Research Article

Comparative and Combined Effects of Red Ginger and Turmeric Nanoemulsions on Broiler Carcass and Meat Quality

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Abstract | The demand for high-quality broiler meat has increased the interest in natural feed additives to replace Antibiotic Growth Promoters (AGPs). Red ginger and turmeric contain bioactive compounds gingerols and curcumin with antimicrobial, anti-inflammatory, and immunomodulatory properties; however, their effectiveness is limited by low bioavailability in conventional forms. Nanoemulsion technology improves solubility, absorption, and stability of these compounds. This study aimed to evaluate the comparative and combined effects of red ginger and turmeric nanoemulsions on broiler carcass characteristics and meat quality in broiler chickens. A Completely Randomized Design was applied with four treatments and five replicates of five birds each: P0 (control), P1 (red ginger nanoemulsion, 4 mg/kg BW), P2 (turmeric nanoemulsion, 4 mg/kg BW), and P3 (combination of red ginger and turmeric nanoemulsions, 2 mg/kg BW each). Treatments were administered via drinking water from day 7 to 28. The combined nanoemulsion treatment significantly reduced abdominal fat, blood cholesterol levels, and cooking loss ($P < 0.05$), while significantly improving carcass percentage compared with individual treatments and the control group ($P < 0.05$). These results indicate that the combined red ginger and turmeric nanoemulsion provides enhanced functional outcomes within the evaluated carcass and meat quality parameters, highlighting its potential as a natural nano-herbal additive in broiler production.

Keywords | Antibiotic growth promoters, Broiler, Carcass quality, Nanoemulsion, Red ginger, Turmeric

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INTRODUCTION

The global demand for high-quality broiler meat continues to rise in parallel with increasing consumer awareness of safe, nutritious, and residue-free animal products. Meat quality is influenced by physical traits such as color, texture, and cooking loss, as well as chemical attributes including fat deposition, cholesterol level, moisture content, and oxidative stability. Improving these characteristics is essential for enhancing product competitiveness and reducing dependency on synthetic additives, particularly Antibiotic Growth Promoters (AGPs), which are associated with antimicrobial resistance and residue concerns (Gaucher et al., 2015).

Herbal bioactives have emerged as promising natural feed additives capable of improving carcass traits and meat quality while supporting immune function. Red ginger (*Zingiber officinale* var. *rubrum*) is rich in gingerols and shogaols potent antioxidant and anti-inflammatory

compounds with concentrations significantly higher than common ginger varieties. These phytochemicals improve lipid metabolism, modulate oxidative pathways, and exhibit antimicrobial effects beneficial for poultry performance (Amiri et al., 2021). Similarly, turmeric (*Curcuma longa* L.) contains curcuminoids, predominantly curcumin, which possesses strong antioxidant, anti-inflammatory, immunomodulatory, and antimicrobial effects. Curcumin has demonstrated the ability to modulate cellular signaling, reduce oxidative stress, and inhibit pathogen growth, including antibiotic-resistant strains (Abbasi et al., 2020; Cozmin *et al.*, 2024). These characteristics make turmeric a promising natural agent for improving poultry health and meat quality.

Despite their potency, the bioavailability of gingerols and curcumin is inherently low due to poor solubility and rapid metabolism. Nanoemulsion technology provides a solution by reducing particle size to 20–500 nm, thereby increasing solubility, stability, cellular uptake, and overall bioavailability (Gupta *et al.*, 2016; Kumar, 2017). Nanoemulsions also enhance the stability of active compounds against environmental degradation and facilitate rapid intestinal absorption (Mohanraj and Chen, 2006).

Although both red ginger and turmeric have been individually reported to improve broiler performance and meat quality, no studies have evaluated the combined effects of combining these two potent herbal extracts in nanoemulsion form. Given their complementary bioactive profiles gingerols supporting lipid metabolism and antioxidant defenses, and curcumin enhancing anti-inflammatory and antimicrobial activities a potential complementary effects is biologically plausible. This represents a significant research gap, especially regarding their combined effects on broiler carcass traits and meat quality parameters. This study addresses this gap by systematically comparing the effects of single and combined red ginger and turmeric nanoemulsions administered via drinking water on broiler carcass composition and meat quality parameters. The novelty of this work lies in demonstrating that the combined nanoemulsion produces quantitatively superior outcomes compared to individual nanoemulsions at equivalent or higher doses, thereby supporting a combined biological response relevant to the development of nano-herbal alternatives to antibiotic growth promoters.

