Effects of Moringa oleifera Leaf on Growth Performance, Slaughter Performance, Antioxidant Function, and Meat Quality in Finishing Pigs (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary supplementation with different levels of Moringa leaves on growth performance, slaughter performance, antioxidant function, and meat quality of fattening pigs. A total of 144 healthy three-way crossbred (Duroc × Landrace × Large White) fattening pigs with an average body weight of (65.40$±$1.63) kg were selected and randomly divided into 4 groups with 6 replicates per group and 6 pigs per replicate. The control group was fed a basal diet, while the experimental groups were fed experimental diets supplemented with 3%, 6%, and 9% Moringa leaves in the basal diet. The experiment consisted of a 7-day pre-trial period and a 45-day formal trial period. The results showed: 1) Compared with the control group, the final body weight and average daily gain of fattening pigs in the 6% Moringa leaf group were significantly increased (P<0.05), and the feed conversion ratio of fattening pigs in the 3% and 6% Moringa leaf groups was significantly decreased (P<0.05). 2) Compared with the control group, the carcass straight length of fattening pigs in the 6% Moringa leaf group was significantly increased (P<0.05), and the backfat thickness of fattening pigs in the 6% Moringa leaf group was significantly decreased (P<0.05). 3) Compared with the control group, the serum superoxide dismutase (SOD) activity of fattening pigs in the 6% and 9% Moringa leaf groups was significantly increased (P<0.05), and the serum malondialdehyde content of fattening pigs in the 3%, 6%, and 9% Moringa leaf groups was significantly decreased (P<0.05). 4) Dietary supplementation with Moringa leaves had no significant effect on muscle dry matter, crude protein, and crude fat contents of fattening pigs (P>0.05). Compared with the control group, the muscle SOD activity and total antioxidant capacity of fattening pigs in the 6% and 9% Moringa leaf groups were significantly increased (P<0.05). In conclusion,

dietary supplementation with Moringa leaves can improve the growth performance and antioxidant function of fattening pigs, and improve meat quality. Under the conditions of this experiment, the appropriate supplementation level of Moringa leaves is 6%.

Full Text

Effects of Moringa Leaf on Growth Performance, Slaughter Performance, Antioxidant Function and Meat Quality of Finishing Pigs

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with different levels of Moringa leaf on growth performance, slaughter performance, antioxidant function, and meat quality of finishing pigs. A total of 144 healthy crossbred (Duroc × Landrace × Yorkshire) finishing pigs with an average initial body weight of (65.40$±$1.63) kg were randomly allocated into 4 groups with 6 replicates per group and 6 pigs per replicate. Pigs in the control group were fed a basal diet, while those in the experimental groups were fed the basal diet supplemented with 3%, 6%, and 9% Moringa leaf, respectively. The pre-experimental period lasted for 7 days, and the experimental period lasted for 45 days. The results showed that: (1) Compared with the control group, the final body weight and average daily gain of finishing pigs in the 6% Moringa leaf group were significantly increased ($P<0.05$), and the feed-to-gain ratio of finishing pigs in both the 3% and 6% Moringa leaf groups was significantly decreased ($P<0.05$). (2) Compared with the control group, the carcass straight length of finishing pigs in the 6% Moringa leaf group was significantly increased ($P<0.05$), while the backfat thickness of finishing pigs in the 6% Moringa leaf group was significantly decreased ($P<0.05$). (3) Compared with the control group, the serum superoxide dismutase (SOD) activity of finishing pigs in the 6% and 9% Moringa leaf groups was significantly increased ($P<0.05$), and the serum malondialdehyde content of finishing pigs in the 3%, 6%, and 9% Moringa leaf groups was significantly decreased ($P<0.05$). (4) Dietary Moringa leaf supplementation had no significant effect on muscle dry matter, crude protein, or ether extract contents of finishing pigs (P>0.05). However, compared with the control group, the muscle SOD activity and total antioxidant capacity of finishing pigs in the 6% and 9% Moringa leaf groups were significantly increased (P<0.05). In conclusion, dietary supplementation with Moringa leaf can improve growth performance and antioxidant function while enhancing meat quality of finishing pigs. Under the conditions of this experiment, the appropriate supplemental level of Moringa leaf is 6%.

