



Effect of Moringa Leaves (*Moringa oleifera*) Oil Microcapsules (MOM) on Growth and Plasma Metabolites Related to Inflammation in Sentul Chickens

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Abstract | This study aims to investigate the effects of microencapsulated moringa leaf essential oil (MOM) on body weight gain, plasma metabolites, and liver inflammation in Sentul chickens. The microcapsules, which contain the natural active compounds of moringa leaf essential oil (*Moringa oleifera*), were prepared using a complex coacervation method with alginate coatings, a glutaraldehyde crosslinker, and a polysorbate emulsifier. The study utilized a completely randomized design. A total of 280 Sentul chickens were randomly assigned to four treatment groups with seven replicates each, where each replicate consisted of ten chickens. The treatments were administered when the chickens were two weeks old. The groups were as follows: T0 (basal feed as the control), T1 (basal feed + 150 mg/kg MOM), T2 (basal feed + 250 mg/kg MOM), and T3 (basal feed + 350 mg/kg MOM). The results indicated significant differences ($P < 0.05$) in body weight gain, as well as levels of glucose, triglycerides, cholesterol, total protein, albumin, globulin, SGOT, SGPT, and gamma GT among the treatment groups. In conclusion, the study found that moringa leaf essential oil (*Moringa oleifera*) can enhance body weight, glucose levels, total protein, albumin, globulin, and SGPT, while reducing triglycerides, cholesterol, SGOT, and gamma GT levels.

Keywords | Microencapsulation, Essential oil, Moringa, Sentul chicken, Growth, Metabolism

Received | October 22, 2024; **Accepted** | November 21, 2024; **Published** | March 18, 2025

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Citation | Aritonang HN, Adriani L, Mushawwir A (2025). Effect of moringa leaves (*Moringa oleifera*) oil microcapsules (MOM) on growth and plasma metabolites related to inflammation in sentul chickens. Adv. Anim. Vet. Sci. 13(4): 835-842.

DOI | <https://dx.doi.org/10.17582/journal.aavs/2025/13.4.835.842>

ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331



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INTRODUCTION

High growth rates, productivity, and immune responses are crucial in the chicken farming industry. The use of supplements and medications, such as antibiotics, can result in harmful chemical residues in the products and contribute to antibiotic resistance in harmful bacteria within the chickens (Founou *et al.*, 2016; Pazla *et al.*, 2023).

To enhance the productivity of Sentul chickens, it is essential to pay attention to their physiological conditions, which are closely linked to the metabolic processes within their bodies. The liver plays a crucial role in various functions, including glucose and lipid metabolism, digestion, fat and fat-soluble vitamin absorption, and detoxifying harmful substances. Damage to the liver can occur due to increased metabolic activity during the starter phase of Sentul chick-

ens, producing free radicals. These free radicals can cause cellular damage and apoptosis or necrosis, ultimately decreasing liver function. This impairment raises the risk of liver tissue damage, negatively impacting the immune response.

Moreover, the metabolic processes within the body require ATP (adenosine triphosphate) as an energy source, which is produced through oxidation-reduction reactions in the mitochondria. Therefore, maintaining optimal liver health is vital for the overall well-being and productivity of Sentul chickens. Damage and death of liver cells are indicated by an increased presence of transaminases, which are enzymes that transfer amine groups. Specifically, the levels of SGOT (Serum Glutamic Oxaloacetic Transaminase) and SGPT (Serum Glutamic Pyruvic Transaminase) rise in the bloodstream. As a result, the levels of SGPT and SGOT in blood plasma increase.

One feasible alternative is to use feed additives derived from herbal plants to protect livestock and consumers from antibiotic residues while ensuring a safe supply of protein and promoting sustainable animal production. These plants contain natural active compounds that can be beneficial (Uyanga *et al.*, 2022; Wanapat *et al.*, 2015).

Moringa leaves contain approximately 65% water, 28% carbohydrates (primarily fructans), 2.3% organosulfur compounds, 2% protein (specifically alkaloid), 1.2% free amino acids (such as arginine), and 1.5% fiber (Santhosha *et al.*, 2013). These leaves exhibit various health benefits, acting as antifungal, antiviral, antibacterial, anticancer, anthelmintic, antihypertensive, antiatherosclerosis, antiseptic, and anti-inflammatory agents (Bhatwalkar *et al.*, 2021).

Previous studies indicate that certain active substances in flavonoids possess antibacterial properties that can enhance digestive function by relaxing the small intestine and inhibiting harmful microorganisms within the digestive tract. The active compounds found in this natural extract can improve digestion by promoting the growth of beneficial intestinal flora, which may lead to increased body weight (Mushawwir *et al.*, 2021a).

Furthermore, some active substances derived from natural ingredients may serve as additives to boost immunity and improve blood profiles (Mushawwir *et al.*, 2018). They have also been shown to reduce cell death (Korivi *et al.*, 2012; Lee *et al.*, 2014). The active compounds in moringa leaves can decrease hemorrhage in liver tissue (Cortes-Coronado *et al.*, 2017), and their antioxidant content-particularly the diallyl component-helps mitigate oxidative stress, which can negatively impact the immune system.

The administration of active plant compounds in local chickens often yields ineffective results due to the instability

of these compounds. This instability is primarily caused by exposure to oxygen, high humidity, gastric HCl damage (in the proventriculus of poultry), and the degradation of monomers before absorption (Chawda *et al.*, 2017; Julaeha *et al.*, 2022).

