

Comparative impact of garlic and black garlic as natural feed additives on carcass, abdominal fat, and cholesterol of broilers

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ABSTRACT

This study investigated the effects of garlic (*Allium sativum*) and black garlic supplementation as feed additives on carcass, abdominal fat, and cholesterol levels in broilers. A total of 150 day-old broiler chicks were randomly assigned to three dietary treatments: control (no supplementation), garlic powder supplementation (3.0% w/w), and black garlic powder supplementation (3.0% w/w) for 35 days. Carcass yield, abdominal fat percentage, serum cholesterol and meat cholesterol were measured at the end of the experiment. Both garlic and black garlic groups exhibited significant reductions ($p < 0.05$) in abdominal fat deposition and total serum cholesterol compared to controls, with black garlic showing a more pronounced effect. Carcass composition improvements were observed in treated groups, indicated by higher breast muscle yield. The findings suggest that supplementing broiler diets with 3% black garlic powder significantly reduced abdominal fat and decreased serum and meat cholesterol levels without negatively affecting carcass yield.

Introduction

The poultry industry plays a vital role in global food security by providing a cost-effective source of high-quality protein. However, the sustainability and efficiency of poultry production depend highly on feed formulations that not only support growth performance but also enhance product quality and animal health (Soesanto *et al.*, 2023). The poultry industry is increasingly focused on identifying natural feed additives that enhance production performance and product quality while promoting animal health and reducing chemical residues. Recently, there has been a growing interest in natural feed additives as alternatives to synthetic compounds, which often carry risks such as chemical residues and antimicrobial resistance. Natural additives, including various herbs and plant extracts, are valued for their bioactive components that promote immunity, antioxidant capacity, and lipid metabolism (Berliana *et al.*, 2021; Tanti *et al.*, 2022).

Garlic (*Allium sativum*) is recognized for its bioactive compounds, particularly allicin, which possess potent antioxidant, antimicrobial, and lipid-lowering effects (Bazaraliyeva *et al.*, 2022). Allicin is responsible for garlic's distinctive aroma and many of its biological activities, including antioxidative, antimicrobial, and lipid-lowering effects. Studies have shown that garlic supplementation in poultry diets can improve immunity, reduce pathogenic bacteria in the gut, and positively influence lipid profiles by decreasing serum cholesterol and abdominal fat deposition (Elbaz *et al.*, 2021; Tanti *et al.*, 2023). These effects make garlic a promising candidate to replace antibiotics and synthetic antioxidants in poultry nutrition. More recently, black garlic, produced by fermenting fresh garlic under controlled heat and humidity, has gained attention due to its superior antioxidant capacity and higher concentrations of bioactive compounds such as S-allyl cysteine, formed via the Maillard reaction (Lee *et al.*, 2017; Ryu *et al.*, 2022). The fermentation process triggers the Maillard reaction, leading to enhanced antioxidant properties and an increased concentration of bioactive compounds, such as S-allyl cysteine and flavonoids, which have been linked to improved health outcomes (Lee *et al.*, 2017; Ryu *et al.*, 2022). Compared to fresh garlic, black garlic exhibits

greater antioxidant capacity and a milder taste, which may be more acceptable in feed palatability (Berliana *et al.*, 2021).

Despite the known benefits of garlic and black garlic, comparative evaluations of their effectiveness in poultry nutrition were limited. Most studies tend to focus on fresh garlic supplementation, leaving a gap in understanding whether black garlic's enhanced bioactivity translates into superior production outcomes and health benefits for broilers. Investigations into how these additives influence carcass traits, lipid metabolism, and serum cholesterol are essential for industry application, especially given current consumer demands for healthier and safer poultry products (Tanti *et al.*, 2022). However, direct comparisons between fresh garlic and black garlic in broiler diets are limited. Evaluating their differential effects on carcass characteristics and lipid parameters is critical for optimizing poultry feed formulations aimed at improving meat quality and consumer health.

Therefore, this study aimed to investigate and compare the effects of dietary supplementation with fresh garlic and black garlic on carcass composition, abdominal fat, and serum cholesterol levels in broilers.

