



Research Article

Effects of *Turbinaria murayana* Alginate Oligosaccharides as Feed Additives on Broiler Lipid Profiles

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ABSTRACT

This study aimed to evaluate the effect of *Turbinaria murayana* alginate oligosaccharides on the blood lipid profile of broiler chickens, including total cholesterol, triglycerides, LDL, and HDL. A total of 180 seven-day-old Cobb CP 707 broiler chickens were used in this experiment. The study was conducted using a completely randomised design consisting of five treatments: *Turbinaria murayana* alginate oligosaccharides at 0, 100, 200, and 300 mg/L, and 45 mg/L tetracycline as a positive control, administered through drinking water. Each treatment was replicated four times, and the study lasted 4 weeks. The observed variables were serum total cholesterol, triglycerides, LDL, and HDL. Statistical analysis showed that administering *Turbinaria murayana* alginate oligosaccharides via drinking water had a highly significant effect ($P < 0.01$) on total cholesterol, triglycerides, and LDL, but no significant effect ($P > 0.05$) on HDL. Administration with 200 mg/L of *Turbinaria murayana* alginate oligosaccharides reduced serum total cholesterol, triglycerides, and LDL at 67.50 mg/dL, 21.88 mg/dL, and 60.18 mg/dL, respectively, while maintaining HDL concentrations. These findings suggest that alginate oligosaccharides derived from *Turbinaria murayana* may serve as functional natural feed additive for improving lipid metabolism in broilers.

Keywords: Alginate oligosaccharides, broiler, lipid profile, feed additive, *turbinaria murayana*

INTRODUCTION

Broiler chickens are among the most important poultry commodities, contributing to the supply of animal protein for human consumption. One of the commonly used broiler strains is Cobb CP 707, characterised by a rapid growth rate, a low feed conversion ratio (FCR), and a higher proportion of breast meat (Umaternate et al., 2023). However, as public awareness of health increases, poultry meat products are expected not only to exhibit high productivity but also to be healthier for consumption, particularly in terms of fat and cholesterol content. Elevated lipid levels in the body, especially total cholesterol, triglycerides, and low-density lipoprotein (LDL), are closely associated with various human health disorders and may negatively influence consumer acceptance. Therefore, the development of broiler meat with lower fat and cholesterol content has become an important concern in poultry nutrition research.

In recent years, the use of natural feed additives has gained considerable attention to improve lipid metabolism in poultry. Brown seaweed *Turbinaria murayana* has been reported to possess potential as a feed additive due to its alginate content, which exhibits hypolipidemic, antioxidant, anti-inflammatory, and antimicrobial activities (Reski et al., 2025, Liu et al., 2021). Previous studies demonstrated that alginate can reduce blood cholesterol levels in rats (Pratiwi et al., 2016). Similarly, alginate extract supplementation derived from *Sargassum crassifolium* on rats demonstrated a reduction in blood cholesterol levels due to the fiber content of alginate, which enhances bile acid excretion through faeces. According to Idota et al. (2016), the cholesterol-lowering mechanism of alginate involves the formation of complexes between calcium alginate and bile salts in the digestive tract, thereby inhibiting the absorption of fat and cholesterol and promoting their excretion via faeces.

Alginate derivatives, known as alginate oligosaccharides (AOS) possess better solubility and higher biological activity than alginate in its polymeric form, particularly in reducing fat and cholesterol levels (Afni et al., 2017). AOS can be produced through chemical or enzymatic degradation of alginate polymers. Subaryono (2017) stated that enzymatic degradation using alginate lyase is superior to chemical degradation because it produces more structurally uniform AOS. Song et al. (2025) reported that after oral administration, only a small portion of AOS is absorbed and distributed into tissues such as the liver and brain, while the majority is fermented by intestinal microbiota (Nishikawa et al., 2008; Lu et al., 2022). Zhu La et al. (2023) demonstrated that supplementation of 200 mg/kg AOS in broiler diets improved feed intake, growth performance, increased lactic acid bacteria populations, and reduced *Escherichia coli* populations in the intestine and cecum.

