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Research Article

Hematology Profile, Growth Hormone, and Performance of Broilers Fed Microbeads of Noni Fruit Extract (Minofe) Across Age Periods

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Abstract | Attention to food safety and antimicrobial resistance has become crucial in livestock development. These factors are essential for ensuring consumer safety and promoting cultivation methods that avoid synthetic substances, especially growth stimulants, which can lead to residue buildup in liver tissue. Natural extracts are a promising alternative, and various herbs have been studied. In this study, noni fruit extract encapsulated in microbeads was evaluated in 400 broilers to assess hematologic status, growth hormone levels, and performance. The birds were raised in litter-type cages and divided into four groups, each receiving 225 mg of noni extract microbeads (Minofe). The first group received no Minofe (Minofe-0), while the second, third, and fourth groups received Minofe at 8-21 days (Minofe-1), 8-35 days (Minofe-2), and 22-35 days (Minofe-3), respectively. Blood samples were collected at the end of the study, and performance data were recorded weekly. Hematological levels were measured using a hematology analyzer, and growth hormone levels were determined via spectrophotometry (ELISA method). Data analysis employed the Kruskal-Wallis test to assess treatment effects, with Mann-Whitney tests for pairwise comparisons. Results indicated that Minofe-2 was the most effective application ($P<0.01$) in optimizing hematological parameters. The immune response increased, with a greater increase in the proportion of lymphocytes (72.406%) ($P<0.01$) across all treatment groups, and a decrease in the proportion of neutrophils (6.724%) ($P<0.01$), the lowest among all treatment groups. Growth hormone levels, including GH (10.92), insulin (12.17), T4 (5.99), and IGF-1 (5.85 ng/dL), were highest in the Minofe-2 group broilers, and followed by an increase in final body weight (2512.50 g), feed efficiency (1.38), and income over feed and chick cost (17,555 IDR).

Keywords | Animal productivity, Broiler, Feed additive, Metabolism, Natural extract

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INTRODUCTION

Feed additives enhance broiler chicken growth, particularly in weight gain and feed efficiency. They also support nutrient absorption, reduce mortality, and promote faster growth. In Indonesia, antibiotics are widely used as feed additives for their dual role as growth promoters and antimicrobials, boosting productivity. The Indonesian government has officially banned the use of Antibiotic Growth Promoters (AGP) in poultry feed since January 1, 2018. This policy is set out in the Minister of Agriculture Regulation (Permentan) Number 14 of 2017 on the Classification of Animal Drugs. However, the ban on antibiotic growth promoters (AGPs) in poultry feed has led to the adoption of alternative methods that focus on healthy, residue-free poultry production. As a result, herbal plants are being considered as natural alternatives to antibiotics.

The search for sustainable, plant-based alternatives to enhance growth without antibiotics is crucial for maintaining productivity and food safety in intensive poultry production systems (Obinna and Dim, 2026). Phytogenic feed additives, which include secondary metabolites such as flavonoids and isoprene derivatives, have been widely reported to have significant potential as natural anabolic agents that improve growth performance and physiological health (David *et al*., 2024; Olabode *et al*., 2025).

The physiological responses of broiler chickens vary across growth phases, so the effectiveness of feed additives can depend on the timing of addition. The starter phase is marked by rapid development of the digestive organs and metabolic system, whereas the finisher phase focuses more on muscle tissue deposition. Therefore, testing the addition of noni fruit extract microbeads at different growth stages is important to determine the optimal timing to support growth performance.

One feed additive that has not been widely explored in poultry practice is noni fruit (*Morinda citrifolia* L.). Noni fruit contains various bioactive compounds, including flavonoids, phenolics, scopoletin, and saponins, which act as antimicrobials. These compounds help maintain the digestive tract, allowing optimal nutrient absorption, and can boost broiler growth performance. These bioactive compounds must be obtained through extraction.