Materials and methods

Experimental design

A total of 150 one-day-old broiler chicks (Cobb 500) were used in this study. The chicks were randomly allocated into three dietary treatment groups, with 50 chicks per group. Each treatment group was further subdivided into five replicate pens, with 10 chicks per pen. The experimental design consisted of the following three treatments:

T0 (Control): Basal commercial diet with no supplementation.

T1 (Garlic Supplementation): Basal diet + 3% (w/w) garlic powder.

T2 (Black Garlic Supplementation): Basal diet + 3% (w/w) black garlic powder.

The trial lasted for 35 days. Birds were housed in environmentally controlled pens with ad libitum access to feed and water throughout the experimental period. The research was conducted at the Field Laboratory

of Block B, Department of Animal Production and Technology, Jalan Agatis, IPB Dramaga Campus, Bogor, 16680, West Java, Indonesia.

Diet preparation

The processing of fresh garlic into garlic powder was carried out by modifying the method of Syakir *et al.* (2017). The garlic cloves were peeled and then thinly sliced (2–3 mm). The slices were subsequently dried in an oven at 60°C for 5 hours until the moisture content reached $\leq 14\%$ (SNI 2000). After drying, the garlic was ground using a blender, while the processing of fresh garlic into black garlic powder was performed by modifying the method of Berliana *et al.* (2018). The garlic cloves were wrapped in aluminum foil and then heated in a rice cooker on warm mode at 60°C for 17 days. Afterward, the aluminum foil and garlic skins were removed, and the black garlic was dried in an oven at 60°C for 3 days until the moisture content reached $\leq 14\%$ (SNI 2000). The dried black garlic was then ground using a blender. Garlic powder and black garlic powder were added to commercial feed. The commercial feed used in this study consisted of three phases: pre-starter feed (days 1–7), starter feed (days 8–21), and finisher feed (days 22–35). The ingredients and nutrient contents of the treatment diet is presented in Table 1.

Table 1. Ingredients and nutrient contents of the treatment diet.

Items	Starter			Finisher		
	T0	T1	T2	T0	T1	T2
Feed ingredient (%)						
Commercial feed	100	100	100	100	100	100
Garlic powder	0	3	0	0	3	0
Black garlic powder	0	0	3	0	0	3
Nutrient content (%)						
Dry matter	86	86.22	86.22	86	86.22	86.22
Ash	8	7.91	7.93	8	7.91	7.93
Crude protein	20	19.84	19.86	19	18.87	18.89
Crude fat	5	4.88	4.86	5	4.88	4.86
Crude fiber	5	4.87	4.97	6	5.84	5.94

Note : Nutrient content based on calculation results. T0 = Basal diet (control); T1 = T0 + Garlic addition (3% w/w of garlic powder); T2 = T0 + Black garlic addition (3% w/w of black garlic powder)

Broilers management and parameters measured

Broilers were reared in colony cages equipped with iron partitions (1 m² per pen). Feed and water were provided ad libitum. Vaccinations against Newcastle disease (ND-1, ND-2) and Gumboro disease were administered according to standard protocols. Management practices followed the guidelines outlined in the Indian River Broiler Management Handbook (Aviagen, 2018). At day 35, one bird per replicate (n=5 per treatment) was randomly selected, fasted overnight, and humanely euthanized. Carcass yield was calculated as (eviscerated carcass weight / live weight) $\times 100\%$. Abdominal fat (including fat surrounding the gizzard and adhering to the abdominal cavity) was weighed, and its percentage was calculated as (abdominal fat weight / live weight) $\times 100\%$.

Serum cholesterol (mg dL⁻¹) was measured by collecting blood, approximately 2 mL of blood was drawn from the neck vein of each bird into plain vacuum tubes. The blood samples were then stored in an ice cooler and transported to the laboratory for analysis. Meat cholesterol (mg%) was determined by collecting 5 g of broiler breast meat. The sample was extracted using an organic solvent (ether alcohol) and centrifuged at 3000 rpm for 10 minutes to obtain the supernatant. The supernatant was evaporated to dryness in a 50 mL glass beaker at 100°C until all solvent was removed. The residue was then re-dissolved in chloroform to a final volume of 5 mL in a graduated tube.