AOS derived from brown seaweed has been reported to exhibit significant biological activity in reducing hyperlipidemia (Paxman et al., 2008). The mechanisms by which AOS lowers blood lipid levels may occur through several pathways. First, AOS can form a gel in the stomach, thereby delaying gastric emptying and slowing the intestinal absorption of fats and cholesterol (Yao et al., 2023). Second, AOS can interact with fat and cholesterol molecules to form complexes that are poorly absorbed in the intestine and are subsequently excreted in the faeces (Paxman et al., 2008). Third, AOS may form a protective layer on the intestinal mucosa, thereby inhibiting the absorption of fat into the bloodstream (Aguero et al., 2017). In addition, AOS possesses antibacterial, antioxidant, and antitumor activities (Liu et al., 2021). Hu et al. (2005) reported that AOS inhibited the growth of *Escherichia coli* and *Salmonella paratyphi A* *in vitro*.

Furthermore, AOS has been shown to influence lipid metabolism by modulating intestinal microbiota and suppressing lipogenesis-related gene expression (Wang et al., 2020). Wang et al. (2020) explained that AOS can increase LDL receptor expression in the liver, thereby enhancing LDL uptake from the bloodstream and reducing serum LDL levels. AOS also promotes the growth of beneficial bacteria, such as *Akkermansia muciniphila*, *Lactobacillus reuteri*, and *Lactobacillus gasseri*, thereby increasing the production of short-chain fatty acids, including acetate, propionate, and butyrate, which positively affect lipid metabolism and inflammation control (Wang et al., 2020; Wu et al., 2023). *Lactobacillus* bacteria are known to effectively reduce serum total cholesterol, triglycerides, LDL cholesterol, and liver cholesterol, while increasing faecal cholesterol excretion (Wang et al., 2012). Tabuchi et al. (2004) reported that *Lactobacillus* can bind bile acids in the small intestine, thereby enhancing bile acid excretion in faeces. Increased bile acid excretion stimulates the utilisation of blood cholesterol for the synthesis of new bile acids in the liver, which may subsequently reduce blood cholesterol levels.

Based on the above findings, *Turbinaria murayana* has considerable potential as a source of alginate that can be degraded into alginate oligosaccharides (AOS) and utilised as a natural feed additive to improve broiler blood lipid profiles. However, to date, limited information is available regarding the use of AOS derived from *Turbinaria murayana* in broiler chickens, particularly when administered through drinking water, and its effects on broiler serum lipid profiles. Therefore, this study was conducted to evaluate the effects of *Turbinaria murayana* alginate oligosaccharides administered through drinking water on total serum cholesterol, triglycerides, LDL, and HDL levels in broiler chickens.

MATERIAL AND METHODS

Materials

The experimental animals used in this study were 180 eight-day-old Cobb CP 707 broiler chickens obtained from CV. Dunia Unggas, Padang City, West Sumatra, without sex separation. The average body weight of the broilers at the beginning of the treatment period was 214.14 ± 10.48 g/bird. The feed ingredients used were commercial feed Vivo 311, ground yellow corn, soybean meal, fish meal, rice bran, bone meal, coconut oil, top mix, and *Turbinaria murayana* alginate oligosaccharides, as specified for each treatment.

Methods

The study was conducted using a completely randomised design consisting of five treatments and four replications. Each replication consisted of nine broiler chickens, giving a total of 36 birds per treatment. The treatments consisted of different doses of *Turbinaria murayana* alginate oligosaccharides administered via broiler drinking water. The treatments were as follows: 0 mg/L (negative control), 100, 200, and 300 mg/L *Turbinaria murayana* alginate oligosaccharides, and 45 mg/L tetracycline as a positive control. The variables observed in this study were serum total cholesterol, triglycerides, LDL, and HDL levels in broiler chickens.

Research Implementation

The study began with the preparation of alginate oligosaccharides derived from the seaweed *Turbinaria murayana*. Alginate was first extracted from *T. murayana* and subsequently hydrolysed with an alginate lyase enzyme to produce alginate oligosaccharides, which were administered to broiler chickens via drinking water at different doses. Drinking water was provided *ad libitum* for each treatment using 1-L manual drinkers connected to nipples. The treatments were administered daily via drinking water at 0, 100, 200, and 300 mg/L of *Turbinaria murayana* alginate oligosaccharides (AOSTm), while 45 mg/L tetracycline served as a positive control for antibiotic growth promotion. Daily water consumption was measured by subtracting the remaining water from the total amount provided.