Noni fruit extract contains beneficial bioactive compounds, but these bioactive compounds are easily degraded by heat, oxidation, and digestive enzymes. Microbead technology has been developed to maintain the quality and effectiveness of noni fruit extract. This technology protects the active compounds in the coating material, thereby maintaining their stability and bioavailability.

Microbeads are small particles with a diameter of 0.5–1000 µm that serve as carriers for active compounds. Microbeads not only protect a specific compound but also carry and stabilize multiple active compounds, enabling optimal release in the digestive tract (Chen *et al*., 2023; Li *et al*., 2022). These particles are typically made from cationic polymers such as chitosan, anionic polymers such as sodium alginate, or binders such as gelatin and chondroitin sulfate, in specific ratios to ensure their effectiveness.

These active compounds in noni fruit optimize intestinal barrier function and modulate the gut microbiota, thereby facilitating more efficient nutrient absorption and systemic immune homeostasis (Liu *et al*., 2024; Aritonang *et al*., 2025). Furthermore, other researchers have shown that integrating these bioactive compounds into poultry diets has been associated with modulation of various hematological indices and growth-regulating hormone secretion (Flees *et al*., 2020; Adu *et al*., 2020; Abdullahi *et al*., 2025). Stabilizing these biochemical pathways ensures the controlled release of antioxidants and anti-inflammatory agents throughout the gastrointestinal tract, which is crucial for optimizing metabolic responses across various developmental stages (Lal *et al*., 2020; Li *et al*., 2022).

Many researchers have reported the use of noni fruit extract, with highly variable results. A report by Lal *et al*. (2020) showed no difference in the growth of chicken groups given noni extract and those without. Meanwhile, another report showed that feed efficiency appeared to increase, although not significantly (Widjastuti *et al*., 2023; Alharthi *et al*., 2023). Studies on ileal histology by Lal *et al*. (2020) also showed that villus growth appeared to increase, although this did not translate into improved performance. Meanwhile, the administration of noni fruit flour at a dose of 450 mg/kg appeared to increase growth, although not significantly (Adeyeye, 2020; Lal *et al*., 2020). These research results show that presenting noni fruit extract without encapsulation technology resulted in inconsistent and unsatisfactory responses in chickens.

Although previous studies have noted some benefits, limited information exists on how protected bioactive delivery systems influence the endocrine and metabolic functions of broiler chickens across different growth stages (Choiri *et al*., 2017; Meligy *et al*., 2023; Mullenix *et al*., 2024). Additionally, data on administering these natural extracts at specific ages are scarce. Consequently, it is important to investigate how microbead forms of these extracts affect hematological and hormonal responses across age groups to improve growth efficiency.

MATERIALS AND METHODS

Animal sample, housing, and feed

Four hundred broiler chicks were used in this study and were intensively raised from 0 to 35 days of age. The chickens were divided into four treatment groups, each containing 100 individuals. The treatment consisted of Noni Fruit Extract Microbeads (Minofe) at 225 mg/kg of feed (levels were determined based on preliminary research). The Minofe-0 group received only a basal ration without Minofe; Minofe-1: A group fed a basal ration plus Minofe at 225 mg/kg of feed from 8 to 21 days of age; Minofe-2: a group fed a basal ration plus Minofe at 225 mg/kg of feed from 8 to 35 days of age; and Minofe-3: a group fed a basal ration plus Minofe at 225 mg/kg of feed from 22 to 35 days of age.

The cages were constructed from wood, with each cage measuring 3 x 3 x 1 m per treatment group. Each cage was numbered by treatment group to facilitate checking and data collection. The cages were equipped with round feeders and waterers and lined with rice husks.

The rations used consisted of a mixture of various feed ingredients with a total metabolizable energy content of 3196 kcal/kg, while the total protein, crude fat, crude fiber, calcium, phosphorus, lysine, methionine, tryptophan, and threonine ratios were 20.00; 5.00; 5.00; 1.10; 0.50; 1.20; 0.45; 0.19; and 0.75%, respectively.