One identified weakness in research involving Moringa leaves is the standard method of administration, which typically relies on extracts or flour. These methods do not ensure that the active compounds are effectively delivered to the target cells. To overcome this issue, coating technology using microbeads and microcapsules can be utilized. This technique encapsulates the core ingredients of herbal extracts within a polymer matrix, employing irradiated chitosan and alginate as wall materials. With this information in mind, this study aims to investigate the effects of feeding microencapsulated Moringa leaf essential oil as a substitute for antibiotics on body weight gain, blood plasma metabolite levels, and liver inflammation.

MATERIALS AND METHODS

The material used in this study was moringa leaves essential oil (*Moringa oleifera*). The dressing materials used were sodium alginate, glutaraldehyde crosslinker, and tween 80 emulsifier.

PREPARATION OF THE MICROCAPSULES

Preparation of microcapsules using the complex coacervation method involved the following steps. Moringa leaves were distilled at 100°C for 3 hours. A gelatin solution was prepared by stirring 140 mL of distilled water at 60±1°C; then, 0.8 g of Tween-80 was added, followed by 3.5 g of essential oil extracted from the lime peel. In a separate container, 0.8 g of sodium alginate was dissolved in 40 mL of distilled water and stirred for 15 minutes at 60°C with a stirring rate of 600 rpm. Glacial acetic acid was added to adjust the pH to 3.75. The solution was cooled to 5-10°C, and 1.25 mmol of glutaraldehyde was slowly introduced. The temperature was then raised to 35°C, and the mixture was stirred using a magnetic stirrer for 3 to 4 hours. After mixing, the solution was allowed to cool to room temperature while continuing to stir. The resulting microcapsules were filtered and washed with water. Finally, they were dried to achieve a solid state and ground into a powdery consistency.

ANIMAL SAMPLE AND TREATMENTS

The study involved 280 Sentul chicken day-old chicks (DOCs) that were not sex-separated. These chicks were raised in semi-closed housing-type cages until they reached the developmental phase and were randomly selected for each experimental group. The research was conducted using a completely randomized design (CRD).

The chicks were divided into four treatment groups based on different essential oil feeding patterns, with each treatment placed in seven replicate cages. Each cage measured 2 × 1 meters and was equipped with feed and water containers and lamps for heating and lighting. Each experimental unit consisted of ten chickens.

At 14 days of age, the chicks were administered microcapsules of essential oil from moringa leaves (MOM) at varying concentrations. The treatment design was as follows: T0: Basal ration without MOM (control); T1: Basal ration + 150 mg/kg MOM; T2: Basal ration + 250 mg/kg MOM; and T3: Basal ration + 350 mg/kg MOM.

ANALYSIS OF BODY WEIGHT GAIN

The body weight of the Sentul was measured at the beginning of the study and every week after that until the end.

ANALYSIS OF BLOOD PLASMA METABOLITES IN SENTUL CHICKENS

Circulating metabolites can provide insights into cellular metabolic phenomena. The metabolites measured include glucose, triglycerides, cholesterol, total protein, and globulin levels. Plasma metabolites will be analyzed using the UV spectrophotometer technique, following the instructions and protocols outlined in the Biolabo Kit from France and the Randox S2DE Kit from the UK.

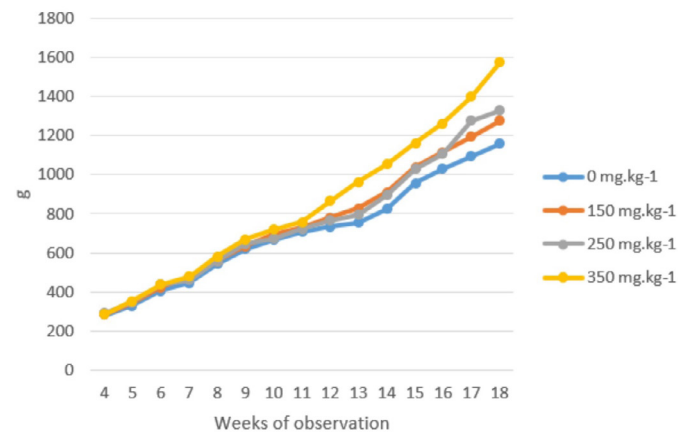


Figure 1: Effect of MOM on Body Weight Gain of Sentul Chicken from Starter Phase to Developer Phase.

LIVER INFLAMMATION ANALYSIS

SGOT, SGPT, and Gamma GT levels were analyzed using spectrophotometer techniques, following measurement procedures based on the Biolabo KIT analysis protocol.

STATISTICAL ANALYSIS

Data on body weight gain, blood plasma metabolite levels, and liver inflammation were analyzed using a completely randomized design with analysis of variance (ANOVA). Duncan's multiple range test was employed to explore

significant differences between treatment groups, with a significance level set at $P < 0.05$. The SAS program (SAS Institute Inc.) conducted the data analysis.

RESULTS AND DISCUSSION

EFFECT OF MOM ON BODY WEIGHT GAIN

The impact of MOM in the feed on the body weight gain of Sentul chickens during the starter-to-developer phase is illustrated in Figure 1.

The results indicate that higher levels of MOM administration from the starter phase to the developer phase significantly affect the weight gain of Sentul chickens ($P < 0.05$). Duncan's multiple range test (Figure 1) further shows that the average body weight gain of Sentul chickens significantly differed among the treatment groups ($P < 0.05$).