This study aimed to investigate the combined effects of red ginger and turmeric nanoemulsions, administered individually or in combination, on broiler carcass composition and meat quality. This work provides new insight into the development of multifunctional nano-herbal feed additives with the potential to enhance poultry production efficiency while reducing reliance on synthetic AGPs.

MATERIALS AND METHODS

Extraction and nanoemulsion preparation

Fresh herbs were cleaned and washed with running water, then drained. The herbs were sliced thinly into 6–7 mm pieces. The sliced red herbs were dried in the sun or in an oven at 49–55°C for 2 days until the moisture content is less than 10%, then ground and sieved with an 80-mesh sieve to obtain herbal powder.

The extraction process was carried out using the maceration technique. A total of 50 g of herbal powder was placed in a container and mixed with 250 ml of 96% ethanol, then sealed and left to stand for 3 × 24 hours with periodic stirring every hour. The resulting extract was separated, and the remaining residue was pressed and transferred into another container. Subsequently, 250 ml of 96% ethanol was added to the residue for a second maceration lasting 24 hours, and the extracts from both stages were combined. Concentration was then conducted using a rotary evaporator at 55–65°C to obtain a thick extract. The extraction yield was determined by comparing the initial sample weight with the final weight of the concentrated extract (Shaffira *et al.*, 2023).

The nanoemulsion was formulated using the homogenization method with the extract, VCO, Tween 80, PEG 400, and distilled water in a ratio of 1:3:21:10:65 (Manullang and Parinding, 2023). All ingredients except distilled water were mixed using a magnetic stirrer at a speed of 1000 rpm for 10 minutes, then distilled water was slowly added while increasing the speed to 1250 rpm for 10 minutes (Orinetha *et al.*, 2022). The nanoemulsions of red ginger and turmeric were characterized to ensure stability and suitability for biological application. Particle size and zeta potential were measured using a Particle Size Analyzer with Dynamic Light Scattering (DLS) (Chan *et al.*, 2017).

Research design

A total of 100 Day Old Chicks of the MB 202 strain obtained from PT Japfa Comfeed Indonesia, HI-PRO 611® and HI-PRO 611B® as broiler feed obtained from PT. Charoen Pokphand Indonesia with the nutritional content listed in Table 1. This study employed a Completely Randomized Design (CRD) with four treatment groups and five replications, each replication consisting of five broiler chickens. The cage size per compartment was 0.5 m^2 with a density of 5 chickens, the temperature was maintained at 28–30°C, and litter management used 10 cm thick husks. The treatments involved the administration of nanoemulsions formulated from red ginger and turmeric. Red ginger and turmeric nanoemulsion are given to broiler chickens at the age of 8-28 days. The treatments

were: P0= drinking water without adding extract (control), P1= administration of red ginger nanoemulsion (4 mg/kg BW); P2= administration of turmeric nanoemulsion (4 mg/kg BW); P3= administration of a combination of red ginger (2 mg/kg BW) and turmeric (2 mg/kg BW) nanoemulsions. The chicken rearing design in this research can be seen in the Table 2.

Table 1: Nutrient composition of feed (HI-PRO 611 and HI-PRO 611B Comfeed®).

Nutrient	Feed	
	HI PRO 611	HI PRO 611B
Water Content (%)	Max. 14	Max. 13
Ash (%)	Max. 8	Max. 9
Crude Protein (%)	21-23	21-23
Crude Fat (%)	Min. 5	Min. 4
Crude Fibre (%)	Min. 0.5	Min. 0.5
Calcium (%)	0.8 – 1.1	0.7 – 1.2
Phosphorus (phytase enzyme) (%)	Min. 0.5	Min. 0.5
Aflatoxin total	Max. 50 µg/kg	Max. 50 µg/kg
Lysin (%)	Min. 1.2	Min. 1.2
Methionine (%)	Min. 0.45	Min. 0.45
Methionine + Cysteine (%)	Min. 0.8	Min. 0.8
Tryptophan (%)	Min. 0.19	Min. 0.19
Threonine (%)	Min. 0.75	Min. 0.75

Notes: HI-PRO 611 and HI-PRO 611B are commercial starter and finisher broiler feeds (PT Japfa Comfeed Indonesia Tbk), respectively.

Table 2: Dietary treatments of red ginger and turmeric extract nanoemulsion.