Rations and drinking water were provided ad libitum (without restrictions). Rations were provided every morning and evening. No vaccinations or antibiotics were administered during the trial period to avoid the metabolic effects of these agents, which could suppress the treatment effects in this experiment.

Minofe preparation

Noni fruit extract microbeads (Minofe) were prepared by mixing a gelatin solution (0.25% w/v) and sodium alginate (1.75% w/v), then stirring with a magnetic stirrer at 600 rpm for 5 minutes until homogeneous. Ethanol extract of noni fruit was then added and stirred until evenly distributed. The mixture was then dripped from a height of 16 cm using a 23-G syringe into a 2% (w/v) $CaCl_2$ solution. The entire microbead preparation procedure was adapted from Julaeha *et al*. (2024).

Blood sampling and sample analysis

Blood sampling was performed at 35 days of age in broiler chickens. From each experimental unit, 15 chickens were randomly selected for blood sampling, yielding a total of 60 samples. Blood samples were collected from the pectoral vein in the wing using a syringe, for a total of 3 mL. The blood samples were collected in vacuum tubes containing Ethylenediaminetetraacetic acid (EDTA), labeled according to treatment, and stored on an ice pack to prevent sample damage.

Sample analysis included hematology using a hematology analyzer and plasma growth hormone levels measured by the MyBiosource KIT via ELISA. Performance measurements were conducted in accordance with performance measurement research standards (Aritonang *et al*., 2025).

Data analysis

The data obtained were analyzed using Microsoft Excel and SPSS. The Kruskal-Wallis test was used to assess the treatment effect at the 99% significance level ($\alpha = 0.05$). Differences between treatments were tested using the Mann-Whitney test.

RESULTS AND DISCUSSION

Hematology and growth hormone level

Table 1 and Figure 1 present changes in hematological parameters and growth hormones induced by Minofe supplementation in broiler diets.

Based on recent research results, the use of Minofe appears very promising and could be an excellent alternative feed additive. Hematologic levels (Table 1) showed significant

Table 1: Effect of Minofe administration at different age periods on hematological levels in broilers.

Parameters	Treatments				p-value
	Minofe-0	Minofe-1	Minofe-2	Minofe-3	
Erythrocytes(10^6.mm^3)	2.674±0.01^a	2.860±0.01^b	3.030±0.02^c	2.854±0.01^b	0.011
Hemoglobin (g/dL)	12.728±0.50^a	12.970±0.35^b	13.344±0.15^c	12.902±0.50^b	0.001
Hematocrit (%)	27.788±1.50^a	30.396±0.50^b	30.500±1.15^b	30.380±1.25^b	0.002
Leukocytes (10^3.mm^3)	27.958±0.01^a	28.748±0.02^b	29.320±0.01^c	28.690±0.03^b	0.002
Lymphocytes (%)	67.554±2.13^a	71.484±2.42^b	72.406±2.05^c	71.314±1.32^b	0.013
Neutrophils (%)	10.614±1.03^a	8.580±0.15^b	6.724±0.14^c	8.646±1.10^b	0.011

^{a,b}Different superscript notations on the same line indicate significant differences.