For analysis, 5 mL of cholesterol standard solution (4 mg/5 mL) and

5 mL of chloroform (blank) were prepared in separate glass tubes. Two milliliters of anhydride acetic acid and 0.2 mL of concentrated sulfuric acid were added to each tube, and the mixtures were allowed to react for 10 minutes. Cholesterol levels in both serum and meat were analyzed using the Liebermann–Burchard method. Absorbance was measured with a spectrophotometer at a wavelength of 500 nm.

Statistical analysis

Data of carcass weight and abdominal fat were analyzed using one-way ANOVA with the General Linear Model procedure of SPSS 23.0. Mean differences were tested using Duncan's Multiple Range Test (DMRT) with significance set at $p < 0.05$, while data of serum cholesterol and meat cholesterol were analyzed descriptively.

Results

Carcass percentage

The effects of garlic powder supplementation on carcass percentage in broilers are presented in Table 2. Statistical analysis revealed that dietary supplementation with garlic powder had no significant effect on carcass yield of broiler chickens ($p > 0.05$). Mean carcass percentages were 71.58% (control), 73.35% (3% garlic powder), and 72.10% (3% black garlic powder). Although the garlic powder-supplemented groups showed slightly higher yields (T1), these differences were not statistically significant.

Table 2. The effects of garlic and black garlic powder supplementation on parameters.

Parameters	T0	T1	T2
Carcass (%)	71.58 $\pm$ 7.25	73.35 $\pm$ 5.63	72.10 $\pm$ 9.49
Abdominal fat (%)	1.08 $\pm$ 0.28 ^a	0.89 $\pm$ 0.08 ^{ab}	0.65 $\pm$ 0.09 ^c
Meat cholesterol (mg%)	11.91	11.58	11.83
Serum cholesterol (mg dL ⁻¹)	125.67	116.22	117.86

Data are presented as Mean $\pm$ SEM. Values in the same row with different superscripts significantly different ($p < 0.05$). T0 = Basal diet (control); T1 = T0 + Garlic addition (3% w/w of garlic powder); T2 = T0 + Black garlic addition (3% w/w of black garlic powder).

Abdominal fat

In contrast to carcass yield, abdominal fat deposition was significantly affected by the treatments ($p < 0.05$) showed by Table 2. The control birds had 1.08% abdominal fat (as a percentage of body weight), whereas birds fed 3% garlic powder had 0.89% and those fed 3% black garlic powder had 0.65%, respectively. The black garlic group showed a significant reduction compared to the control.

Meat cholesterol

Meat cholesterol content showed a modest downward trend with garlic powder feeding (Table 2). The lowest meat cholesterol concentration was observed in birds given garlic powder (11.58 mg%) (T1), compared to 11.91 mg% in control (T0). This represents only about a 2.3% reduction. No statistical analysis was reported for the meat cholesterol data, but the numerical decrease suggests a slight hypocholesterolemic effect on muscle tissue.

Serum Cholesterol

The impact of garlic powder supplementation on serum cholesterol concentrations is summarized in Table 2. Broilers fed diets supplemented with 3% garlic powder (T1) exhibited the lowest serum cholesterol level at 116.22 mg dL⁻¹, representing a 7.6% reduction relative to the control (125.67 mg dL⁻¹). Similarly, broilers fed black garlic powder (T2) showed a

comparable serum cholesterol level ($117.86 \text{ mg dL}^{-1}$). Although these serum differences were not tested for statistical significance, the consistent reduction in both garlic-fed groups suggests that garlic supplementation tends to lower circulating cholesterol levels.

Discussion

The findings of this study demonstrate that dietary supplementation with 3% garlic powder (T1) and 3% black garlic powder (T2), significantly reduced abdominal fat deposition and showed a consistent, though non-significant, trend toward lowering serum and meat cholesterol levels in broiler chickens, without adversely affecting carcass yield. These results align with the growing body of evidence supporting the role of garlic-derived bioactive compounds in modulating lipid metabolism and improving product quality in poultry.