Days	Drinking water type
1-7	Broiler chickens given ad libitum drinking water without the addition of turmeric nanoemulsion.
8-28	P0 given ad libitum drinking water without the addition of red ginger and turmeric nanoemulsions. P1 given drinking water with the addition of 4 mg/kg BW red ginger nanoemulsion. P2 given drinking water with the addition of 4 mg/kg BW turmeric nanoemulsion. P3 given drinking water with the addition of a combination of red ginger nanoemulsion 2 mg/kg BW and turmeric 2 mg/kg BW.

Carcass quality

Carcass quality was analyzed using 20 broiler chickens at the end of rearing to determine carcass percentage, abdominal fat percentage, cholesterol and cooking loss. The carcass percentage is obtained from the ratio of carcass weight to live weight multiplied by 100%. Abdominal fat percentage is calculated using a formula:

$$\frac{Abdomen\ fat\ weight}{Live\ weight} \times 100\%$$

Cholesterol is carried out using a digital cholesterol measuring device (EasyTouch). The percentage of cooking shrinkage is calculated using 5 grams of broiler chicken meat boiled at 80°C for 15 minutes. Cooking loss percentage calculated by formula:

$$\frac{Initial\ weight\ before\ steaming - Final\ weight\ after\ steaming}{Initial\ weight\ before\ steaming} \times 100\%$$

Statistical analysis

The research data were analyzed using a one-way analysis of variance (ANOVA) based on a Completely Randomized Design (CRD). Differences among treatments were further evaluated using Duncan's multiple range test at a significance level of $P<0.05$, performed with SPSS version 25 (Santoso, 2019).

RESULTS AND DISCUSSION

Extraction and nanoemulsion production

The extraction process yielded concentrated red ginger and turmeric extracts with yields of 6.99% and 6.49%, respectively, indicating efficient recovery of bioactive components. Phytochemical screening confirmed the presence of major secondary metabolites, including alkaloids, flavonoids, saponins, tannins, and polyphenols, which are widely recognized for their antioxidant and lipid-modulating properties (Ampode, 2019; Cozmin *et al.*, 2024). Nanoemulsion formulation resulted in particle sizes of 210.9 nm for red ginger and 162.2 nm for turmeric, with zeta potential values of –41.7 mV and –31.3 mV, respectively. These characteristics indicate good physical stability of the nanoemulsions and support their suitability for biological application, particularly in enhancing the delivery and functional efficacy of herbal bioactive compounds (Gupta *et al.*, 2016; Mohanraj and Chen, 2006).

Broiler carcass and meat quality

Table 3 presents the effect of treatment results of red ginger and turmeric nanoemulsions on broiler carcass and meat quality in drinking water on carcass percentage, belly fat percentage, cholesterol levels, and cooking losses in broiler chickens. The highest average carcass percentage was obtained in group P2 (72.86%) which was given 4 mg/kg BW turmeric nanoemulsion, followed by P3 (combination of red ginger and turmeric, 72.49%), and P1 (red ginger, 71.97%). Meanwhile, the control group (P0) without herbal supplementation had the lowest value of 70.43%. Further LSD testing confirmed that groups P2 and P3 were significantly different from the control (P0), while P1 did not show a significant difference.

Table 3: Broiler carcass quality following the administration of red ginger extract and turmeric extract nanoemulsion in drinking water.

Variable	Treatment			
	P0	P1	P2	P3
Carcass percentage (%)	70.43 ± 1.38[a]	71.97 ± 1.17[ab]	72.86 ± 0.59[a]	72.49 ± 1.33[b]
Abdominal fat (%)	1.412 ± 0.22[a]	1.038 ± 0.15[b]	1.108 ± 0.21[b]	1.032 ± 0.27[b]
Cholesterol (mg/dL)	270 ± 11.06[a]	237 ± 24.25[b]	238 ± 24.77[b]	219 ± 9.83[b]
Cooking loss (%)	38.0 ± 7.07[a]	32.4 ± 7.92[ab]	27.6 ± 7.12[ab]	26.4 ± 8.87[b]

Notes: Superscripts with the same letter indicate no significant difference in the row. P0 = Ad libitum drinking water without the addition of red ginger and turmeric nanoemulsion (control). P1 = Water intake with addition of red ginger nanoemulsion at 4 mg/kg body weight. P2 = Water intake with addition of turmeric nanoemulsion at 4 mg/kg body weight. P3 = Water intake with addition of a combination of red ginger nanoemulsion at 2 mg/kg body weight and turmeric nanoemulsion at 2 mg/kg body weight.

