Effects of Mulberry Stem-Leaf Feed on Production Performance and Meat Quality of Meat Rabbits (Postprint)

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Abstract

This experiment aimed to investigate the effects of mulberry stem-leaf feed on growth performance and muscle quality of meat rabbits. A single-factor experimental design was adopted, in which one hundred and forty-four healthy New Zealand meat rabbits at 35 days of age with similar body weight were randomly allocated to 4 groups (6 replicates per group, 6 rabbits per replicate) and fed experimental diets containing mulberry stem-leaf feed at supplementation levels of 0 (control group), 8%, 16%, and 24%, respectively. The pre-trial period lasted 7 days, and the formal trial period lasted 42 days. The results showed: the average daily gain of the 24% group was significantly lower than that of the control group ($P<0.05$), and the feed-to-gain ratio was significantly higher than that of the control group ($P<0.05$); the a* values (redness-greenness) at 45 min and pH at 24 h of dorsal and leg muscles in the 16% and 24% groups were significantly higher than those in the control group ($P<0.05$); the drip loss rates of dorsal and leg muscles in the 16% and 24% groups were significantly lower than those in the control group ($P<0.05$); the inosine monophosphate content in dorsal and leg muscles of the 16% and 24% groups was significantly higher than that of the control group ($P<0.05$); the linolenic acid content in dorsal muscle and the palmitic acid and linolenic acid contents in leg muscle of the 16% and 24% groups were significantly higher than those of the control group ($P<0.05$). It was concluded that dietary mulberry stem-leaf feed supplementation not exceeding 16% had no significant effect on growth performance of meat rabbits, while it could increase the content of flavor substances in muscle and improve meat quality.

Full Text

Effects of Stem and Leaf Feed of Mulberry on Performance and Meat Quality of Meat Rabbits

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Abstract

This experiment was conducted to investigate the effects of stem and leaf feed of mulberry on the production performance and muscle quality of meat rabbits. Using a single-factor experimental design, 144 healthy 35-day-old New Zealand meat rabbits with similar body weight were randomly allocated to four groups (six replicates per group, six rabbits per replicate). The experimental diets contained mulberry stem and leaf feed at supplementation levels of 0 (control group), 8%, 16%, and 24%, respectively. The pre-trial period lasted 7 days, followed by a 42-day formal trial period. The results showed that the average daily gain in the 24% group was significantly lower than that in the control group ($P<0.05$), while the feed-to-gain ratio was significantly higher ($P<0.05$). The 16% and 24% groups exhibited significantly higher a* values (redness-greenness) at 45 minutes and pH values at 24 hours in both back and leg muscles compared to the control group ($P<0.05$). Additionally, the drip loss rates in these groups were significantly lower ($P<0.05$), and inosinic acid contents were significantly higher ($P<0.05$) in both muscle types. The linolenic acid content in back muscle and the palmitic and linolenic acid contents in leg muscle were also significantly elevated in the 16% and 24% groups ($P<0.05$). It was concluded that mulberry stem and leaf feed supplementation up to 16% had no significant adverse effects on rabbit performance while enhancing flavor compound content and improving meat quality.

Keywords: mulberry stem and leaf feed; meat rabbit; performance; meat quality; nutritional composition

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Introduction

Mulberry stem and leaf feed is a newly cultivated mulberry variety developed for feed purposes in recent years, characterized by strong regional adaptability and stress resistance. Nutritional analysis indicates that mulberry leaves have nutritional value similar to alfalfa meal, belonging to the category of high-protein, high-mineral feed ingredients rich in amino acids, various trace elements, vitamins, and natural active substances such as isoquercitrin and 1-deoxynojirimycin. Research has demonstrated that substituting mulberry stem and leaf feed for alfalfa in castrated sheep diets yields comparable crude protein digestibility, with similar results observed in cattle trials. Moreover, mulberry supplementation does not affect rumen pH and can better control gastric nitrogen balance. Studies in pigs have shown improved performance with mulberry feed, yielding better results than wild taro and snake gourd, while poultry trials have reported increased feed intake and conversion rates. Mulberry stem and leaf feed has also shown significant effects on improving meat quality in livestock and poultry. Jeon et al. reported that adding silage mulberry leaves to beef cattle diets increased fatty acid content in beef, while Li et al. and Yang et al. found that 10-15% mulberry leaf powder in pig diets elevated muscle fat content. Lan et al. reported that 8% and 11% mulberry leaf powder in broiler diets increased intramuscular unsaturated fatty acid content. Although progress has been made in mulberry leaf research both domestically and internationally, most studies have focused on cattle, sheep, pigs, and chickens, with limited experimental research on meat rabbits. This trial was designed to explore the effects of different levels of mulberry stem and leaf feed on growth performance and meat quality in meat rabbits, providing a reference for rational utilization of mulberry resources to reduce production costs and improve economic benefits.