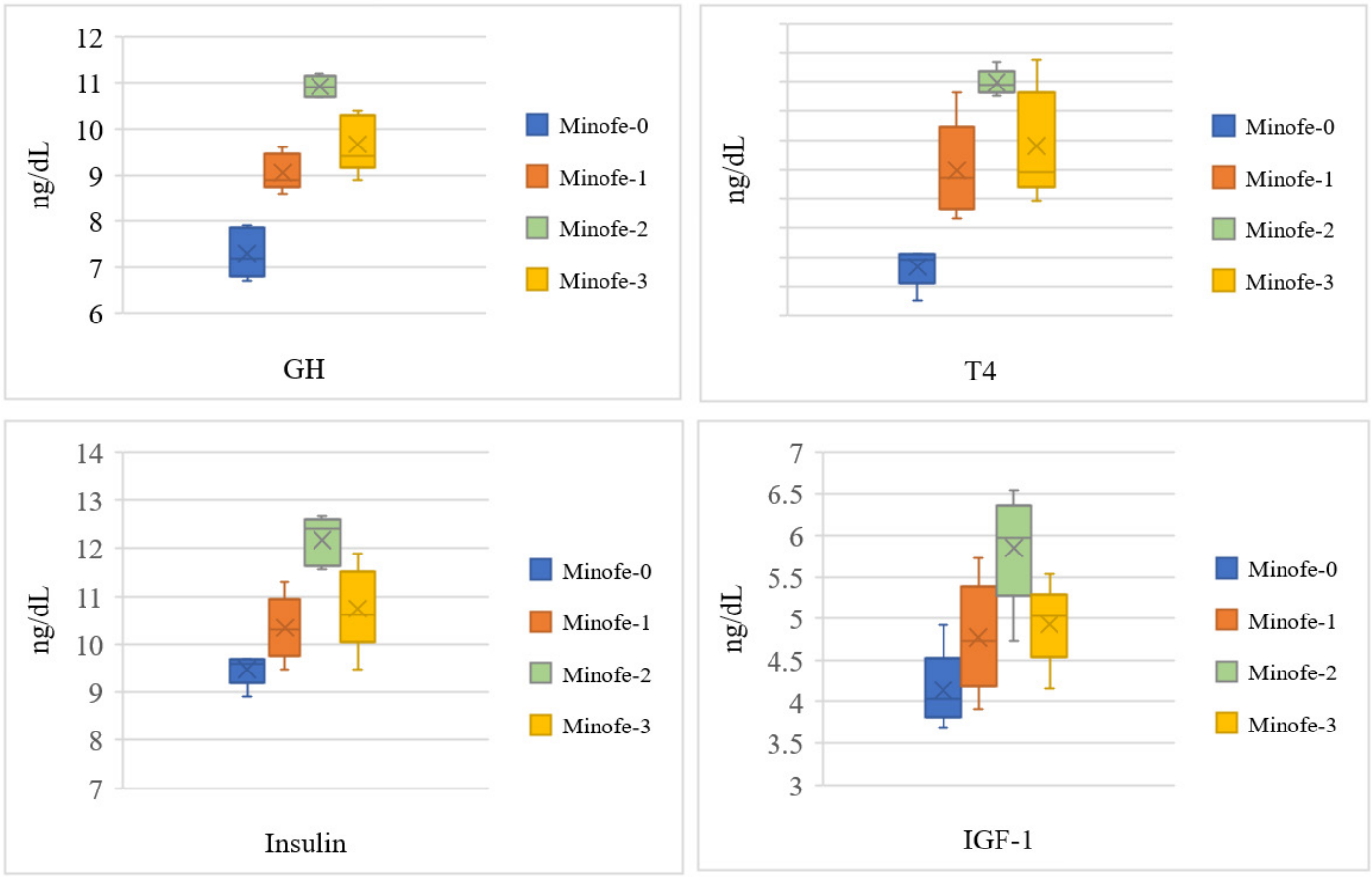

Figure 1: Concentrations of growth hormones (GH, T4, insulin, and IGF-1) in broilers as a result of Minofe administration at different ages.

differences (P<0.01), although overall, hematologic values were within the normal range. Broiler blood biosynthesis appeared to be stimulated by administering Minofe at 8 to 35 days of age (Minofe-2). Another very interesting result of this application is the potential to increase the immunomodulatory activity of the experimental chickens. Minofe-2 treatment appeared to stimulate lymphocyte counts by up to 72,406%, significantly higher (P<0.01) than with other Minofe administration methods, while reducing neutrophil levels by up to 6,724%, significantly lower (P<0.01) than with the others. Campbell (2015) reported that normal levels of broiler lymphocytes range from 40-75%