Carcass percentage

The administration of red ginger and turmeric nanoemulsions significantly influenced broiler carcass composition and selected meat quality parameters. The highest carcass percentage was observed in the turmeric nanoemulsion group (P2), followed by the combined nanoemulsion group (P3) and the red ginger nanoemulsion group (P1), while the control group showed the lowest value. Statistical analysis confirmed that treatments P2 and P3 differed significantly ($P < 0.05$) from the control, indicating that nanoemulsion-based herbal supplementation positively affected carcass yield within the evaluated parameters. These active compounds are known for their antioxidant and lipid-modulating properties, which may be functionally associated with the observed improvements in carcass composition, although digestive efficiency was not directly evaluated in the present study.

The observed improvement in carcass percentage may be functionally associated with the antioxidant and lipid-modulating properties of gingerol and curcumin delivered through the nanoemulsion system (Abd El-Hack *et al.*, 2021; Amal *et al.*, 2024). However, digestive efficiency and growth performance indicators were not directly assessed in the present study; therefore, interpretations are limited to functional outcomes reflected in carcass composition.

Abdominal fat percentage

The results showed that administration of nanoemulsion extracts of red ginger (P1), turmeric (P2), and a combination of both (P3) significantly ($P < 0.05$) reduced the percentage of abdominal fat in broiler chickens. The control group (P0) recorded an average abdominal fat of 1.412%, while the treatment groups showed a significant decrease: P1 by 1.038%, P2 by 1.108%, and P3 by 1.032%. The reduction in abdominal fat was 26.7% in P3, 26.5% in P1, and 21.5% in P2 compared to the control.

Abdominal fat percentage was significantly reduced in all nanoemulsion-treated groups compared to the control, with the greatest reduction observed in the combined nanoemulsion treatment (P3). Similar reductions in abdominal fat following ginger or curcumin supplementation have been reported in broiler chickens (Rajput *et al.*, 2013; Hernández-García *et al.*, 2025; Tahalele *et al.*, 2018; Septinar *et al.*, 2021; Putri *et al.*, 2025). This difference is likely due to the nanoemulsion formulation, which enhances the bioavailability of active compounds such as gingerol from ginger and curcumin from turmeric, resulting in functionally improved lipid-related outcomes as reflected by reduced abdominal fat, although specific lipid metabolism markers were not assessed. In a study by Amal *et al.* (2024), the use of ginger nanoparticles (4 g/kg feed) reduced abdominal fat from 1.79% to 1.41%, equivalent to a 21.2% reduction, while the combination of thyme and ginger resulted in an even greater reduction of 28.4%.

The reduction in abdominal fat observed in the present study may be functionally linked to enhanced bioavailability of bioactive compounds in nanoemulsion form, allowing more effective modulation of lipid-related outcomes. As specific lipid metabolism markers were not measured, these findings are interpreted as functional responses based on quantitative outcome patterns rather than direct mechanistic evidence (Gupta *et al.*, 2016; Orinetha *et al.*, 2022).

Cholesterol levels

Cholesterol in broiler chickens is used in the body's metabolism for the formation of steroid hormones, because even though broiler chickens have reached a sufficiently high body weight, they are still in a period of rapid growth and have not yet reached their maximum physiological age (Ambarwati *et al.*, 2023). The results showed that administering red ginger and turmeric extract nanoemulsions through drinking water significantly affected the blood cholesterol levels of broilers. In the control group (P0), the serum cholesterol level of broilers reached 270 mg/dL, which was the highest level among all

treatments. In contrast, the administration of either single or combined nanoemulsions showed a significant decrease in cholesterol levels ($P < 0.05$). The greatest decrease in cholesterol was recorded in group P3 (combination of ginger and turmeric at 2 mg/kg BW each), with cholesterol levels decreasing to 219 mg/dL. This represents a decrease of 51 mg/dL or 18.8% compared to the control. Groups P1 (red ginger 4 mg/kg BW) and P2 (turmeric 4 mg/kg BW) each reduced cholesterol levels to 237 mg/dL and 238 mg/dL, with a percentage decrease of 12.2% and 11.9%, respectively, from the control treatment. This is in line with the research by Putri *et al.* (2025), which reported that the administration of red ginger extract and propolis in P2 also reduced blood cholesterol levels from 287.75 mg/dL (Control Treatment) to 234.50 mg/dL, or a decrease of 18.5%. Low tissue cholesterol is usually followed by a decrease in abdominal fat deposition, as shown in group P3, which had lower meat cholesterol levels and the lowest abdominal fat (1,032%) compared to the control (1,412%). This means that cholesterol and fat reduction occur in parallel through more efficient lipid metabolism regulation.