Parameter measurements were conducted at the end of the four-week treatment period, when the broilers were five weeks old. Blood samples were collected from broilers in each treatment group during slaughter by cutting the jugular vein and carotid artery at the base of the jaw using a sharp knife. The blood was allowed to flow and was collected into 3-mL Vacutainer tubes without EDTA. The blood-containing vacutainers were then placed in a cooler box and transported to the Animal Biotechnology Laboratory at the Faculty of Animal Science, Universitas Andalas, for serum separation. Serum was separated using a Universal 320 Hettich centrifuge at 3,800 rpm for 10 min. The yellowish blood serum was then separated from the red blood cells at

the bottom of the tube. The serum samples were transferred into Eppendorf tubes and transported to the Biochemistry Laboratory, Faculty of Medicine, Universitas Andalas, for analysis of total cholesterol, LDL, HDL, and triglycerides.

Data Analysis

The data obtained in this study were statistically analysed using analysis of variance (ANOVA). When the treatment effect was significant, mean comparisons among treatments were further performed using Duncan's Multiple Range Test, following Steel and Torrie (1991). Statistical significance was declared at $P < 0.01$, and the results were presented as means with standard error.

RESULTS AND DISCUSSION

The results of administering different doses of AOSTm through broiler drinking water on total cholesterol, triglycerides, LDL, and HDL levels are presented in Table 1.

Table 1. Mean total cholesterol, triglyceride, LDL, and HDL levels in the serum of broiler chickens supplemented with different doses of AOSTm

Treatment	Total Cholesterol (mg/dL)	Triglycerides (mg/dL)	LDL (mg/dL)	HDL (mg/dL)
0 mg/L AOSTm	106.43 ^a	28.85 ^{ab}	72.08a	25.23
100 mg/L AOSTm	79.23 ^c	25.43 ^{bc}	64.00bc	29.88
200 mg/L AOSTm	67.50 ^d	21.88 ^{cd}	60.18cd	32.08
300 mg/L AOSTm	63.80 ^d	18.30 ^d	56.20de	33.38
45 mg/L Tetracyclin	94.60 ^b	31.33 ^a	66.08b	31.78
SE	2.00	1.25	1.84	2.83

Note: Different superscripts within the same row indicate highly significant differences ($P < 0.01$); SE = standard error.

Effect of Treatments on Total Serum Cholesterol of Broiler Chicken

The mean total serum cholesterol levels of broilers in each treatment ranged from 63.80 to 106.43 mg/dL. Analysis of variance showed that administering AOSTm via drinking water had a highly significant effect ($P < 0.01$) on total serum cholesterol levels in broiler chickens.

Table 1 shows that increasing the level of AOSTm supplementation in broiler drinking water progressively reduced total serum cholesterol levels, and the reduction was greater than that observed with tetracycline antibiotic treatment. The ability of AOSTm to reduce serum cholesterol levels in this study may be attributed to its role in improving lipid metabolism by modulating the intestinal microbiota and stimulating beneficial bacteria such as *Akkermansia muciniphila*, *Lactobacillus reuteri*, and *Lactobacillus gasseri*. This modulation enhances the production of short-chain fatty acids, including acetate (C2), propionate (C3), and butyrate (C4), which are known to exert positive effects on lipid metabolism and inflammation control (Wang et al., 2020; Wu et al., 2023). Previous studies reported that *Lactobacillus* species effectively reduce serum total cholesterol, triglycerides, LDL cholesterol, and liver cholesterol while simultaneously increasing faecal cholesterol excretion (Wang et al., 2012). This effect is associated with the probiotic activity of *Lactobacillus*, which can bind bile acids in the small intestine and stimulate bile acid excretion through faeces (Tabuchi et al., 2004). Increased bile acid excretion reduces the amount of bile acids reabsorbed in the intestine and returned to the liver through enterohepatic circulation. In addition, AOS can also conjugate with bile acids in the small intestine and subsequently be excreted through faeces. Therefore, as bile acid excretion increases, the liver may utilise more

circulating cholesterol for the synthesis of new bile acids, resulting in reduced serum cholesterol concentration.

