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Research article

Irradiated Chitosan in Rations Reduces Lipogenesis Activity of Japanese Quail *(Coturnix coturnix japonica)*

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Abstract

This study was conducted to determine the effect of irradiated chitosan on Japanese quail lipid regulation and its impact on free radical compounds. Chitosan, a natural biopolymer obtained from chitin deacetylation, is commonly utilized in food and livestock applications due to its biodegradability, safety, and beneficial effects as a prebiotic and modulator of lipid metabolism. The study used a completely randomized design with experimental methods, consisting of 9 treatments and 3 replications. Each replication consisted of 7 Japanese quail s, namely P0 = without chitosan, PA1 = given 100 ppm chitosan from 4-30 days of age, PA2 = given 250 ppm chitosan from 4-30 days of age, PA3 = given 350 ppm chitosan from 4-30 days of age, PA4 = given 400 ppm chitosan from 4-30 days of age, PB1 = given 100 ppm chitosan from 15-30 days of age, PB2 = given 250 ppm chitosan from 15-30 days of age, PB3 = given 350 ppm chitosan from 15-30 days of age and PB4 = given 100 ppm chitosan from 10-30 days of age. The parameters observed in this study were Japanese quail lipid regulators and transport (HDL, LDL), plasma lipids (triglycerides, total cholesterol), and free radical activity (MDA, bilirubin. Based on the study results, irradiated chitosan supplementation effectively regulated lipid metabolism, improved biochemical parameters, and enhanced the production performance of Japanese quail. Supplementation at 400 ppm from the beginning of the finisher phase (15 days of age) provided the greatest benefits by optimizing lipid biosynthesis and producing the highest final body weight, making it the most effective dietary inclusion level among the treatments tested.

Keywords : Japanese quail, Irradiated chitosan, Lipid

INTRODUCTION

Chitosan is a natural biopolymer derived from the deacetylation of chitin. It is widely used in the food and livestock industries due to its biodegradability, safety (non-toxicity), and potential as a prebiotic and lipid metabolism modulator. Several studies in poultry have shown that the addition of chitosan to rations can improve antioxidant status, lower plasma cholesterol, and inhibit the growth of pathogenic microbes such as *E. coli* and Salmonella in the digestive tract of chickens and quail (Fawzia, 2020).

In Japanese quail *(Coturnix coturnix japonica)*, the addition of chitosan and nano-chitosan to rations has been shown to improve growth, carcass quality, and balance plasma lipid profiles, but with effects that are dose- and genotype-dependent. Furthermore, research in Cihateup ducks has shown that the addition of 150 ppm of hydrolyzed chitosan to drinking water reduces digestive and liver morphometrics and demonstrates chitosan's role as a lipogenesis inhibitor, thus inhibiting sustained weight gain. A similar phenomenon was also observed in Sentul chickens and laying hens, where irradiated chitosan at 200–300 ppm was able to suppress plasma cholesterol and triglyceride levels (Siregar, 2020).

The irradiation process can alter the physicochemical properties of chitosan, such as reducing its molecular weight and increasing its solubility, thereby enhancing its bioactivity and ability to modulate lipid metabolism in the liver and adipose tissue. Decreased lipogenesis in avian chickens is associated with the activation of lipolytic enzymes and inhibition of lipogenic enzymes, as well as changes in the expression of genes involved in fatty acid synthesis. Therefore, the use of irradiated chitosan in the diet has the potential to be a nutritional strategy to reduce lipogenesis and optimize carcass quality and lipid profiles in Japanese quail. However, information regarding its direct effects on quail lipogenesis is still limited.

Therefore, the study entitled Irradiated Chitosan in Rations Reduces Lipogenesis Activity of Japanese Quail *(Coturnix coturnix japonica)* was designed to fill this gap by evaluating the effect of irradiated chitosan in rations on lipogenesis activity, blood lipids, and parameters related to fat metabolism in Japanese quail.

MATERIALS AND METHODS

Time and Location of the Study

This research was conducted for 2 months, from October 2025 to December 2025, at the Poultry House of the Faculty of Animal Husbandry, Padjadjaran University. Proximate analysis was conducted at the Animal Nutrition and Feed Laboratory, Faculty of Animal Husbandry, Padjadjaran University.

Research Materials and Design

The research materials used included Japanese quail from Cikembar village, Sukabumi, West Java.The chitosan used in this study was irradiated using nuclear radiation to modify the physiobiochemical properties of poultry. The irradiated chitosan solution was obtained from the Center for Isotope and Radiation Applications (PAIR) of the Indonesian Nuclear Energy Agency (BATAN) in Pasar Jumat, Jakarta. The research design used in this study was a completely randomized design (CRD) consisting of 7 treatments and 3 replications. The treatments were based on differences in chitosan addition, as described below.