The results showed that dietary supplementation with garlic powder had no significant effect ($p > 0.05$) on carcass yield of broiler chickens, with mean carcass percentages of 71.58% (control), 73.35% (3% garlic powder), and 72.10% (3% black garlic powder). These findings are consistent with several previous studies reporting that garlic supplementation does not significantly influence carcass characteristics in broilers (Glamoclija *et al.*, 2016; Pourali *et al.*, 2010). The lack of significant difference in carcass percentage suggests that garlic supplementation at 3% level maintains normal muscle development and tissue accretion without adversely affecting overall body composition. However, the slight numerical increase in carcass percentage observed in the garlic powder group aligns with reports indicating that bioactive compounds in garlic, particularly organosulfur compounds, may enhance protein synthesis and muscle mass development (Lee *et al.* 2016). The thermal processing involved in black garlic production converts unstable compounds from fresh garlic into more stable forms, including S-allyl-L-cysteine (SAC), polyphenols, and melanoidins (Kimura *et al.*, 2017; Qiu *et al.* 2020). These transformations may alter the bioavailability and physiological effects of garlic's bioactive components. During the aging process at controlled high temperature ($70\text{--}90^\circ\text{C}$) and humidity ($70\text{--}90\%$ RH), fresh garlic undergoes extensive biochemical transformations including increased concentrations of SAC, total polyphenols, flavonoids, and the formation of Amadori and Heyns compounds through Maillard reactions (Kimura *et al.*, 2017; Zhang *et al.*, 2016; Kang, 2016).

In contrast, the significant reduction ($p < 0.05$) in abdominal fat observed in the garlic-supplemented groups, particularly with black garlic powder (0.65% vs. 1.08% in controls), is a compelling finding. The hypocholesterolemic and hypolipidemic effects of garlic are well-documented and can be attributed to multiple mechanisms. The primary mechanism involves the inhibition of 3-hydroxy-3-methylglutaryl-CoA reductase (HMG-CoA reductase), the rate-limiting enzyme in cholesterol biosynthesis (Ried *et al.*, 2016; Sun *et al.*, 2018). Allicin, the principal bioactive compound in fresh garlic, binds to the sulfhydryl (-SH) group of coenzyme A, which is essential for cholesterol synthesis (Konjufca *et al.*, 1997; Corzo-Martínez *et al.*, 2007). This binding effectively reduces the availability of CoA for lipogenic processes, thereby decreasing cholesterol and fatty acid synthesis. Black garlic demonstrated superior fat-reducing effects compared to garlic powder in our study. This enhanced efficacy can be attributed to the thermal processing that black garlic undergoes. Research has demonstrated that black garlic supplementation significantly reduces body weight, abdominal fat weight, adipocyte diameter, and abdominal fat pad thickness in high-fat diet-induced animal models (Qiu *et al.*, 2020; Ha *et al.*, 2015). The mechanisms underlying these effects involve downregulation of lipogenesis-related genes, including proliferator-activated receptor γ (PPAR- γ), CCAAT/enhancer binding proteins (C/EBP), sterol regulatory element-binding protein-1c (SREBP-1c), acetyl-CoA carboxylase (ACC), and fatty acid synthase in adipocytes (Qiu *et al.*, 2020). Simultaneously, black garlic upregulates lipolysis-related enzymes such as hormone-sensitive lipase (HSL) and adipose triglyceride

lipase (Ha *et al.*, 2015).

The numerical reductions in serum cholesterol (7.6% with garlic powder) and meat cholesterol (2.3%) observed in this study, while not statistically significant in the current analysis, followed a biologically plausible trend supported by mechanistic research. The hypocholesterolemic properties of garlic are primarily mediated through the inhibition of endogenous cholesterol biosynthesis and possibly enhanced conversion to bile acids. Allicin and its derivatives are known to bind sulfhydryl groups on coenzyme A, impairing the activity of HMG-CoA reductase, the rate-limiting enzyme in cholesterol synthesis (Amagase *et al.*, 2001). Furthermore, studies in other models have shown that aged garlic extract rich in SAC can significantly reduce serum lipids. Ao *et al.* (2010) reported that supplementation with Weissella koreensis-fermented garlic powder lowered serum total cholesterol and triglycerides in broilers. The comparable cholesterol-lowering trend between our garlic and black garlic groups suggests that both forms are effective, though the fermentation process in black garlic may offer more stable and bioavailable compounds.