In the present study, AOSTm also demonstrated a greater ability to reduce total serum cholesterol levels in broilers compared with supplementation with 45 mg/L tetracycline. The mechanism of action of tetracycline primarily inhibits the growth of pathogenic bacteria in the intestine (Yaqoob et al., 2022). In contrast, AOSTm offers additional advantages by enhancing lipid metabolism through the modulation of beneficial intestinal microbiota, such as *Akkermansia muciniphila*, *Lactobacillus reuteri*, and *Lactobacillus gasseri*, which are associated with cholesterol-lowering effects (Wang et al., 2020; Wu et al., 2023).

Previous studies also reported that supplementation with 200 mg/kg AOS in broiler diets improved feed intake and growth performance, increased lactic acid bacteria populations, and reduced *Escherichia coli* populations in the intestine and cecum (Zhu La et al., 2023). AOS modulates the intestinal microbiota of chickens by promoting the growth of short-chain fatty acid (SCFA)-producing bacteria and increasing SCFA concentrations in the gut. Increased SCFA production lowers intestinal pH, thereby suppressing the growth of pathogenic bacteria. In addition, SCFAs can enhance bile acid binding, thereby reducing bile salt availability in the small intestine. Consequently, the liver becomes more active in synthesising new bile acids to replace those lost in the intestine, utilising cholesterol from the bloodstream in the process (Tabuchi et al., 2004). This mechanism may explain why AOSTm was more effective than tetracycline antibiotic in reducing serum cholesterol levels in broiler chickens. However, since gut microbiota and faecal bile acid excretion were not measured in this present study, these mechanisms should be interpreted as a possible explanation rather than direct evidence from this experiment.

Effect of Treatments on Serum Triglycerides of Broiler Chickens

The mean serum triglyceride levels of broilers ranged from 18.30 to 31.33 mg/dL. Statistical analysis showed that the administration of AOSTm through broiler drinking water had a highly significant effect ($P < 0.01$) on reducing serum triglyceride levels in broiler chickens.

In this study, administration of AOSTm via drinking water at 200 and 300 mg/L reduced serum triglyceride levels, with greater reductions than those observed in the tetracycline antibiotic and negative control (0 mg/L AOSTm) treatments. The decrease in serum triglycerides may be associated with the ability of alginate oligosaccharides to enhance lipoprotein lipase (LPL) activity, a key enzyme in lipid metabolism. LPL hydrolyses triglycerides in very low-density lipoprotein (VLDL), producing free fatty acids and glycerol, which are subsequently utilised by body cells as energy sources (Mead et al., 2002). The reduction of triglycerides observed in this present study is consistent with the reduction in total cholesterol in broilers treated with 200 and 300 mg/L AOSTm., suggesting that AOSTm. may influence overall lipid metabolism in broiler chickens. Likewise, Astawan et al. (2005) reported that a decrease in blood cholesterol levels is also associated with a reduction in blood triglyceride levels, because cholesterol and triglycerides are absorbed together as micelles and chylomicrons.

Furthermore, the administration of AOSTm at 100 and 200 mg/L showed similar effects in reducing serum triglyceride levels, indicating that both doses had comparable ability to lower triglycerides in broiler blood. However, increasing the AOSTm dose to 300 mg/L resulted in a greater reduction in serum triglyceride levels, suggesting that this dose was more effective than 100 or 200 mg/L. Similarly, Refera (2025) reported that serum triglyceride levels in broilers decreased after the inclusion of 5% TRLPaF in the diet. Increasing TRLPaF levels to 10 and 15%

produced a similar triglyceride-lowering effect to that observed at 5% inclusion. The concentrations of alginate bioactive compounds in TRLPaF at 0, 5, 10, and 15% dietary inclusion were 0.00, 1.85, 3.70, and 5.55%, respectively, indicating comparable effectiveness in reducing serum triglyceride levels in broiler chickens.

Effect of Treatments on Serum LDL Levels of Broiler Chickens

The mean serum LDL levels of broilers ranged from 56.20 to 72.08 mg/dL. Statistical analysis showed that the administration of AOSTm through broiler drinking water had a highly significant effect ($P < 0.01$) on reducing serum LDL levels in broiler chickens. Increasing the dose of AOSTm in broiler drinking water reduced serum LDL levels.