Moringa leaves contain active compounds, specifically flavonoids, which enhance the height of intestinal villi and the depth of intestinal crypts. This development expands the nutrient absorption area and improves digestion. The growth of intestinal villi is beneficial for both intestinal function and the overall growth of Sentul chickens (Qaisrani *et al.*, 2015; Rahman *et al.*, 2021). Scordinin, a compound found in Moringa leaves, also aids in accelerating and enhancing body cell formation, contributing to optimal final weight (Dahlan and Haqiqi, 2012). Trisnadi (2014) suggests that scordinin acts as a growth promoter by facilitating the binding and breakdown of proteins within the body.

Peinado *et al.* (2013) discovered that compounds in Moringa leaves can increase nutrient digestibility and enhance the activity of intestinal mucosal enzymes in Cobb strain broilers. The essential oils in Moringa leaves, including scordinin, also offer strength and promote growth.

Moringa leaves also contain mitogenic gurwich rays, which stimulate body cell growth while rejuvenating various bodily functions (Syamsiah and Tajudin, 2004). Scordinin promotes muscle growth, while allicin inhibits the formation of fatty tissue. This leads to increased weight gain attributed to muscle mass rather than fat accumulation (Hidayati, 2005; Mushawwir *et al.*, 2022). Figure 2.

EFFECT OF MOM ON BLOOD PLASMA METABOLITE LEVELS OF SENTUL CHICKEN

The study summarizes the effect of incorporating MOM in the feed on the blood plasma metabolites of Sentul chickens in Table 1.

Based on the study's findings, it is clear that higher concentrations of Moringa oleifera leaves (MOM) lead to

an increase in glucose levels. Results from Duncan's difference test (Table 1) indicated that the average glucose levels in Sentul chickens were significantly different ($P < 0.05$) across the treatment groups. Moringa leaves possess antioxidant and antibacterial properties that can reduce oxidative stress, contributing to better regulation of blood glucose levels. This regulation is crucial for improving glucose metabolism in Sentul chickens.

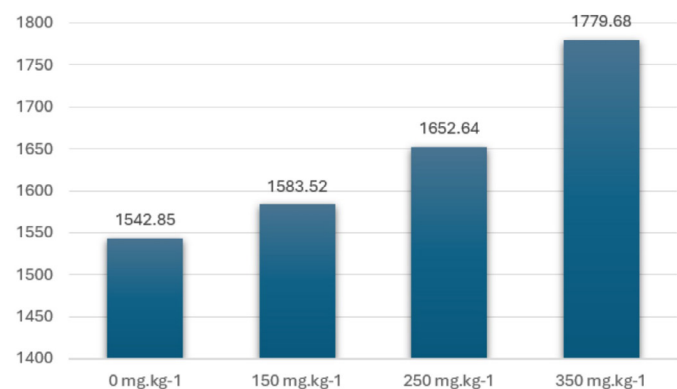


Figure 2: Effect of MOM on body weight of Sentul chicken in the Developer Phase.

Table 1: The average blood plasma metabolite levels (mg/dL) of Sentul chicken fed with MOM.

Treat-ment	Glucose	Triglyc-eride	Choles-terol	Total Protein	Albu-men	Globulin
T0	185.98 ^a	927.42 ^a	117.23 ^a	6.31 ^a	1.69 ^a	4.31 ^a
T1	195.87 ^a	794.23 ^b	109.45 ^b	8.53 ^b	1.83 ^b	6.74 ^{ab}
T2	199.76 ^a	753.11 ^c	83.64 ^c	8.63 ^b	2.74 ^c	6.63 ^{ab}
T3	192.79 ^a	578.05 ^d	74.83 ^d	8.86 ^{bc}	2.78 ^c	6.37 ^{bc}

Mean followed by superscript of different alphabetical elements showed significant difference ($P < 0.05$).

Blood glucose levels are regulated by hormonal mechanisms, specifically hormones produced by the pancreas: insulin, secreted by beta cells, and glucagon, produced by alpha cells. Glucose is synthesized into glycogen through the process of gluconeogenesis, and this glycogen is stored in the liver and muscles. When blood glucose levels decrease, glycogen is converted back into glucose through glycogenolysis. The glucose then enters cells and undergoes phosphorylation to form glucose-6-phosphate, facilitated by the enzyme hexokinase. Glucose-6-phosphate subsequently undergoes glycolytic metabolism to produce pyruvate and ATP, which serve as energy sources (Prata, 2018).

The triglyceride profile showed a decrease as the concentration of MOM increased. This reduction in triglyceride levels suggests that the sulfur compounds found in moringa leaves, particularly allicin, inhibit enzymes involved in cholesterol and triglyceride synthesis in the liver, such as HMG-CoA reductase (Rahmania *et al.*, 2022). Consequently, there is a reduction in endogenous triglyceride

production. Additionally, moringa leaves can enhance the activity of lipoprotein lipase, an enzyme responsible for breaking down triglycerides in the bloodstream. This increased activity leads to a faster breakdown of triglycerides into free fatty acids, which can be used as energy sources.