Keywords: Moringa leaf; growth performance; antioxidant function; meat quality

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Introduction

Currently, conventional protein feed resources in China are severely scarce and expensive, which has become a major factor restricting the development of animal husbandry. Therefore, seeking novel protein feeds that are inexpensive, high-yielding, and efficient to completely or partially replace conventional protein feeds has become a research hotspot for animal nutritionists. Moringa (Moringa oleifera) belongs to the family Moringaceae and genus Moringa Adans., a perennial plant native to the Himalayan region of northern India and Africa. It is a fast-growing multipurpose tree species that can flower and bear fruit just six months after planting[1]. To date, more than 30 countries have introduced and cultivated Moringa. China has also introduced seeds and cultivation techniques from India, Myanmar, and other regions, establishing large-scale plantations in Guangdong, Guangxi, Hainan, Sichuan, and Yunnan provinces that have formed scaled raw material production bases[2]. Moringa exhibits high yield, with an annual fresh weight production of approximately 126 t/ha[3] and an annual dry weight production of 10.4–24.7 t/ha[4]. Moringa is drought-tolerant and can survive in barren areas, making it a resource that does not compete with grain crops for land[5]. The leaves, tender pods, buds, flowers, tender stems, and roots of Moringa are all edible, rich in various minerals, vitamins, and pharmacologically active components. As a plant with both medicinal and food value, its nutritional and medicinal benefits have been widely confirmed and are being developed and utilized. Moringa seeds have high oil content, and Moringa oil is a functional edible oil extremely beneficial to human health. Additionally, Moringa seeds contain active coagulating components with special water-purifying functions[6]. Consequently, Moringa is also known as the "miracle tree" and the "diamond among plants."

Moringa leaves are rich in vitamins A, B, and C, protein, and minerals such as calcium, potassium, and iron. Every 100 g of Moringa leaf powder contains 27.1 g of crude protein, 38.2 g of carbohydrates, 2.3 g of ether extract, 7.5 g of moisture, 19.2 g of dietary fiber, 16.3 mg of vitamin A, 2.6 mg of vitamin B1, 20.5 mg of vitamin B2, 113 mg of vitamin E, 8.2 mg of niacin, 17.3 mg of vitamin C, 2,000.3 mg of calcium, 204 mg of phosphorus, 1,324 mg of potassium, and 28.2

mg of iron[7-8]. In recent years, Moringa used as a substitute for conventional protein feed has been added to diets for chickens, cattle, sheep, and other animals, achieving favorable results. Kakengi et al.[9] found that using Moringa leaf meal to replace sunflower seed meal as a protein source in laying hen diets demonstrated that Moringa leaf powder could replace 20% of sunflower seed meal without any negative effects, with the highest utilization efficiency at a 10% replacement ratio, which was considered the appropriate supplementation level. Sánchez et al.[10] reported that adding Moringa leaf powder to diets based on Brachiaria grass not only increased dry matter intake in dairy cows but also significantly improved the apparent digestibility of dry matter, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber, as well as milk yield. Aregheore[11] fed goats with different proportions of Moringa leaf and Setaria sphacelata grass, finding that 20% and 50% Moringa leaf supplementation levels yielded better results, significantly improving average daily gain, dry matter intake, and digestibility of crude protein and neutral detergent fiber in goats at these levels. However, studies on adding Moringa leaf to pig diets have not been reported, limiting the application of Moringa leaf as a substitute for conventional protein feed in swine production. Therefore, this experiment aimed to investigate the effects of dietary supplementation with different levels of Moringa leaf on growth performance, slaughter performance, antioxidant function, and meat quality of finishing pigs, providing a theoretical basis for the application of Moringa leaf in pig production.

