wu et al. [11] studied the effects of SBP on meat quality and slaughter performance of free-range yellow-feathered broilers, finding that dietary SBP supplementation increased muscle CP content without significantly affecting slaughter percentage, eviscerated percentage, or moisture content. The current results showed that different SBP supplementation levels did not significantly affect dressing percentage, net meat percentage, or meat-to-bone ratio in fattening sheep. The GR value indicates carcass fat content, with higher values representing greater fat deposition [12]. Chen [13] found that dietary *Allium mongolicum* flavonoids significantly improved mutton sheep performance, dressing percentage, eye muscle area, and GR values by altering nutrient metabolic pathways. Conversely, the present study demonstrated that GR values decreased with increasing SBP supplementation, with the lowest value observed in the 24SBP group, indicating reduced carcass fat content. This reduction may be attributed to two factors: first, SBP contains bioactive compounds that lower blood glucose, lipids, and cholesterol, thereby reducing fat deposition; second, certain functional components in SBP may alter nutrient deposition pathways during metabolism.

3.3 Effects of Dietary SBP Supplementation on Meat Quality of Fattening Sheep

Meat quality evaluation encompasses sensory characteristics, physicochemical properties, and nutritional value, which collectively reflect meat quality [14]. Routine muscle nutrients objectively assess meat quality, with primary chemical components including moisture, protein, fat, and ash. Research indicates that muscle chemical composition correlates with growth stage, showing decreased moisture and increased fat content with age and body weight, while protein content remains relatively stable [15]. Ma et al. [16] reported that dietary nutrient levels did not significantly affect routine chemical composition of Hu sheep *Longissimus dorsi* muscle. The present study similarly found no significant differences in muscle moisture, CP, or crude ash content between treatment and control groups, consistent with previous findings. Intramuscular fat content positively correlates with meat juiciness and flavor [17]. The significantly higher muscle EE content in the 16SBP and 24SBP groups suggests that SBP supplementation increased fat deposition in muscle, though the specific mechanisms require further investigation.

Muscle pH is a critical meat quality indicator. Watanabe et al. [18] reported that normal pH range for fresh muscle during aging is 5.4–7.2; fresh muscle pH is near neutral but decreases over time as muscle glycogen is metabolized to lactic acid. In this study, muscle pH values remained within the normal range without significant differences between control and treatment groups, indicating that SBP supplementation did not significantly affect muscle pH. Meat color is another important quality parameter, primarily determined by myoglobin and hemoglobin content [19]. During fresh meat storage, color changes result from interconversion of myoglobin, oxymyoglobin, and metmyoglobin [20]. The present data showed no significant differences in L*, a*, or b* values between control and treatment groups at either 1 hour or 24 hours post-slaughter, demonstrating that dietary SBP supplementation did not significantly affect meat color.

Muscle tenderness is a crucial sensory quality indicator, related to water holding capacity, shear force, and cooked meat rate. Studies report that beef cooked meat rate correlates with dietary nutrient levels, with higher nutrient levels improving cooked meat rate, tenderness, and intramuscular fat content, thereby enhancing meat quality [21]. Greater shear force indicates poorer tenderness and can reflect intramuscular fat content [22], while cooked meat rate indicates muscle protein water-holding capacity, with lower values suggesting poorer water retention. Although water holding capacity and cooked meat rate did not differ significantly among groups in this study, numerical values tended to increase with SBP supplementation, suggesting potential improvement in water-holding capacity. Shear force in the 8SBP and 16SBP groups was significantly lower than in the control group, while the 24SBP group did not differ significantly from the control group. These results suggest that appropriate SBP supplementation levels can effectively reduce mutton shear force and improve meat quality, though excessive supplementation may diminish these benefits, warranting further mechanistic investigation.

3.4 Effects of Dietary SBP Supplementation on Digestive Tract Content pH of Fattening Sheep

Gastrointestinal pH is a crucial factor affecting the digestive environment and forms the basis for regulating acid-base and electrolyte balance, with appropriate pH being essential for normal digestive function. Rumen fluid pH is a key indicator of rumen fermentation status, with normal range of 5.5–7.0, primarily influenced by diet composition, saliva secretion, and rumen fermentation product utilization and absorption efficiency [23]. Salivary sodium, potassium, and phosphate form a buffering system that maintains rumen pH. Research indicates that dietary changes do not affect average rumen pH but cause temporal fluctuations post-feeding [24]. In this study, rumen fluid pH remained within the normal range without significant differences among groups, though the 24SBP group showed numerically lower values than the control group. This suggests that 16.0% SBP supplementation does not negatively affect rumen pH, while 23.5% supplementation may increase rumen acidity. Although SBP supplementation reduced roughage proportion, it also decreased corn proportion, substantially lowering dietary starch content. Additionally, pomace typically contains high pectin levels, which help stabilize the rumen environment [25-26]. However, the 24SBP diet may have contained higher NFC that fermented rapidly in the rumen, and the lower roughage proportion may have reduced rumination time, causing decreased rumen pH.

Abomasal pH varies with physiological state, with normal range of 3-4. pH increases during starvation or low feed intake, while high volatile fatty acid (VFA) production in the rumen stimulates abomasal HCl secretion, further lowering abomasal pH [27]. In this study, abomasal fluid pH remained within the normal range and decreased with increasing SBP supplementation, likely because SBP promoted dietary degradation in the rumen, increasing VFA production that entered the abomasum and stimulated greater HCl secretion.

Small intestinal pH is regulated by endogenous secretions and neurohumoral factors. When chyme enters the duodenum, pancreatic juice secretion is neurally regulated to neutralize acidic substances, increasing small intestinal pH. The small intestine also secretes various enzymes, mucus, and bicarbonate ions that protect intestinal mucosa from gastric acid erosion. Duodenal and jejunal content pH ranges from 6.30-6.69, while posterior jejunal content pH ranges from 7.22-7.73 [28]. In this study, all digestive tract content pH values remained within normal ranges, with duodenal and jejunal pH decreasing with SBP supplementation, demonstrating that SBP can alter intestinal content pH.

4 Conclusion

Dietary supplementation of SBP can improve growth performance indicators including ADG, DMI, and net meat weight, increase muscle EE content, enhance muscle tenderness, and improve intestinal environment in fattening sheep. SBP can be developed as a novel feed resource for fattening sheep, with an optimal supplementation level of 16% under the conditions of this experiment.

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Note: Figure translations are in progress. See original paper for figures.