The cholesterol profile improved as the concentration of microcapsules containing moringa leaf (*Moringa oleifera*) essential oil increased. This essential oil reduces cholesterol levels, serum triglycerides, very low-density lipoprotein (VLDL), and low-density lipoprotein (LDL) while increasing high-density lipoprotein (HDL). As a result, the ratio of LDL to HDL decreases, which is attributed to the presence of the active compound alkaloid. Alkaloids inhibit the enzyme 3-Hydroxy-3-methylglutaryl-CoA (HMG-CoA) reductase, which plays a crucial role in cholesterol biosynthesis. By inhibiting HMG-CoA reductase, cholesterol synthesis decreases, leading to an increase in the number of LDL receptors (Mushawwir *et al.*, 2021; Rahmania *et al.*, 2022; Firmansyah *et al.*, 2024).

The total protein profile increases with higher *Moringa oleifera* leaves (MOM) concentrations. Moringa leaves contain the active compound allicin, which has antimicrobial and anti-inflammatory properties. Allicin can combat infections caused by gram-negative and gram-positive bacteria and prevent damage to the small intestine (Tanuwiria *et al.*, 2023), thereby optimizing protein absorption from the intestine. The increase in total protein is also influenced by nutritional status (Kharazi *et al.*, 2022). Higher concentrations of moringa leaf powder in feed can reduce the levels of *Salmonella typhimurium* and improve feed conversion in broiler chickens (Mushawwir *et al.*, 2024), leading to enhanced protein intake and increased plasma protein levels.

Additionally, moringa leaves contain active compounds that stimulate the growth of body cells and rejuvenate overall bodily functions, including those of the liver. Since most plasma proteins are synthesized in the liver, optimal liver function contributes to increased plasma protein levels.

The albumin profile increased as the concentration of microencapsulated essential oil from *Moringa oleifera* increased, compared to the control group that received no treatment. The sulfur compounds present in moringa leaves—such as allicin, ajoene, S-allyl cysteine (SAC), alkaloid, S-methyl cysteine sulfoxide, and S-allyl cysteine sulfoxide—have therapeutic benefits. Previous studies indicate that diallyl disulfide inhibits the enzyme HMG CoA reductase in microsomes and reduces hepatocyte cholesterol levels. Furthermore, the administration of essential oils can suppress the inflammatory response related to dietary albumin, increasing the plasma albumin profile (Nurfauzi-ah *et al.*, 2024).

Similarly, the globulin profile also increased with higher concentrations of microencapsulated essential oil from moringa leaves compared to the control group. The essential oil derived from moringa leaves is known for its immune-boosting properties. Incorporating moringa leaf powder into the feed has enhanced gamma globulin levels in broiler chickens (Tanuwiria and Mushawwir, 2020; Manin *et al.*, 2024). This effect is believed to arise from the increased activity of lymphoid cells, which produce globulin and support immune strength as a defense mechanism. The active compound scordinin influences immune function and has phagocytic properties. Moringa leaves act as immunomodulators by promoting the production of T lymphocytes (Adriani *et al.*, 2024). As lymphocyte activity increases, so do the concentrations of various components associated with the immune system, including globulins. Helper T cells play a crucial role in regulating immune functions by producing protein mediators known as lymphokines (Tanuwiria *et al.*, 2022).

EFFECT OF MOM ON LIVER INFLAMMATION OF SENTUL CHICKEN

The impact of MOM in feed on the liver inflammation of Sentul chickens is shown in Table 2. The results of Duncan's difference test (Table 2) showed that the average SGOT and SGPT levels of Sentul chickens were significantly different ($P < 0.05$) across each treatment group. The findings indicated that higher levels of *Moringa oleifera* extract (MOM) administration decreased SGOT and SGPT profiles. MOM contains active compounds that possess antioxidant and anti-inflammatory properties, which can reduce liver inflammation, subsequently lowering SGOT and SGPT levels.

Table 2: The Effect of MOM on Sentul Chicken Liver Inflammation.

Treatment	Inflammatory Biomarkers (IU/L)		
	SGOT	SGPT	Gamma GT
T0	182.39 ^a	40.33 ^a	17.45 ^a
T1	123.43 ^a	33.41 ^b	11.11 ^b
T2	83.18 ^b	23.17 ^c	7.28 ^c
T3	52.28 ^a	16.26 ^d	5.51 ^d

^{a,b}Averages followed by different notations in the same column indicate significant differences ($P < 0.05$).

Previous research on natural extracts has demonstrated that MOM positively impacts kidney histology (Ansar *et al.*, 2014; Eyng *et al.*, 2015; Kharazi *et al.*, 2022; Setiawan *et al.*, 2024). Specifically, it reduces damage to kidney cells and tissues and decreases cell death caused by free radicals, thereby lowering necrosis and apoptosis (cell death) rates while improving immune function. According to Mushawwir *et al.* (2017), increasing essential oil concentration can

enhance nutrient absorption and utilization, reduce SGOT and SGPT levels, and improve liver cell function. Other studies have also indicated that the administration of active ingredients, such as essential oils, is linked to reduced cellular inflammation (Sirovina *et al.*, 2013; Muhammad *et al.*, 2023; Chatterjee *et al.*, 2015; Dudi *et al.*, 2023). This results in decreased oxidative stress, improved tissue metabolism, and reduced apoptosis or cell death (Figure 3), and these results, similar to previous research reports (Rahmania *et al.*, 2022; Mushawwir *et al.*, 2024).