1.1 Experimental Materials

Moringa leaves were provided by Century Love International Investment Group Co., Ltd. The plants were harvested when they reached approximately 1.5 m in height. The fresh samples were dried, after which the leaves were stripped from the main stems and ground into powder. The powdered Moringa leaves were bagged and stored for later use. The conventional nutritional composition of the Moringa leaves used in this study was determined as follows: dry matter 86.7%, crude protein 22.0%, ether extract 9.42%, crude ash 13.7%, neutral detergent fiber 41.0%, acid detergent fiber 17.9%, and digestible energy 16.0 MJ/kg, where digestible energy was a calculated value and the others were measured values.

1.2 Experimental Design and Diets

A single-factor randomized block design was adopted in this experiment. A total of 144 healthy crossbred (Duroc × Landrace × Yorkshire) finishing pigs with similar body weight were randomly allocated into 4 groups with 6 replicates per group and 6 pigs per replicate. The experiment used a corn-soybean meal basal diet formulated according to the nutrient requirements for growing-finishing pigs in NRC (1998) and the Chinese Feeding Standard for Swine (2004), combined with the practical production conditions of the farm. The diets were prepared in powder form, and the energy and protein levels were maintained essentially consistent across all groups. The composition and nutrient levels of the experimental diets are presented in Table 1 . The control group was fed the basal diet, while the experimental groups were fed the basal diet supplemented with 3%, 6%, and 9% Moringa leaf, respectively. The pre-experimental period lasted for 7 days, and the experimental period lasted for 45 days.

1.3 Animal Management

The experimental pig houses were semi-open buildings with cement floors. Throughout the experimental period, pigs had free access to feed and water, were immunized according to the routine procedures of the farm, and the houses were regularly disinfected. The pens were cleaned daily to maintain a clean and dry environment, and the houses were naturally ventilated.

1.4.1 Growth Performance

Body weight was measured pen by pen before morning feeding on the first and last days of the experiment to record initial and final body weights for calculating average daily gain. Meanwhile, feed intake was recorded daily during the experimental period, and the total feed consumption of each group was calculated after the experiment to determine average daily feed intake. The feed-to-gain ratio was calculated based on average daily gain and average daily feed intake.

1.4.2 Slaughter Performance

After the feeding trial, one pig with body weight close to the group average was selected from each replicate. After 12 hours of fasting, the live weight before slaughter was measured, and the pigs were then slaughtered. The slaughtering procedure was strictly conducted according to the Chinese Operating Procedures of Pig Slaughtering (GB/T 17236-2008). Subsequently, carcass weight, carcass straight length, and carcass oblique length were measured. Backfat thickness was measured at three points: the thickest part of the shoulder, the thoracolumbar junction, and the lumbosacral junction. The slaughter percentage and average backfat thickness were then calculated.

1.4.3 Serum Antioxidant Indices

On the day before the end of the experiment, one pig from each replicate was selected for venous blood collection, and serum was separated and stored at -20°C for later analysis. Serum antioxidant indices were measured using assay kits produced by Nanjing Jiancheng Bioengineering Institute. The measured indices included serum superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities, malondialdehyde (MDA) content, and total antioxidant capacity (T-AOC).

1.4.4 Meat Quality and Antioxidant Indices

After slaughter, the middle portion of the longissimus dorsi muscle was sampled to determine muscle crude protein and ether extract contents. The longissimus dorsi muscle was then cut into small pieces, placed in petri dishes, weighed, and put in a freeze-dryer. After the samples were completely dried, they were removed and weighed again to calculate muscle dry matter content. Antioxidant indices of the freeze-dried muscle samples were measured using assay kits from Nanjing Jiancheng Bioengineering Institute. The measured indices included muscle SOD and GSH-Px activities, MDA content, and T-AOC.

1.5 Statistical Analysis

Experimental data were organized using Excel 2007 and analyzed using SAS 9.2 statistical software. One-way analysis of variance (ANOVA) was performed, and Duncan' s multiple comparison test was used for significance analysis, with P<0.05 as the criterion for significant difference.

2.1 Effects of Moringa Leaf on Growth Performance of Finishing Pigs

As shown in Table 2 , dietary Moringa leaf supplementation significantly affected the final body weight, average daily gain, and feed-to-gain ratio of finishing pigs (P<0.05). Compared with the control group, the average daily gain of finishing pigs in the 3%, 6%, and 9% Moringa leaf groups increased by 5.05% (P>0.05), 14.14% (P<0.05), and 4.04% (P>0.05), respectively. The feed-to-gain ratio of finishing pigs in both the 3% and 6% Moringa leaf groups was significantly decreased (P<0.05). Moringa leaf had no significant effect on average daily feed intake of finishing pigs (P>0.05).