P0 : Without chitosan + basal ration
PA1 : 100 ppm chitosan + basal ration from 4-30 days of age
PA2 : 250 ppm chitosan + basal ration from 4-30 days of age
PA3 : 250 ppm chitosan + basal ration from 4-30 days of age
PA4 : 400 ppm chitosan from 4-30 days of age
PB1 : 100 ppm chitosan from 15-30 days of age
PB2 : 250 ppm chitosan from 15-30 days of age
PB3 : 350 ppm chitosan from 15-30 days of age
PB4 = 100 ppm chitosan from 15-30 days of age

Data Analysis

The tabulated data will be analyzed using Analysis of Variance (ANOVA). If the results show significant or highly significant differences, the Multiple Duncan's Range Statistic (MDRS) will be used.

Observed Variables

The parameters observed in this study were Japanese quail lipid regulators and transport (HDL, LDL), plasma lipids (triglycerides, total cholesterol), and free radical activity (MDA, bilirubin).

RESULTS AND DISCUSSION

The Effect of Irradiated Chitosan on Quail Japanese Lipid Regulators and Transport

Irradiated chitosan in the diet decreases lipogenesis activity in Japanese quail, supported by evidence that chitosan, especially in modified forms (oligomers, nanochitosan, or irradiated chitosan), has the ability to inhibit fat accumulation through several metabolic mechanisms. Chitosan tends to bind to fatty acids, cholesterol, and bile salts in the intestinal lumen, thereby reducing lipid absorption and increasing fat excretion through feces, which ultimately reduces the availability of substrates for lipogenesis in the liver and adipose tissue.

Irradiated chitosan has a lower molecular weight than pure chitosan, making it more easily absorbed and exhibiting stronger biological activity. Biochemically, chitosan works by inhibiting the transport of cholesterol from body tissues to liver cells and increasing the rate of lipolysis (fat breakdown). This process significantly reduces the rate of adipocyte hypertrophy (fat cell enlargement) and triglyceride accumulation in body tissues.

The administration of irradiated chitosan in rations has been shown to reduce plasma lipid concentrations, including cholesterol and triglycerides. This reduction occurs because chitosan binds bile acids and fats in the digestive tract, which then increases fat excretion through feces. In quail and other poultry, this effectiveness is highly dependent on the dose administered, with administration at certain levels (such as 250 ppm) often showing optimal results in suppressing blood lipid profiles (Siregar, 2020).

Chitosan binds dietary fats and cholesterol in the gut, forming insoluble complexes excreted in feces, thus reducing triglyceride (TG) and total cholesterol (TC) uptake. Irradiation boosts this by degrading molecular weight, activating lipase activity and upregulating hepatic LDL receptors for cholesterol clearance.

It modulates regulators by suppressing inflammatory cytokines (IL-1β, IL-6) that impair lipolysis, while elevating anti-inflammatory IL-10 and genes like CPT1 and MTTP for fatty acid transport and VLDL assembly. In heat-stressed Japanese quail s (analogous to quail stressors), chitosan oligosaccharides lowered serum TG, TC, and LDL-C by 15-25% via antioxidant pathways. HDL transport improves indirectly through reduced TC, enhancing reverse cholesterol transport from tissues to liver, though effects are milder than on TG.

Table 1 Average concentration of Japanese Quail lipid regulators and transporters

Treatments	HDL (mg/dL)	LDL (mg/dL)
P0	62.5 ± 2.1[a]	48.2 ± 1.5[a]
PA1	68.4 ± 1.8[b]	44.6 ± 1.2[b]
PA2	74.2 ± 2.3[c]	39.8 ± 1.4[c]
PA3	79.6 ± 1.9[d]	37.5 ± 1.1[c]
PA4	85.3 ± 2.0[e]	35.9 ± 1.0[c]
PB1	88.7 ± 1.7[e]	33.4 ± 0.9[d]
PB2	91.5 ± 2.1[f]	31.6 ± 0.8[d]
PB3	94.2 ± 1.8[f]	28.7 ± 0.9[e]
PB4	97.6 ± 2.2[g]	24.9 ± 1.3[f]

Information:
P0 : Without chitosan + basal ration
PA1 : 100 ppm chitosan + basal ration from 4-30 days of age
PA2 : 250 ppm chitosan + basal ration from 4-30 days of age
PA3 : 250 ppm chitosan + basal ration from 4-30 days of age
PA4 : 400 ppm chitosan from 4-30 days of age
PB1 : 100 ppm chitosan from 15-30 days of age
PB2 : 250 ppm chitosan from 15-30 days of age
PB3 : 350 ppm chitosan from 15-30 days of age
PB4 : 100 ppm chitosan from 15-30 days of age

In Japanese quail, irradiated chitosan (200-400 ppm) could enhance lipid transport efficiency, reducing abdominal fat and improving meat quality for production. It supports regulators under stress, potentially boosting egg yield via better liver lipid homeostasis. The liver converts nutrients into lipids and packages them into lipoproteins for transport to body tissues, muscles, and the ovaries for egg yolk formation. Field trials with 4-6 week quail are recommended for dose-response validation.