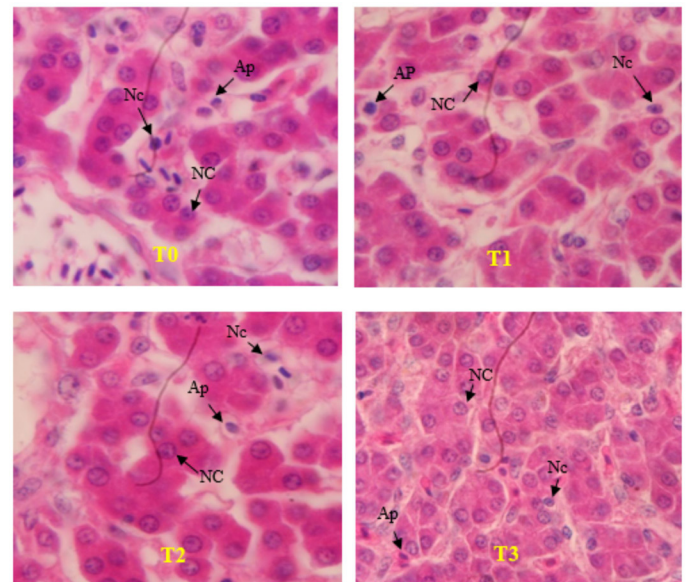


Figure 3: Liver Histology of Sentul Chicken without and with MOM treatment. NC: Normal Cells, Ap: Apoptosis, Nc: Necrosis. Object magnification 100x.

Data analysis in Table 2 revealed that the levels of gamma-glutamyl transpeptidase (γ -GT) in the blood plasma of treated Sentul chickens decreased compared to the control group (untreated). This finding indicates a positive correlation with the administration of MOM. Significant differences were also observed in the average levels of gamma-glutamyl transpeptidase (γ -GT) ($P < 0.05$) among the treated groups, as presented in Table 2.

In this experiment, MOM was able to reduce the death of Sentul chicken liver cells, both apoptosis and necrosis (Table 3 and Figure 3). Table 3 also shows an increase in normal cells and a decrease in the number of cell deaths (apoptosis and necrosis) as the level of MOM in the diet increased. This means that the administration of MOM can reduce damage to liver cells and prevent the migration of SGOT, SGPT, and Gamma-glutamyl transpeptidase into the blood plasma.

Gamma-glutamyl transpeptidase (γ -GT) plays a crucial role in glutathione metabolism and detoxification. Elevated levels of γ -GT in the blood often indicate stress and liver damage in livestock. Liver function impairment can

result from various factors, including free radicals in the body, which increase with rising environmental temperatures (Mushawwir and Latipudin, 2013; Mushawwir *et al.*, 2021a, b; 2023; 2024). When free radical production surpasses the body's antioxidant capacity, oxidative stress, apoptosis, or necrosis can occur in cells, including hepatocytes.

Table 3: Liver Cell Profile in Sentul chickens without and with MOM Administration (one field of view, with 10x object magnification).

Treatment	Liver Cell Profile		
	Normal	Apoptosis	Necrosis
T0	535.53 ^b	107.26 ^b	64.44 ^b
T1	654.66 ^c	86.25 ^c	47.358 ^b
T2	603.27 ^d	75.63 ^d	41.23 ^a
T3	617.40 ^e	63.42 ^{ad}	29.35 ^c

Mean followed by superscript of different alphabetical elements showed significant difference ($P < 0.05$).

As chickens age, organ function typically declines due to increased cell degeneration—*Moringa oleifera* essential oil exhibits antibacterial and anti-inflammatory properties. Several studies have shown that consuming moringa leaves can enhance animal health and positively influence enzyme profiles, particularly gamma-glutamyl transpeptidase (γ -GT). The anti-inflammatory properties of moringa leaves may lead to improved liver health, the primary organ responsible for producing γ -GT. Improved liver function may contribute to better regulation of γ -GT levels, and previous researchers have reported similar findings (Adriani *et al.*, 2024; Purwanti *et al.*, 2024; Aritonang *et al.*, 2024).

CONCLUSIONS AND RECOMMENDATIONS

The results of the current study indicate that higher concentrations of moringa leaves essential oil (*Moringa oleifera*) during the developmental phases of Sentul chickens significantly affect body weight gain ($P < 0.05$). As the moringa essential oil (MOM) concentration increased, the average blood plasma metabolite levels, such as triglycerides and cholesterol, decreased. Conversely, glucose, total protein, albumin, and globulin levels increased with higher concentrations of MOM. Additionally, mean liver inflammation decreased as the concentration of MOM increased.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to the funders of this research, the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia. They also thank the research team for their collabora-

tive efforts in completing this study and the accompanying article.

NOVELTY STATEMENT

Herbal extracts often have poor stability due to particle size, type of solvent, temperature, extraction time, pH, and the ratio of solvent to plant material. Additionally, these extracts are prone to degradation through oxidation and photolysis. In particular, extracts that use non-polar solvents can be challenging for oral administration, as they typically have low solubility and bioavailability. One effective way to address these stability issues is through microencapsulation. This technology isolates the active ingredients of essential oils within microcapsules, protecting them from external conditions and enabling controlled release.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to the writing of this manuscript.