2.2 Effects of Moringa Leaf on Slaughter Performance of Finishing Pigs

As shown in Table 3 , compared with the control group, the carcass straight length of finishing pigs in the 3%, 6%, and 9% Moringa leaf groups increased by 2.35% (P>0.05), 3.17% (P<0.05), and 1.13% (P>0.05), respectively. The backfat thickness of finishing pigs in the 3%, 6%, and 9% Moringa leaf groups decreased by 4.25% (P>0.05), 10.13% (P<0.05), and 4.58% (P>0.05), respectively. Dietary Moringa leaf supplementation had no significant effect on carcass weight, slaughter percentage, or carcass oblique length of finishing pigs (P>0.05).

2.3 Effects of Moringa Leaf on Serum Antioxidant Indices of Finishing Pigs

As shown in Table 4 , compared with the control group, the serum SOD activity of finishing pigs in the 6% and 9% Moringa leaf groups was significantly increased

(P<0.05), and the serum MDA content of finishing pigs in the 3%, 6%, and 9% Moringa leaf groups was significantly decreased (P<0.05). Dietary Moringa leaf supplementation had no significant effect on serum GSH-Px activity or T-AOC of finishing pigs (P>0.05).

2.4 Effects of Moringa Leaf on Meat Quality and Antioxidant Indices of Finishing Pigs

As shown in Table 5 , dietary Moringa leaf supplementation had no significant effect on muscle dry matter, crude protein, or ether extract contents of finishing pigs (P>0.05).

As shown in Table 6 , compared with the control group, the muscle SOD activity and T-AOC of finishing pigs in the 6% and 9% Moringa leaf groups were significantly increased (P<0.05). Dietary Moringa leaf supplementation had no significant effect on muscle GSH-Px activity or MDA content of finishing pigs (P>0.05).

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3 Discussion

3.1 Effects of Moringa Leaf on Growth Performance and Slaughter Performance of Finishing Pigs Currently, numerous studies have investigated dietary Moringa leaf supplementation in poultry, dairy cattle, and sheep, but research in pigs remains limited. Sarwatt et al.[12] reported that replacing 40% of cottonseed meal with Moringa leaf powder in dairy cow diets increased milk yield. Conversely, Mendieta-Araica et al.[13] found that replacing soybean meal in dairy cow concentrate with Moringa leaf powder on an iso-nitrogenous and iso-energetic basis reduced protein digestibility but had no significant effect on milk yield or quality. Therefore, Moringa leaf powder can replace soybean meal as a protein source in dairy cow diets on an iso-nitrogenous and iso-energetic basis. In recent years, rumen acidosis has become common in high-yielding dairy cows, which not only directly affects production and reproductive performance but also induces other diseases or even death, causing serious economic losses to producers[14]. Hoffmann et al.[15] used in vitro rumen fermentation simulation technology to study the effects of Moringa seed extract on rumen fermentation in dairy cows, demonstrating that Moringa seed extract could delay protein digestion, thereby reducing the incidence of rumen acidosis. Meanwhile, Moyo et al.[16] found that on an iso-nitrogenous and iso-energetic basis, replacing part of the sunflower seed meal in goat diets with Moringa leaf powder significantly improved growth performance and carcass quality. Gadziray et al.[17] added Moringa leaf powder to soybean meal-based diets for broiler chicks and adult broilers, showing that Moringa leaf powder had no significant effect on feed intake but improved feed conversion efficiency, with an appropriate supplementation level of 25%. This indicates that Moringa leaf powder as a soybean meal substitute has similar efficacy to conventional protein feeds for broiler growth performance. However, no studies have reported the use of Moringa leaf in pig production. The present study found that adding Moringa leaf to finishing pig diets increased average daily gain and decreased feed-to-gain ratio, demonstrating that Moringa leaf can replace soybean meal as a conventional protein feed substitute in finishing pig diets, with an appropriate supplementation level of 6%.