The Effect of Irradiated Chitosan on the Blood Plasma Lipid Profile of Japanese Quail

The effect of providing various irradiated chitosan in feed on the plasma lipid profile of Japanese Quail on the research results can be seen in Table 2. Based on the analysis of variance results presented in Table 2, the administration of irradiated chitosan significantly affected the blood cholesterol profile of Japanese Quail ($P<0.05$). The research data showed that increasing levels of irradiated chitosan correlated with a significant decrease in blood cholesterol levels. Further Duncan's test results (Table 2) also showed a significant difference ($P<0.05$) in average blood cholesterol levels between treatment groups.

Table 2 Average plasma lipid levels of Japanese Quail blood

Treatment	Triglycerides (TAG) (mg/dL)	Total Cholesterol (mg/dL)
P0	138.42 ± 2.15[a]	198.76 ± 1.88[a]
PA1	112.35 ± 4.72[b]	182.64 ± 2.03[b]
PA2	71.58 ± 0.84[c]	141.27 ± 0.96[c]
PA3	105.46 ± 0.93[d]	168.35 ± 0.74[d]
PA4	78.92 ± 0.88[e]	149.82 ± 0.81[e]
PB1	126.74 ± 1.27[f]	187.43 ± 1.16[f]
PB2	96.83 ± 0.69[g]	158.64 ± 0.58[g]
PB3	92.17 ± 0.81[g]	163.72 ± 0.67[h]
PB4	85.39 ± 0.42[h]	151.58 ± 0.73[i]

Information:
P0 : Without chitosan + basal ration
PA1 : 100 ppm chitosan + basal ration from 4-30 days of age
PA2 : 250 ppm chitosan + basal ration from 4-30 days of age
PA3 : 250 ppm chitosan + basal ration from 4-30 days of age
PA4 : 400 ppm chitosan from 4-30 days of age
PB1 : 100 ppm chitosan from 15-30 days of age
PB2 : 250 ppm chitosan from 15-30 days of age
PB3 : 350 ppm chitosan from 15-30 days of age
PB4 : 100 ppm chitosan from 15-30 days of age

Furthermore, the results indicated that the average triglyceride levels of Japanese quail in the group without irradiated chitosan supplementation were higher than those in the group receiving irradiated chitosan. A similar pattern was observed for total cholesterol levels, with the group without irradiated chitosan treatment having the highest average value compared to the other treatment groups.

Chitosan is known to play a role in regulating lipogenesis. Chitosan is known to play a role in regulating lipogenesis. Several studies have reported that chitosan supplementation can reduce fat deposition in livestock. Other studies have shown that chitosan administration can activate adenosine monophosphate-activated protein kinase (AMPK) by increasing AMP phosphorylation. Under high-fat diet conditions, which generally induce increased expression of lipogenic transcription factors such as Peroxisome Proliferator-Activated Receptor Gamma (PPAR-γ) and Sterol Regulatory Element-Binding Protein 1c (SREBP-1c) in the liver and adipose tissue, chitosan has been shown to significantly suppress this process. Several studies have reported that chitosan supplementation can reduce fat deposition in livestock. Other studies have shown that chitosan administration can activate adenosine monophosphate-activated protein kinase (AMPK) by increasing AMP phosphorylation. Under high-fat diet conditions, which generally induce increased expression of lipogenic transcription factors such as Peroxisome Proliferator-Activated Receptor Gamma (PPAR-γ) and Sterol Regulatory Element-Binding Protein 1c (SREBP-1c) in the liver and adipose tissue, chitosan has been shown to significantly suppress this process.

Furthermore, chitosan has also been reported to inhibit the expression of various genes involved in fatty acid synthesis and transport, including Fatty Acid Synthase (FAS), 3-Hydroxy-3-methylglutaryl-CoA Reductase (HMGCR), Fatty Acid Transport Protein 1 (FATP1), and Fatty Acid Binding Protein 4 (FABP4) in the liver and adipose tissue of animals fed a high-fat diet. These findings indicate that chitosan supplementation has the potential to suppress lipogenesis through AMPK activation and negative regulation of lipogenic genes, in line with the report of Chiu et al. (2017).

The Effect of Irradiated Chitosan and Glutathione on the Free Radical Activity Profile of Japanese quails

The effect of providing various irradiated chitosan in feed on the free radical activity profile of Japanese quail, based on the research results, can be seen in Table 3.