ETHICAL APPROVAL

All procedures for this study have received approval from the Ethical Review Committee for Animal Experiments, Research and Technology Division, Agency for Agricultural Technology, under number 6353/PT.Riset.ttRE/08/24.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

REFERENCES

- Adriani L, Latipudin D, Mayasari N, Mushawwir A, Kumalasari C, Nabilla TI (2024). Consortium Probiotic Fermented Milk using *Bifidobacterium* sp. and *Lactobacillus acidophilus* Protects against *Salmonella typhimurium* and Repairs the Intestine. *Asian J. Dairy Food Res.*, 43 (2): 216-218. <https://doi.org/10.18805/ajdfr.DRF-326>
- Ansar S, Iqbal M, Aljameil N (2014). Diallyl sulfide, a component of moringa leaves, abrogates ferric nitrilotriacetate-induced oxidative stress and renal damage in rats. *Hum. Exp. Toxicol.*, 33(4): 1209-1216. <https://doi.org/10.1177/0960327114524237>
- Aritonang HN, Mushawwir A, Adriani L, Puspitasari T (2024). Lipid Regulation by Early Administration of Irradiated Chitosan and Glutathione in Heat-stressed Broilers. *IOP Conf. Series: Earth Environ. Sci.*, 1292: 012011. <https://doi.org/10.1088/1755-1315/1292/1/012011>
- Bertaggia E, Scabia G, Dalise S, Lo Verso F, Santini F, Vitti P, Chisari, C, Sandri M, Maffei M (2014). Haptoglobin is required to prevent oxidative stress and muscle atrophy. *PLoS One.* 9: e100745. <https://doi.org/10.1371/journal.pone.0100745>
- Bhatwalkar SB, Mondal R, Krishna SBN, Adam JK, Govender P, Anupam R (2021). Antibacterial Properties of Organosulfur