1.1 Experimental Materials

The mulberry stem and leaf feed was provided by Southwest University, harvested during the vigorous growth period, then dried and pulverized. The main nutritional components were: dry matter 89.82%, crude protein 14.50%, crude fiber 32.11%, neutral detergent fiber 40.82%, and crude fat 1.32%. The experimental animals consisted of 144 New Zealand growing meat rabbits (half male and half female) provided by the Rabbit Research Institute of Sichuan Animal Science Academy.

1.2 Experimental Design

The 144 rabbits at 35 days of age, healthy and well-developed with an average body weight of (700$±$10) g, were divided into four groups according to the principle of equal gender distribution and similar body weight (six replicates per group, six rabbits per replicate). Based on different supplementation levels of mulberry stem and leaf feed in the diet, the groups were designated as control (0% addition), 8% group, 16% group, and 24% group. The pre-trial period lasted 7 days, followed by a 42-day formal trial period. At the end of the experiment, one rabbit was randomly selected from each replicate (six rabbits per group) for slaughter and subsequent determination of performance and meat quality indicators. The dietary formulations were designed according to recommended nutrient levels from reference [9] combined with local feed resources, with consistent nutrient levels across groups. Diets were prepared as pelleted feed. The composition and nutrient levels of experimental diets are shown in .

Prior to the experiment, the rabbit house was thoroughly cleaned and disinfected. The trial period consisted of a pre-feeding phase and a formal feeding phase. During the trial, rabbits were fed twice daily at 8:00 and 18:00. Body weight and feed weight were recorded weekly. Conventional feeding management and immunization procedures were employed with natural lighting and ventilation. Rabbits had free access to feed and water.

1.3 Measurement Indicators and Methods

1.3.1 Production Performance

Body weight was measured weekly in the morning after fasting, with weekly feed intake, initial body weight, final body weight, and total feed consumption recorded to calculate average daily gain, average daily feed intake, and feed-to-gain ratio.

1.3.2 Determination of Muscle pH, Meat Color Indices [a* (redness-greenness), b* (blue-yellowness), L* (lightness) values], and Drip Loss Rate

After slaughter, 3 cm × 4 cm samples of the left longissimus dorsi and biceps femoris muscles were excised with a scalpel for determination of drip loss and pH and color indices (a*, b*, L*) at 45 minutes and 24 hours post-mortem. pH was measured using a portable precision pH-3B pH meter, drip loss rate was determined by the 4°C hanging bag method, and meat color indices were measured using an Opto-STAR meat color meter.

1.3.3 Determination of Rabbit Meat Nutritional Composition

After slaughter, 3 cm × 4 cm samples of the right longissimus dorsi and biceps femoris muscles were excised, minced in a meat grinder, and stored in sealed bags at 4°C for subsequent analysis. Moisture, crude protein, crude fat, and fatty acid contents were determined according to Zhang Liying [10], while inosinic acid content was determined according to Wen Quan et al. [11].

1.4 Data Processing and Analysis

Experimental data were expressed as mean ± standard deviation. One-way ANOVA was performed using SPSS 18.0 statistical software, with Duncan' s multiple comparison test applied. The significance level was set at $P<0.05$.

2.1 Effects of Mulberry Stem and Leaf Feed on Performance of Meat Rabbits

As shown in , the average daily gain of meat rabbits showed a decreasing trend with increasing mulberry supplementation, with the 24% group being significantly lower than the control group ($P<0.05$). Mulberry stem and leaf feed had no significant effect on average daily feed intake ($P>0.05$). The feed-to-gain ratio increased gradually with mulberry supplementation, with the 24% group being significantly higher than the control group ($P<0.05$), while the 8% and 16% groups showed no significant difference from the control group ($P>0.05$).

2.2 Effects of Mulberry Stem and Leaf Feed on Muscle Quality Traits of Meat Rabbits

As shown in and , the a* values at 45 minutes in back and leg muscles of the 16% and 24% groups were significantly higher than those of the control group ($P<0.05$), while the 8% group showed no significant difference ($P>0.05$). Mulberry stem and leaf feed had no significant effect on meat color indices at 24 hours or pH at 45 minutes in either muscle type ($P>0.05$), though these indicators tended to increase with supplementation level. The pH values at 24 hours in both back and leg muscles of the 16% and 24% groups were significantly higher than those of the control group ($P<0.05$). Additionally, the drip loss rates in back and leg muscles of the 16% and 24% groups were significantly lower than those of the control group ($P<0.05$).