The effectiveness of Minofe-2 treatment is closely related to microencapsulation technology (microbeads), which helps maintain the stability of noni's bioactive compounds, such as iron, vitamin C, and alkaloids, against digestion-related damage. Controlled release ensures optimal absorption of these micronutrients in the small intestine, supporting hemoglobin formation. These results align with previous research reported by La *et al.* (2023), which found that the phytogenic components in noni fruit possess immunomodulatory properties that can improve the hematological profile of livestock. The use of encapsulated natural feed additives has been shown to increase the bioavailability of nutrients needed for blood protein synthesis (Zhang *et al.*, 2024), resulting in superior health outcomes compared to conventional feeding (Zhao *et al.*, 2023; Mullenix *et al.*, 2024).

Normal hematologic conditions are also closely associated with the resilience and increased function of extracellular fluids (Alharthi *et al.*, 2023; Urban *et al.*, 2024). This stimulation is related to the function of blood plasma as an oxygen transporter (So-In and Sunthamala, 2022), a nutrient transporter, and a hormonal transporter (Sirivibulkovit *et al.*, 2018; Adeyeye, 2020). This condition can be a major factor in increasing metabolism, as indicated by improved anabolic hormone function (Chen *et al.*, 2023). Current research shows that stimulation of blood biosynthesis can enhance metabolic functions, including increased muscle synthesis and other anabolic processes. This condition can be demonstrated by elevated growth hormone levels (Figure 1).

Confirmation of the effect of Minofe administration in stimulating anabolism and supporting tissue growth is evident in the higher levels of growth hormones (Figure 1) in the experimental group of chickens supplemented with Minofe (1-3) in the ration, compared to the group without Minofe (Minofe-0). Growth hormone (GH), T4, insulin, and IGF-1 levels were higher in the broiler group receiving

Minofe-2, which was administered at 225 mg/kg of ration between 8 and 35 days of age.

Plasma growth hormone (GH) levels were closely monitored to assess the impact of encapsulated noni fruit extract on endocrine regulation of growth and development in broiler chickens. Specifically, GH concentrations varied with birds' ages. These results provide insight into its potential to improve growth performance metrics. Significant fluctuations in somatotropin (GH) concentrations across treatment groups indicate that Minofe directly affects somatotropin, potentially mediating increased protein synthesis and nutrient distribution. This mechanism is possible because the active compound can stimulate transcription factors that signal the synthesis of GH and IGF-1 (Choiri *et al*., 2017) and somatotropin (Rajaei-Sharifabadi *et al*., 2017).

This suggests that Minofe may act as a potent modulator of the hypothalamic-pituitary-somatotropin axis in broiler chickens (Ormilla *et al*., 2025). High somatotropin levels stimulate protein synthesis in skeletal muscle, GH, and IGF-1, and increase total body mass (Mullenix *et al*., 2024; Ormilla *et al*., 2025), although they may also stimulate fat cell growth (Chen *et al*., 2023; Wahed *et al*., 2023).

While these research results confirm a strong correlation between Minofe and growth hormone excretion, its effectiveness in modulating growth hormone secretion warrants further investigation, particularly given the fruit's rich bioactive compounds, which are known to possess antioxidant and anti-inflammatory properties (Widjastuti *et al*., 2023), previous research has reported that compounds such as iridoids, polysaccharides, and scopoletin interact effectively through endocrine pathways, potentially influencing somatotropin and overall growth regulation in broiler chickens (Paredes *et al*., 2024; Rajaei-Sharifabadi *et al*., 2017).

This investigation may reveal how encapsulated extracts influence the complex interactions between growth hormones and other metabolic pathways, leading to more efficient nutrient utilization and improved physiological responses in broiler chickens (Ormilla *et al*., 2025). For example, improvements in erythrocyte profiles and hematocrit values have been linked to the antioxidant properties of *M. citrifolia*, which contribute to increased oxygen transport and metabolic efficiency, which are crucial for growth (Paredes *et al*., 2026).