- Compounds of Moringa leaves (*Moringa oleifera*). Front. Microbiol., 12: 1-20. <https://doi.org/10.3389/fmicb.2021.613077>
- Chatterjee N, Das S, Bose D, Banerjee S, Jha T, Saha KD (2015). Leishmanial lipid affords protection against oxidative stress-induced hepatic injury by regulating inflammatory mediators and confining apoptosis progress. Toxicol. Lett., 232(3): 499-512. <https://doi.org/10.1016/j.toxlet.2014.11.023>
- Chawda PJ, Shi J, Xue S, Young Quek S (2017). Co-encapsulation of bioactives for food applications. Food Qual. Saf., 1(4). <https://doi.org/10.1093/fqsafe/fyx028>
- Cortes-Coronado RF, Gomez-Rosales SMDL, Angeles MT, Casaubon H, Sorensen DT (2017). Influence of a yeast fermented product on the serum levels of the mannan-binding lectin and the antibodies against the Newcastle disease virus in Ross broilers. J. Appl. Poult. Res., 26(5): 38-49. <https://doi.org/10.3382/japr/pfw044>
- Dahlan M, Haqiqi S (2012). Effect of moringa leaves flour (*Moringa oleifera*) on mortality and body weight of broilers. J. Livestock, 3 (2):3-9.
- Dudi D, Hilmi N, Khaerunnisa I, Mushawwir A (2023). DGAT1 gene polymorphism and their association with fat deposition and carcass quality in Pasundan cattle of Indonesia. Biodiversitas 24:4202-4208. <https://doi.org/10.13057/biodiv/d240765>
- Eyng C, Murakami AE, Santos TC, Silveira TGV, Pedrosa RB, Lourenco DAL (2015). Immune responses in broiler chicks fed propolis extraction residue supplemented diets. Asian-Australas. J. Anim. Sci., 28(1): 135-142. <https://doi.org/10.5713/ajas.14.0066>
- Firmansyah A, Adriani L, Mushawwir A, Mayasari N, Rusmana D, Ishmayana S (2024). Effect of Feed Supplementation with Liquid and Powdered Probiotic Yogurt on the Lipid Profile of Chicken Egg Yolk. Adv. Anim. Vet. Sci., 12 (7): 1371-1377. <https://doi.org/10.17582/journal.aavs/2024/12.7.1371.1377>
- Founou LL, Founou RC, Essack, SY (2016). Antibiotic resistance in the food chain: A developing country-perspective. Front. Microbiol., 7: 1-19. <https://doi.org/10.3389/fmicb.2016.01881>
- Hidayati N (2005). The role of moringa leaves (*Moringa oleifera*) in improving broiler meat quality. Vet. Med. Media, 21(1): 32-34
- Julaeha E, Eddy DR, Wahyudi T, Ningsih BA, Nurzaman M, Permadi N (2022). Coacervate microcapsules of *Citrus aurantifolia* essential oil (LOs): Optimisation and their antibacterial activity study. Chem. Select., 7 (15): e202200187. <https://doi.org/10.1002/slct.202200187>
- Karossi AT, Hanafi M, Sutedja L (1993). Isolation and Antibacterial Test of Moringa Leaves Oil. J App. Chem., 3 (2): 49 -53.
- Kharazi AY, Latipudin D, Suwarno N, Puspitasari T, Nuryanthi N, Mushawwir A (2022). Lipogenesis in Sentul Chickens of Starter Phase Inhibited by Irradiated Chitosan. IAP Conf, Proc., 1001: 1-7. <https://doi.org/10.1088/1755-1315/1001/1/012021>
- Korivi M, Hou CW, Huang CY, Lee S D, Hsu MF, Yu SH, Chen CY, Liu YY, Kuo CH (2012). Ginsenoside Rg1 protects the liver against exhaustive exercise-induced oxidative stress in rats. Evid Based Complement Altern. Med., 2012: 932165. <https://doi.org/10.1155/2012/932165>
- Lai YS, Chen WC, Ho CT, Lu KH, Lin SH, Tseng HC, Lin SY, Sheen LY (2014). Moringa leaves essential oil protects against obesity-triggered nonalcoholic fatty liver disease through modulation of lipid metabolism and oxidative stress. J. Agric. Food. Chem., 62(1): 5897-5906. <https://doi.org/10.1021/jf500803c>
- Lai YS, Chen WC, Ho CT, Lu KH, Lin SH, Tseng HC, Lin SY, Sheen LY (2014). Moringa leaves essential oil protects against obesity-triggered nonalcoholic fatty liver disease through modulation of lipid metabolism and oxidative stress. J. Agric. Food. Chem., 62(1): 5897-5906. <https://doi.org/10.1021/jf500803c>
- Lee DH, Lim SR, Ra SS, Kim JD (2014). Effects of dietary moringa leave powder on growth, feed utilization, and whole body composition change in fingerling sterlet sturgeon, *Acipenser ruthenus*. Asian-Australas. J. Anim. Sci., 27(5): 1419-1429. <https://doi.org/10.5713/ajas.2014.14087>
- Manin F, Yusrizal M, Adriani L, Mushawwir A (2024). Effects of the Combination of the Probiotic Probio Fmand Phytobiotics on the Performance, Gut Dysbiosis, and Lipid Profile of Broiler Meat. Adv. Anim. Vet. Sci., 12 (11): 2110-2117. <https://doi.org/10.17582/journal.aavs/2024/12.11.2110.2117>
- McManaman JL, Bales ES, Orlicky DJ, Jackman M, MacLean PS, Cain S, Crunk AE, Mansur A, Graham CE, Bowman TA, Greenberg AS (2013). Perilipin-2-null mice are protected against diet-induced obesity, adipose inflammation, and fatty liver disease. J. Lipid Res., 54(4): 1346-1359. <https://doi.org/10.1194/jlr.M035063>
- Muhammad L N, Purwanti S, Pakiding W, Marhamah, Nurhayu, Prahesti K I, Sirajuddin, S N, Mushawwir A (2023). Effect of combination of indigofera zollingeriana, black soldier fly larvae, and turmeric on performance and histomorphological characteristics of native chicken at starter phase. Journal of Animal and Feed Research. 13(4): 279-285.
- Mushawwir A, Latipudin D (2013). Biologi Sintesis Telur: Perspektif Fisiologi, Biokimia dan Molekuler dalam Produksi Telur. Graha Ilmu, Yogyakarta.
- Mushawwir A, Tanuwiria UH, Kamil KA, Adriani L, Wiradimadja R (2017). Effects of volatile oil of moringa leaves on feed utilisation, blood biochemistry and performance of heat-stressed Japanese quail. Asian J. Poult. Sci., 11 (2): 83-89. <https://doi.org/10.3923/ajpsaj.2017.83.89>
- Mushawwir A, Tanuwiria UH, Kurnia KA, Adriani L, Wiradimadja R, Suwarno N (2018). Evaluation of haematological responses and blood biochemical parameters of heat-stressed broilers with dietary supplementation of Javanese Ginger Powder (*Curcuma xanthorrhiza*) and Moringa leaves Extract (*Moringa oleifera*). Int. J. Poult. Sci., 17(3): 452-458. <https://doi.org/10.3923/ijps.2018.452.458>
- Mushawwir A, Permana R, Latipudin D, Suwarno N (2021a). Organic Diallyl-n-Sulfide (Dn-S) inhibited the glycogenolysis pathway and heart failure of heat-stressed laying hens. IOP Conference Series: Earth Environ. Sci., 788:012091. <https://doi.org/10.1088/1755-1315/788/1/012091>
- Mushawwir A, Permana R, Darwis D, Puspitasari T, Pangerteni DS, Nuryanthi N, Suwarno N (2021b). Enhancement of the liver histologic of broiler induced by irradiated chitosan (IC). AIP Conf. Proc., 2381:020046 <https://doi.org/10.1063/5.0066271>