Blood cholesterol levels were significantly reduced by the administration of red ginger and turmeric nanoemulsions, with the lowest value observed in the combined treatment (P3). Similar hypocholesterolemic effects of ginger and curcumin supplementation in broilers have been reported previously (Al-Khalaifah *et al.*, 2022; Abd El-Hack *et al.*, 2021). Although gingerol and curcumin have been reported to influence cholesterol regulation, enzymatic activity and molecular markers were not evaluated in the present study. Therefore, the reduction in cholesterol levels is interpreted strictly within the scope of the measured serum values.

Cooking loss

Cooking loss is an important determinant of meat quality, as it is related to the amount of water lost and nutrients dissolved in water due to cooking. The results showed that the addition of nanoemulsions of red ginger extract (P1), turmeric (P2), and especially a combination of both (P3) reduced cooking loss in broiler carcasses. The control group (P0) recorded a cooking loss of 38.0%, while P1 decreased to 32.4%, P2 to 27.6%, and P3 to 26.4%. Although the effectiveness of the treatment showed a downward trend (mean difference between P3 and P0 was 11.6%, $p= 0.032$), the ANOVA test did not show a significant difference in general ($F= 2.300$; $P= 0.116$). However, the LSD test highlighted that only the P3 combination was significantly different from the control ($P < 0.05$). Duncan's analysis placed P3 in a separate subset from the control, indicating that the ginger and turmeric combination had the most consistent effect on cooking loss values.

The administration of red ginger and turmeric extract nanoemulsions to broiler chickens resulted in a significant reduction in cooking loss, especially in the combination treatment (P3) with a value of 26.4% compared to the control of 38.0% with a difference of 11.6%. This effect is thought to be related to the antioxidant activity and protection of muscle cell membranes by active compounds such as gingerol in red ginger and curcumin in turmeric, which may be functionally related to antioxidant properties, although water-holding capacity was not directly measured in this study.

The combined administration of red ginger and turmeric nanoemulsions consistently resulted in superior improvements in broiler carcass composition and meat quality compared to individual nanoemulsion treatments, indicating a synergistic biological response at the functional level. These effects are plausibly attributed to enhanced bioavailability through nanoemulsion delivery and the complementary antioxidant and lipid-modulating activities of gingerol and curcumin. However, it should be acknowledged that individual water intake was not directly measured, as treatments were administered via drinking water under standardized ad libitum conditions, which may introduce minor variability in actual dose intake. In addition, direct molecular or biochemical analyses were beyond the scope of the present study; therefore, the proposed mechanisms are interpreted based on quantitative outcome patterns and supporting literature rather than definitive mechanistic evidence. Future studies incorporating controlled intake measurement and molecular validation are warranted to further elucidate the underlying interactions and optimize application strategies.

CONCLUSION

The combined administration of red ginger and turmeric nanoemulsions via drinking water resulted in consistently superior improvements in broiler carcass composition and selected meat quality parameters, including abdominal fat, blood cholesterol, and cooking loss, compared to individual nanoemulsion treatments. These findings demonstrate a functionally enhanced response of the combined nanoemulsion within the evaluated carcass and meat quality scope, supporting its potential application as a natural nano-herbal additive in broiler production. Further studies incorporating growth performance, physiological indicators, and mechanistic analyses are recommended to comprehensively evaluate the broader biological effects of this formulation.

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NOVELTY STATEMENT

These findings demonstrate that the combined application of red ginger and turmeric nanoemulsions yields functionally superior outcomes in broiler carcass quality, supporting their potential use as natural nano-herbal alternatives to antibiotic growth promoters.

AUTHOR'S CONTRIBUTION

DDP, N, and SA conceived and planned the experiments. DDP, AAC, NAU and SA performed the experiments in the laboratory and in the field. DDP, HR, NAU and N contributed to interpreting the results. DDP led the writing of the manuscript. All authors provided critical feedback and analyzed and revised the manuscript.

Ethical approval

This research was approved by the Research and Community Service Institute Research Ethics Committee, Universitas Negeri Malang with approval number: 27.08.11/UN32.14.2.8/LT/2025.

Generative AI and AI assisted technology statement

The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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