2.3 Effects of Mulberry Stem and Leaf Feed on Muscle Nutritional Composition of Meat Rabbits

As shown in , mulberry stem and leaf feed had no significant effect on moisture, crude protein, or crude fat contents in back or leg muscles ($P>0.05$). However, crude protein content showed an upward trend while crude fat content showed a downward trend with increasing supplementation. Mulberry stem and leaf feed significantly increased the content of inosinic acid, a flavor compound, in both muscle types ($P<0.05$). The inosinic acid contents in back and leg muscles of the 16% and 24% groups were significantly higher than those of the control group ($P<0.05$), while the 8% group showed no significant difference ($P>0.05$).

2.4 Effects of Mulberry Stem and Leaf Feed on Fatty Acid Composition of Meat Rabbit Muscle

As shown in and , the linolenic acid content (an unsaturated fatty acid) in back muscle was significantly higher in the 16% and 24% groups compared to the control group ($P<0.05$). In leg muscle, both palmitic acid (a saturated fatty acid) and linolenic acid contents were significantly higher in the 16% and 24% groups than in the control group ($P<0.05$).

3.1 Effects of Mulberry Stem and Leaf Feed on Performance of Meat Rabbits

The results indicate that mulberry stem and leaf feed supplementation had no significant effect on average daily feed intake of meat rabbits, but average daily gain showed a decreasing trend with increasing supplementation, with the 24% group being significantly lower than the control group and exhibiting a significantly higher feed-to-gain ratio. This decline in performance may be attributed to two factors. First, mulberry stem and leaf feed contains tannin components, and diet astringency is proportional to tannin content. When tannin content exceeds a certain threshold, it affects diet palatability and interferes with protein utilization in the intestinal tract while inhibiting calcium absorption. Second, due to harvesting methods, mulberry stem and leaf feed contains not only leaves but also tender branches that are less digestible for rabbits. Therefore, from a performance perspective, mulberry stem and leaf feed supplementation in meat rabbit diets should not exceed 16%. These findings contrast with Shi et al. [13], who reported that replacing corn and soybean meal with 30% mulberry leaves significantly increased weight gain in meat rabbits, but align with Prasad et al. [14], who found that 15%, 30%, and 45% mulberry leaf supplementation in growing rabbit diets progressively decreased performance, with the control and 15% groups showing significantly better performance than the 30% and 45% groups.

3.2 Effects of Mulberry Stem and Leaf Feed on Muscle Quality Traits of Meat Rabbits

The feeding trial demonstrated that mulberry stem and leaf feed enhanced meat color in rabbits. At 45 minutes post-mortem, the a* values in back and leg muscles of the 16% and 24% groups were significantly higher than those of the control group, while other color indices were also elevated but not significantly. This may be related to the high lutein content in mulberry leaves, which can be absorbed by rabbits and deposited in muscle tissue. However, these results differ from Martinez et al. [15], who reported that mulberry leaves increased meat redness and decreased yellowness.

Post-slaughter muscle rigor intensifies anaerobic glycolysis in muscle cells, leading to continuous lactic acid production and accumulation, which decreases muscle pH and affects water-holding capacity. pH influences muscle water-holding capacity through electrostatic charge effects on protein molecules. The electrostatic charges on protein molecules serve as strong water-attracting centers while increasing electrostatic repulsion between protein molecules, causing muscle fiber structures to loosen and creating water-holding spaces. When muscle pH approaches the isoelectric point of proteins (pH 5.0-5.4), positive and negative charges are nearly balanced, reducing reaction capacity to a minimum and resulting in lowest water-holding capacity. In this experiment, no significant differences in pH at 45 minutes were observed between treatment and control groups for either muscle type. However, at 24 hours, the pH values in back and leg muscles of the 16% and 24% groups were significantly higher than those of the control group, indicating that mulberry stem and leaf feed can delay glycolysis in rabbit muscle, with the 24% group showing the longest delay. These findings are consistent with Li et al. [6] and Yang et al. [7], who reported that 10-15% mulberry leaf supplementation in pig diets slowed the rate of muscle pH decline. However, the mechanism by which mulberry stem and leaf feed affects muscle glycolysis requires further investigation.