- Mushawwir A, Arifin J, Darwis D, Tita P, Sekar P D, Nuryanthi N, Perman R (2022). Liver metabolic activities of pasundan cattle induced by irradiated chitosan. *Biodiversity J. Biol. Divers.*, 21(12): 5571-5578
- Mushawwir A, Permana R, Latipudin D, Suwarno D (2023). Flavonoids Avoid the Damage of Ileal Plaque-Patches of Heat-Stressed Cihateup Ducks. *IAP Conf. Proc.*, 2628.140007-1-14007-6 <https://doi.org/10.1063/5.0144095>
- Mushawwir A, Permana R, Darwis D, Puspitasari T (2024). The villi ileum growth of native quail fed by irradiated chitosan with glutathione from early age in high temperature. *IOP Conf. Series: Earth Environ. Sci.*, 1292:1-6. <https://doi.org/10.1088/1755-1315/1292/1/012016>
- Nurfauziah I, Adriani L, Ramadhan R F, Mushawwir A, Ishmayana S (2024). Bacteriocin activity of yogurt probiotics on increasing production of laying hens. *Adv. Anim. Vet. Sci.*, 12 (8): 1548-1555. <https://doi.org/10.17582/journal.aavs/2024/12.8.1548.1555>
- Pazla R, Zain M, Despal, Tanuwiria UH, Putri EM, Makmur M, Zahera R, Sari LA, Afnan IM, Rosmalia A, Yulianti IY, Putri SD, Mushawwir A, Apriliana RA (2023). Evaluation of rumen degradable protein values from various tropical foliages using in vitro and in situ methods. *Int. J. Vet. Sci.*, 12(6): 860-868.
- Peinado MJ, Ruiz R, Echavarri A, Aranda Olmedo I, Rubio LA (2013). Moringa leaves pts-o derivative modulates gut microbiota composition and improves digestibility in growing broilers. *Anim. Feed Sci. Technol.*, 181(1-4): 87-92 <https://doi.org/10.1016/j.anifeedsci.2013.03.001>.
- Pourali M, Kermanshahi H, Golian A, Razmi GR, Soukhtanloo M (2014). Antioxidant and anticoccidial effects of moringa leaves powder and sulphur amino acids on Eimeria-infected and non-infected broiler chickens. *Iran. J. Vet. Med. Res.*, 15(3): 227-232.
- Prata FSS (2018). Estudo comparativo da taxa de glicemia em amostras colhidas em dois locais distintos em Canis familiaris. (Doctoral Dissertation, Universidade de Lisboa, Faculdade de Medicina Veterinaria).
- Purwanti S, Pakiding W, Nadir M, Nurhayu, Prahesti KI, Sirajuddin SN, Syamsu JA, Mushawwir A (2024). Lipid Regulation and Cardiovascular Biomarkers of Native Chickens Fed a Combination of Maggot, Indigofera and Turmeric. *J. Anim. Health Prod.*, 12 (2): 173-181. <https://doi.org/10.17582/journal.jahp/2024/12.2.173.181>
- Qaisrani SN, Moquet PCA, Van KMM, Kwakkel RP, Verstegen MWA (2015). Effect of feed additives on morphology and growth of small intestine in broiler chickens. *World J. Poult. Sci.*, 71(2): 321-334.
- Rahman MM, Ferdous J, Islam KMS, Khan MJ (2021). Effect of prebiotic supplementation diet on growth performance, carcass traits, intestinal histomorphometry, and cecal microflora of broiler chickens. *Vet. Med. Sci.*, 7(5): 1865-1876.
- Rahmania H, Permana R, Latipudin D, Suwarno N, Puspitasari T, Nuryanthi N, Mushawwir A (2022). Enhancement of the liver status of Sentul chickens from the starter phase induced by irradiated chitosan. *IAP Conf. Proc.*, 1001: 1-7. <https://doi.org/10.1088/1755-1315/1001/1/012007>
- Santhosha SG, Jamuna P, Prabhavathi SN (2013). Bioactive components of moringa leaves and their physiological role in health maintenance: A Rev. *Food Biosci.*, 3 59-74. <https://doi.org/10.1016/j.fbio.2013.07.001>
- Setiawan, Muhammad A, Tanuwiria UH, Mushawwir A (2024). The Balance of Rumen Degradable Protein with Non-Fibre Carbohydrate in Cattle Rations and its Effect on Total Gas Production, Gas Kinetics and Methane Gas Production. *Adv. Anim. Vet. Sci.*, 12 (10): 2000-2007. <https://doi.org/10.17582/journal.aavs/2024/12.10.2000.2007>
- Sirovina D, Orsolic N, Koncic MZ, Kovacevic G, Benkovic V, Gregorovic G (2013). Quercetin vs chrysin: effect on liver histopathology in diabetic mice. *Hum. Exp. Toxicol.*, 32(7): 1058-1066. <https://doi.org/10.1177/0960327112472993>
- Syamsiah SI, Tajudin (2004). Properties and Benefits of Moringa leaves King Natural Antibiotic. Agro Media Library, Jakarta.
- Tanuwiria UH, Mushawwir A (2020). Hematological and Antioxidants Responses of Dairy Cow Feed with a Combination of Feed and Duckweed (Lemna minor) as a Mixture for Improving Milk Biosynthesis. *Biodiversitas*. 21(10): 4741-4746. <https://doi.org/10.13057/biodiv/d211038>
- Tanuwiria UH, Susilawati I, Tasrifin DS, Salman LB, Mushawwir A (2022). Behavioural, physiological, and blood biochemistry of Friesian Holstein dairy cattle at different altitudes in West Java, Indonesia. *Biodiversity*. 23(1): 533-539. <https://doi.org/10.13057/biodiv/d230157>
- Tanuwiria UH, Mushawwir A, Zain M, Despal D (2023). Lipid regulation and growth on native ram lambs in the south coast of West Java, Indonesia fed legume forages. *Biodiversitas*. 24(7):4183-4192
- Trisnadi AD (2014). Moringa Super Nutrition. Centre for Information and Development of Indonesian Moringa Plants.
- Uyanga VA, Oke EO, Amevor FK, Zhao J, Wang X, Jiao H, Onagbesan OM, Lin H (2022). Functional roles of taurine, L-theanine, L-citrulline, and betaine during heat stress in poultry. *J. Anim. Sci. Biotechnol.*, 13(1): 1-20. <https://doi.org/10.1186/s40104-022-00675-6>
- Wanapat M, Cherdthong A, Phesatcha K, Kang S (2015). Dietary sources and their effects on animal production and environmental sustainability. *Anim. Nutr.*, 1 (3): 96-103. <https://doi.org/10.1016/j.aninu.2015.07.004>