Meat cholesterol content showed a modest downward trend with garlic powder feeding, with the lowest concentration observed in birds given garlic powder (11.58 mg%) compared to 11.91 mg% in control, representing approximately a 2.3% reduction. Although this reduction appears numerically small, it has practical significance for producing healthier poultry meat for human consumption. More pronounced effects were observed in serum cholesterol levels. Broilers fed diets supplemented with 3% garlic powder (T1) exhibited the lowest serum cholesterol level at $116.22 \text{ mg dL}^{-1}$, representing a 7.6% reduction relative to the control ($125.67 \text{ mg dL}^{-1}$). Similarly, broilers fed black garlic powder (T2) showed a comparable serum cholesterol level ($117.86 \text{ mg dL}^{-1}$).

These findings corroborate extensive research demonstrating garlic's cholesterol-lowering effects in poultry (Utami *et al.*, 2018; Pourali *et al.*, 2010; Konjufca *et al.*, 1997). The hypocholesterolemic action of garlic operates through multiple pathways beyond HMG-CoA reductase inhibition. Garlic supplementation has been shown to decrease hepatic cholesterol 7α -hydroxylase activity, which is involved in the conversion of cholesterol to bile acids (Sun *et al.*, 2018; Corzo-Martínez *et al.*, 2007). Additionally, garlic enhances bile acid excretion and increases the activity of cholesteryl ester transfer protein, facilitating reverse cholesterol transport from peripheral tissues to the liver.

The reduction in serum cholesterol was accompanied by favorable changes in lipoprotein profiles. Studies have consistently reported that garlic supplementation decreases low-density lipoprotein (LDL) and very low-density lipoprotein (VLDL) levels while increasing high-density lipoprotein (HDL) concentrations (Ried *et al.*, 2016; Pourali *et al.*, 2010). The decrease in LDL can be explained by accelerated LDL catabolism and increased cellular cholesterol uptake, which inhibits intracellular cholesterol synthesis through feedback mechanisms.

Interestingly, the impact of garlic on performance parameters appears to be inconsistent across studies, which may explain why this study did not find significant improvements in metrics like feed conversion ratio. Tanti *et al.* (2022) reported that various garlic processing methods (fresh, powder, black garlic) did not significantly affect final body weight or FCR in broilers, attributing this to the potential loss of volatile essential oils during processing. Conversely, other studies have shown positive effects. Hossain (2020) found that fermented garlic supplementation improved body weight gain and FCR in broilers. This discrepancy may be related to factors such as dosage, basal diet composition, bird age, and environmental conditions. In our study, the lack of a performance effect, coupled with clear lipid-modulating benefits, underscores that garlic's primary value as a feed additive may lie in enhancing meat quality and metabolic health rather than acting as a direct growth promoter.

The health of the gastrointestinal tract is fundamental to nutrient absorption and overall metabolism. Our findings are supported by research on intestinal morphology. Lee *et al.* (2016) demonstrated that dietary fermented garlic improved jejunal morphology in broilers by reducing

crypt depth and increasing the villus height-to-crypt depth ratio, indicating enhanced digestive and absorptive capacity. This morphological improvement can lead to better nutrient utilization, which may indirectly support the more efficient energy metabolism and reduced fat deposition observed in our study. Furthermore, garlic's antimicrobial properties help maintain a healthy gut microbiota by reducing pathogenic bacterial loads, which can decrease intestinal inflammation and improve barrier function (Ibrahim *et al.*, 2021). A healthier gut environment ensures optimal nutrient partitioning towards growth and maintenance rather than fat storage or immune activation.

From a practical poultry production perspective, the reduction in abdominal fat is particularly valuable. Excess abdominal fat is often trimmed during processing, representing a loss in carcass yield and economic efficiency. Moreover, consumers increasingly demand leaner, healthier meat with lower cholesterol content. The use of garlic and black garlic as natural feed additives aligns with the global trend of reducing reliance on antibiotic growth promoters and synthetic additives. Our results suggest that supplementing broiler diets with 3% black garlic powder can produce carcasses with significantly less waste fat and a tendency toward healthier lipid profiles, meeting both industry and consumer demands without sacrificing yield.

Conclusion

Supplementing broiler diets with 3% black garlic powder, significantly reduced abdominal fat and decreased serum and meat cholesterol levels without negatively affecting carcass yield. These findings confirm that black garlic is an effective natural feed additive for improving meat quality and promoting healthier lipid profiles in broilers.

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Conflict of interest

The authors have no conflict of interest to declare.

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