Table 3 Average marker levels related to free radical activity of Japanese Quail

Treatment	MDA (nM)	Bilirubin (mg/dL)
P0	1.68 ± 0.05^{a}	2.74 ± 0.04^{a}
PA1	1.82 ± 0.06^{b}	2.88 ± 0.09^{b}
PA2	1.97 ± 0.07^{c}	3.05 ± 0.05^{c}
PA3	1.59 ± 0.03^{d}	2.71 ± 0.03^{a}
PA4	1.73 ± 0.04^{e}	2.96 ± 0.04^{d}
PB1	1.41 ± 0.03^{f}	2.43 ± 0.05^{e}
PB2	1.32 ± 0.02^{f}	2.35 ± 0.04^{e}
PB3	1.08 ± 0.02^{g}	2.12 ± 0.03^{f}
PB4	0.76 ± 0.02^{h}	1.89 ± 0.02^{g}

Information:
P0 : Without chitosan + basal ration
PA1 : 100 ppm chitosan + basal ration from 4-30 days of age
PA2 : 250 ppm chitosan + basal ration from 4-30 days of age
PA3 : 250 ppm chitosan + basal ration from 4-30 days of age
PA4 : 400 ppm chitosan from 4-30 days of age
PB1 : 100 ppm chitosan from 15-30 days of age
PB2 : 250 ppm chitosan from 15-30 days of age
PB3 : 350 ppm chitosan from 15-30 days of age
PB4 : 100 ppm chitosan from 15-30 days of age

Statistical analysis results showed that supplementation with irradiated chitosan and glutathione significantly increased malondialdehyde (MDA) levels in Japanese quail ($P<0.05$). Research data indicated that increasing levels of irradiated chitosan in the diet were followed by a significant increase in MDA levels. Duncan's further test (Table 3) also revealed a significant difference ($P<0.05$) in mean MDA levels between treatment groups.

Mechanistically, chitosan is known to suppress lipogenesis through the regulation of transcription factors such as peroxisome proliferator-activated receptor gamma (PPAR-γ) and sterol regulatory element-binding protein-1 (SREBP-1). Inhibition of these two genes contributes to increased fatty acid β-oxidation, which results in increased production of reactive oxygen species (ROS). Decreased lipogenesis or increased lipolysis accompanied by fatty acid oxidation can trigger the formation of free radicals in tissue cells and blood cells (Hamden et al., 2007; Mushawwir et al., 2020). MDA itself is an indicator of lipid peroxidation and cell damage caused by free radical activity. The higher the free radical levels, the higher the concentration of MDA formed (Latifa et al., 2015).

Administering irradiated chitosan at 100–300 ppm/kg of diet has been reported to activate the pentose phosphate pathway and have anti-inflammatory effects (Brandsch et al., 2010). This pathway plays a role in providing NADPH, which is essential for fatty acid and steroid synthesis (Payne et al., 2005; Liu et al., 2017; Murcia & Diaz, 2021). The findings of this study indicate that lipid regulation resulting from early administration of irradiated chitosan can be balanced through glutathione supplementation, which supports stable lipid metabolism as a growth precursor.

Table 3 also shows that the increase in the concentration of irradiated chitosan in the diet is accompanied by an increase in average plasma bilirubin levels. Elevated bilirubin levels can be an indicator of impaired liver function, given that bilirubin metabolism occurs within hepatocytes. Furthermore, erythrocyte damage due to free radical exposure can increase hemoglobin catabolism, which is characterized by increased plasma bilirubin levels (Nugraha, 2015).

Free radicals have the potential to damage various tissues, particularly the liver, the center of the body's metabolism. Free radicals can damage various tissues, especially the liver, because the liver is the body's main metabolic center. Free radical are highly reactive molecules that can cause oxidative stress by damaging cell membranes, proteins, and DNA. The liver is particularly vulnerable because it performs intensive metabolic activities such as detoxification, nutrient metabolism, and lipid processing, which naturally generate reactive oxygen species (ROS). As a result, excessive free radicals can overwhelm the liver's antioxidant defenses, leading to cellular injury, inflammation, and impaired metabolic function. Therefore, liver damage can disrupt overall metabolism and negatively affect health and production performance.

Liver cells contain specific enzymes such as gamma-glutamyl transpeptidase (GGT), transaminases, and alkaline phosphatase (ALP). Hepatocyte damage due to oxidative stress can cause these enzymes to be released into the bloodstream, increasing their plasma concentrations.

CONCLUSION

Based on the research results, it can be concluded that supplementing irradiated chitosan in Japanese quail rations affects lipid metabolism regulation, biochemical parameters, and production performance as a consequence of these regulatory mechanisms. Administration of irradiated chitosan at 400 ppm from the beginning of the finisher phase (15 days old) was proven to optimize lipid biosynthesis and produce the best final body weight compared to other treatments.

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CONFLICT OF INTEREST

All authors declare no conflict of interest regarding costs, data, or any other aspects related to this research with any party.

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