Perfomance

Table 2 and Figure 2 present differences in performance such as feed consumption, final body weight, feed conversion, and income over feed-to-chick cost due to Minofe supplementation in broiler diets.

Table 2: Broiler performance with Minofe supplementation at different age periods.

Parameters	Treatments				p-value
	Minofe-0	Minofe-1	Minofe-2	Minofe-3	
Feed consumption (g)	4149.6±45.53[a]	3572.00±45.53[b]	3437.60±45.53[c]	4274.80±45.53[d]	0.022
Final body weight (g)	2322.04±18.01[a]	2357.65±32.66[a]	2553.80±28.96[c]	2512.50±38.17[d]	0.011
Feed conversion	1.86±0.01[a]	1.56±0.12[b]	1.38±0.11[c]	1.74±0.13[d]	0.001
Income over feed and chick cost (IDR)*	3,162.34±1.44[a]	11,226.31±0.75[b]	17,555.06±1.84[c]	6,111.25±0.37[d]	0.001

[a,b]Different superscript notations on the same line indicate significant differences: *Income over feed and chick cost is calculated based on the difference in the selling price of live weight per kilogram with the price of DOC + the cost of the feed consumed.

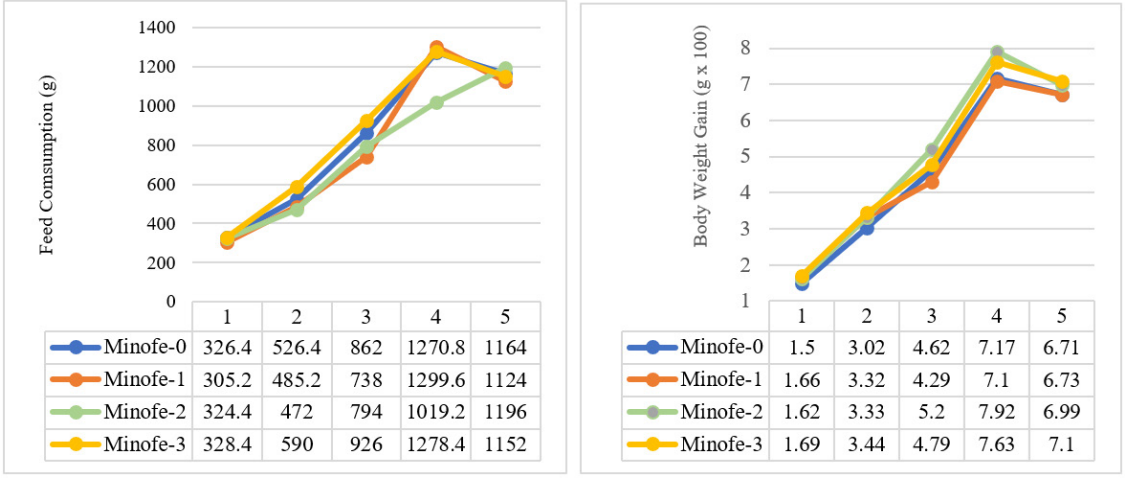

Figure 2: Average feed consumption and weekly weight gain of broilers given Minofe at different age periods.

The results of this experiment showed that the Minofe application to broilers was superior to that of the broiler group without Minofe (Minofe-0) (Table 2). Application at specific age periods also impacts broiler performance. Current research shows that the Minofe application between 8 and 35 days of age (Minofe-2) appears superior to applications between 8 and 21 days of age (Minofe-1) and between 22 and 35 days of age (Minofe-3). Production efficiency with the Minofe-2 application also appears to improve from the first to the fifth week (Figure 2).

Optimizing microencapsulation techniques, as in this study, increases the bioavailability of active compounds in noni fruit, ensuring their delivery to target cells and release, thereby maximizing their physiological impact on growth hormone regulation and overall broiler chicken development (Baetavianti *et al*., 2025). This modulation of Minofe can contribute to improved growth performance, as observed in this study (Table 2 and Figure 2).