Administration of AOSTm at 300 mg/L resulted in a greater reduction in LDL than at 100 or 200 mg/L, with a 22.03% decrease. This effect may be associated with higher AOSTm intake in broilers receiving the 300 mg/L treatment, due to increased water consumption. Alginate oligosaccharides have been reported to increase the expression of low-density lipoprotein receptors (LDLR) and enhance intracellular LDL uptake by hepatocytes, thereby reducing plasma LDL cholesterol levels (Yang et al., 2015). Refera (2025) reported that serum LDL levels in broilers did not show a significant reduction at 5% TRLPaF inclusion in the diet, whereas supplementation at 10% TRLPaF significantly reduced serum LDL levels. Increasing the inclusion level of TRLPaF in the diet was accompanied by higher concentrations of alginate and fucoidan. The alginate concentrations in broiler diets containing 0, 5, 10, and 15% TRLPaF were 0.00, 1.85, 3.70, and 5.55%, respectively.

Tetracycline antibiotic supplementation mainly affects intestinal health by inhibiting pathogenic bacteria and promoting the growth of beneficial bacteria in the broiler digestive tract. A healthier digestive system may improve nutrient absorption, thereby supporting broiler growth and metabolism. To date, there have been no reports indicating that tetracycline directly reduces serum LDL levels in broilers. However, beneficial bacteria such as *Akkermansia muciniphila*, *Lactobacillus reuteri*, and *Lactobacillus gasseri* are known to enhance the production of short-chain fatty acids, including acetate (C2), propionate (C3), and butyrate (C4), which positively influence lipid metabolism and inflammation control (Wang et al., 2020; Wu et al., 2023).

Lactobacillus species have also been reported to effectively reduce serum total cholesterol, triglycerides, LDL cholesterol, and liver cholesterol, while increasing faecal cholesterol excretion (Wang et al., 2012). This effect is related to the probiotic activity of *Lactobacillus*, which can bind bile acids in the small intestine and stimulate their excretion through faeces (Tabuchi et al., 2004). Increased bile acid excretion reduces the amount of bile acids reabsorbed in the intestine and returned to the liver through enterohepatic circulation, thereby promoting the utilisation of blood cholesterol for the synthesis of new bile acids.

Effect of Treatments on Serum HDL Levels of Broiler Chicken

Statistical analysis showed that the administration of AOSTm through broiler drinking water had no significant effect ($P > 0.05$) on serum HDL levels in broiler chickens. The mean serum HDL levels ranged from 25.23 to 33.38 mg/dL, with numerically higher values observed in AOSTm-supplemented groups compared with the control. These results indicate that supplementation with different levels of AOSTm in drinking water-maintained serum HDL levels comparable to those in the control treatment (0 mg/L AOSTm).

Maintaining HDL levels while reducing LDL and triglycerides is a favourable response because HDL plays an important role in reverse cholesterol transport to the liver (Erizon, 2020). HDL also transports LDL from peripheral tissues to the liver, thereby helping to remove atheromatous deposits from blood vessels, which are subsequently excreted through the bile duct (Maulida et al., 2018). Alginate oligosaccharides (AOS) have been reported to influence the expression of lipid metabolism-related genes, such as *Apoa1*, *Apoa4*, *Agpat1*, *DGAT*, *MGAT*, and *ABCG5*, which collectively enhance hepatic lipase activity, facilitate lipid metabolism, and reduce hepatic fat accumulation (Yang et al., 2021).

According to Mangaraj et al. (2015), Apolipoprotein A1 is the major structural and protein component of HDL, accounting for approximately 70% of HDL particles' total protein content. The results of the present study indicate that all AOSTm doses administered through drinking water (0, 100, 200, and 300 mg/L) did not affect Apolipoprotein A1 activity, resulting in similar serum HDL levels among all treatments. Previous studies reported that supplementation with unsaturated alginate oligosaccharides at 600 mg/mL, administered at 1 mL/100 mg body weight per day, significantly increased serum HDL levels in rats (Li et al., 2019).

CONCLUSION

The administration of AOSTm through broiler drinking water effectively reduced serum total cholesterol, triglycerides, and LDL levels without significantly affecting serum HDL levels in broiler chickens. Although the 300 mg/L treatment produced the lowest numerical values for most lipid parameters, the 200 mg/L treatment also showed a remarkable reduction in total cholesterol, triglycerides, and LDL. Therefore, 200 mg/L may be considered an effective supplementation level, considering the practicality of dosage and cost of application. However, future studies should include growth performance, carcass fat deposition, intestinal microbiota, and lipid metabolism-related gene expression to strengthen the biological interpretation.

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