At present, research on feeding Moringa to animals has primarily focused on its effects on growth performance, and no studies have reported the effects of dietary Moringa leaf supplementation on slaughter performance. This study found that dietary Moringa leaf supplementation had no significant effect on the slaughter percentage of finishing pigs but significantly reduced backfat thickness, which may be related to Moringa' s ability to regulate lipid metabolism in animals. Kholif et al.[18] found that adding Moringa leaf to goat diets significantly reduced serum cholesterol content and regulated lipid metabolism in goats.

3.2 Effects of Moringa Leaf on Serum Antioxidant Indices of Finishing Pigs The antioxidant system of the body is primarily composed of chain reaction blockers and antioxidant enzymes, which work synergistically to maintain the balance between free radical generation and elimination. GSH-Px is an important substance for scavenging hydrogen peroxide (H_2O_2) and many organic hydroperoxides in the body. SOD is a crucial antioxidant enzyme that effectively eliminates superoxide anion radicals and prevents free radical damage to biological membranes and cytoplasm. MDA is a small molecular product generated during the chain termination stage of lipid peroxidation reactions, which causes cellular damage through the peroxidation of polyunsaturated fatty acids in biological membranes. Therefore, serum MDA content can reflect the degree of lipid peroxidation in the body and indirectly indicate the extent of cellular damage[19]. The level of T-AOC represents the overall antioxidant capacity of the body and serves as a marker of antioxidant capability. In this study, dietary Moringa leaf supplementation increased serum SOD activity and significantly decreased serum MDA content, indicating that Moringa leaf can enhance the antioxidant capacity of finishing pigs. Improved antioxidant capacity is extremely important for animals to maintain overall health.

3.3 Effects of Moringa Leaf on Muscle Antioxidant Indices of Finishing Pigs Meat contains high levels of unsaturated fatty acids, which readily initiates free radical-autocatalyzed lipid oxidation, thereby increasing drip loss, accelerating meat discoloration, and forming off-flavor compounds. The end product of lipid peroxidation is MDA, which can cause cross-linking between membrane lipids and membrane proteins, leading to conformational changes in membrane proteins, subsequent protein inactivation, and impaired cellular functions. Muscle MDA content serves as an important indicator for evaluating the degree of oxidative deterioration and safety of meat products during storage and is widely used in Western countries as a key metric for assessing fresh meat quality. Additionally, numerous free radical scavenging systems exist within cells, maintaining the body in a dynamic equilibrium state. SOD specifically eliminates superoxide anion radicals and is one of the most important antioxidant enzymes against oxygen free radicals in living organisms[20]. Its primary function is to dismutate oxygen free radicals to generate H_2O_2, playing a vital role in maintaining the oxidative and antioxidant balance in the body. The level of muscle SOD activity can reflect the ability to prevent lipid oxidation reactions in muscle, thereby affecting meat quality and shelf life[21]. GSH-Px is mainly present in the mitochondria and cytosol of organisms. Like SOD, GSH-Px is also a very important antioxidant enzyme in animals, whose main physiological function is to scavenge H_2O_2 and lipid peroxides, with reduced glutathione serving as a reducing agent to specifically provide hydrogen ions (H^+) during the reaction. T-AOC reflects the capacity of both enzymatic and non-enzymatic antioxidant defense systems; therefore, muscle T-AOC can indicate the antioxidant defense capability of muscle. Currently, no studies have reported the effects of Moringa leaf on muscle antioxidant indices of finishing pigs. In this experiment, dietary Moringa leaf supplementation increased muscle SOD activity and T-AOC, indicating that Moringa leaf can enhance the antioxidant capacity of pork, thereby extending its freshness period and shelf life, which is of great significance for prolonging muscle storage time.

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4 Conclusion

Dietary supplementation with Moringa leaf can increase the average daily gain of finishing pigs, reduce carcass backfat thickness, and simultaneously enhance the antioxidant capacity of pork and improve meat quality. Under the conditions of this experiment, the appropriate supplementation level of Moringa leaf is 6%.

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