The results of this research confirm that administering Minofe during a specific age period is effective: the peak growth period, when Minofe is administered, improves feed efficiency and yields the highest growth, as seen in the Minofe-2 experimental group. Similar results have been reported, with noni extract increasing feed conversion and weight gain (Costa *et al*., 2020).

For example, other reports suggest that certain phytochemicals in noni exert pleiotropic effects on cellular signaling, which may indirectly influence pituitary function and growth hormone release at specific ages, thereby optimizing muscle cell growth (Baetavianti *et al*., 2025). Previous research confirms that administering plant extracts can enhance intestinal villi growth (Alharthi *et al*., 2023). Given this potential, post-brooding supplementation appears to offer the best opportunity, as nutrient absorption can be effectively facilitated at an early age. These findings also reinforce previous research showing that good feed efficiency supports growth (Baetavianti *et al*., 2025).

Further research on the dose- and age-dependent responses to Minofe is needed to elucidate the mechanisms by which microencapsulated noni fruit extracts fully influence growth hormone dynamics and contribute to increased productivity in broiler chickens (Tanjung, 2024). Continuous administration of Minofe from 8 to 35 days consistently supports growth-related protein levels (such as hormones and enzymes), thereby stimulating muscle protein anabolism (Paredes *et al*., 2024). Furthermore, with demonstrated immune potential (as shown in this research), Minofe also directly supports higher growth. Research findings (Adu *et al*., 2020; Meligy *et al*., 2023; Zhang *et al*., 2024) indicate that robust immunity stimulates greater growth hormone and IGF-1 signaling.

Further investigation into the molecular mechanisms underlying these hormonal effects, particularly those involving the IGF-1 signaling pathway, will clarify the precise regulatory cascade triggered by noni extract. Furthermore, the complex interactions between growth hormone and downstream effectors, such as IGF-1, are crucial for understanding how Minofe can influence cell proliferation and differentiation, ultimately affecting muscle gain and body mass.

CONCLUSION

Based on current research, it can be concluded that using Minofe in broilers from 8 to 35 days of age (Minofe-2) is optimal, as it improves hematologic parameters and effectively increases growth hormone levels and performance.

Further research should prioritize time-release studies to ensure consistent, targeted delivery of the active compounds in Minofe. This effort is crucial to maximizing in vivo effectiveness across diverse farming environments. Additionally, transcriptomic or proteomic studies of Minofe are needed to elucidate the molecular pathways underlying these phenotypic improvements.

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NOVELTY STATEMENT

This study shows that delivering microencapsulated Morinda citrifolia extract via microbeads significantly affects the somatotropic axis and hematological parameters in broiler chickens, with effects that depend on developmental stage. The results indicate that broilers react differently to the active compounds in Minofe. Additionally, this research offers a basis for understanding variations in growth response by measuring growth hormone levels.

AUTHORS' CONTRIBUTION

All authors listed in this article provided full support and assistance during the research preparation, microbead production, in vivo testing, research evaluation, sample testing and analysis, and writing of this article. Therefore, all authors have contributed equally to the project in accordance with their respective duties and responsibilities.

Ethical approval

The entire planning and implementation process for this research has been submitted to the Animal Ethics Committee of the Directorate of Research Permit Management, Indonesia. It has been carefully evaluated and investigated, and it was determined that this research was feasible in accordance with the principles of animal welfare and research ethics, as reflected in decision number 4941/KEP.11/SK/12/2025.

Generate AI And AI-assisted technology statement

The authors solemnly declare that during the preparation and writing of this article, no assistance or facilities from AI software or similar technologies were used in any form.

Conflict of interest

The authors have declared no conflict of interest related to the writing of this article, whether related to funds, data, patents, or any other aspect related to it, with any party.

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