Muscle water-holding capacity is primarily evaluated through three aspects: free drip, expressible moisture, and water-binding potential, and it influences nutritional content, juiciness, aroma, and tenderness. Poor water-holding capacity leads to weight loss and quality deterioration during post-slaughter storage and processing, resulting in economic losses. This experiment found that the drip loss rates in back and leg muscles of the 16% and 24% groups were significantly lower than those of the control group, decreasing progressively with increasing mulberry supplementation. This suggests that mulberry stem and leaf feed supplementation during the fattening period can improve water-holding capacity of rabbit meat, likely due to the flavonoids and polysaccharides in mulberry that possess natural antioxidant activity, thereby enhancing antioxidant capacity and storage stability.

3.3 Effects of Mulberry Stem and Leaf Feed on Muscle Nutritional Composition of Meat Rabbits

The main nutritional components of muscle are moisture, crude protein, and crude fat. Muscle moisture content is approximately 75%, comprising bound water and free water. Post-slaughter rigor and glycolysis during muscle maturation decrease pH, leading to free water loss, while bound water accounts for only about 10% of total muscle moisture. In this experiment, muscle moisture content in all groups was approximately 75%, indicating minimal impact of mulberry stem and leaf feed on muscle water content.

Parrici et al. [21] reported that increased intramuscular fat content improves pork tenderness and juiciness, while Bejerholm et al. [22] found positive correlations between intramuscular fat content and meat quality, affecting flavor and tenderness. This experiment showed that crude fat content in muscle decreased progressively with increasing mulberry supplementation, consistent with Lan et al. [8] who reported that mulberry leaf powder in broiler diets reduced intramuscular fat content, possibly due to bioactive phenolic compounds in mulberry leaves that decrease intramuscular triglyceride content.

Inosinic acid is an aromatic compound also known as hypoxanthine nucleotide, currently used as an important indicator of meat flavor and freshness in many countries. Zhang et al. [23] demonstrated that heating water-fat mixtures can degrade inosinic acid and glycoproteins to produce distinct meaty flavors, with inosinic acid inhibiting sour and bitter tastes. This experiment found that inosinic acid content in back muscle was significantly higher in the 16% and 24% groups compared to the control group, while leg muscle inosinic acid content was significantly higher in the 24% group. These results align with Lan et al. [8], who reported that mulberry leaf supplementation in broiler diets significantly increased muscle inosinic acid content and improved chicken flavor quality.

3.4 Effects of Mulberry Stem and Leaf Feed on Muscle Fatty Acid Content of Meat Rabbits

Fatty acids are organic compounds containing a carboxyl group at one end of a long aliphatic hydrocarbon chain, classified as saturated or unsaturated based on carbon chain saturation. Saturated fatty acids 主要包括 myristic acid, palmitic acid, stearic acid, arachidic acid, and lauric acid, while monounsaturated fatty acids 主要包括 oleic acid, palmitoleic acid, and myristoleic acid, and polyunsaturated fatty acids 主要包括 linoleic acid, linolenic acid, and arachidonic acid. High intake of C12:0, C14:0, and C16:0 saturated fatty acids is a primary cause of elevated blood cholesterol, triglycerides, and low-density lipoprotein, subsequently leading to arterial stenosis and atherosclerosis. However, Zhang et al. [24] reported that C15:0 and C17:0 saturated fatty acids possess strong anticancer properties. Hernandez et al. [25] demonstrated that polyunsaturated fatty acids can lower cholesterol by inhibiting endogenous cholesterol synthesis and promoting cholesterol excretion, mobility, and polarity. Nutritionally, unsaturated fatty acids are categorized as ω-3, ω-6, and ω-9 families. This experiment measured linolenic acid as ω-3, linoleic acid as ω-6, and oleic acid as ω-9 unsaturated fatty acids. Results showed that mulberry stem and leaf feed supplementation decreased saturated fatty acid content while increasing unsaturated fatty acid content in rabbit muscle, with linolenic acid (ω-3) content in muscle being significantly higher in the 16% and 24% groups compared to the control group. This may be related to bioactive components in mulberry stem and leaf feed that promote neutral or acidic cholesterol excretion and inhibit hepatic lipid and lipoprotein synthesis. These findings are consistent with Martinez et al. [15], who reported that mulberry leaf supplementation increased unsaturated fatty acid content while decreasing saturated fatty acid content in rabbit muscle, particularly increasing ω-3 and ω-6 unsaturated fatty acids, and with Jeon et al. [3], who reported that mulberry silage supplementation increased unsaturated fatty acid content in beef longissimus dorsi muscle.

Conclusion

When mulberry stem and leaf feed supplementation does not exceed 16% of the diet, there are no significant adverse effects on average daily gain, average daily feed intake, or feed-to-gain ratio in growing meat rabbits. However, supplementation can increase muscle redness and water-holding capacity post-slaughter, reduce saturated fatty acid content, and increase polyunsaturated fatty acid and flavor compound contents in muscle.

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