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Effect of Nano-Liquid Extracts of *Andrographis paniculata* and *Moringa oleifera* on The Performance and Carcass Quality of Broiler Chickens

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ABSTRACT

Feed was crucial for achieving optimal productivity in broiler chickens, which required ongoing monitoring of its quantity and quality. The present study aimed to evaluate the effects of nanoliquid extracts from *Andrographis paniculata* and *Moringa oleifera* used as photobiotic on the performance and carcass quality of broiler chickens. The research involved 128 broiler chickens, which were divided into four treatment groups, each with four replications of eight broiler chickens. The treatments included a control group (T0), a 0.25% nano liquid extract mixture of *Andrographis paniculata and Moringa oleifera* (T1), a 0.50% nanoliquid extract mixture (T2), and a 0.75% nanoliquid extract mixture (T3). The study utilized an *in vivo* method and analysed the data using a completely randomized design. The optimal level of nano liquid extract was determined based on chicken performance (feed consumption, body weight, feed conversion ratio (FCR), income-over-feed cost (IOFC)) and carcass quality (carcass percentage, cooking loss, meat color, water-holding capacity, and texture). The findings indicated that the addition of combined *Andrographis paniculata* and *Moringa oleifera* (1:1, w/w) nano-liquid extract in the chickens' feed significantly influenced body weight, FCR, and IOFC. However, there was no significant effect on feed consumption. Furthermore, the use of *Andrographis paniculata* and *Moringa oleifera* combination had a significant impact on all carcass quality parameters beyond *b carcass color. It was concluded that the addition of 0.25% of combined *Andrographis paniculata* and *Moringa oleifera* nano liquid extract yielded the most favorable outcomes for the performance and carcass quality of broiler chickens.

Keywords: *Andrographis paniculata*, Broiler chicken, Carcass quality, *Moringa oleifera*, Nano liquid, Performance

INTRODUCTION

Feed consumption is the primary cost for broiler chickens in production, and improving feed efficiency is a key strategy in broiler chicken management. However, few studies have focused on slow-growing broiler chickens (Wen et al., 2018). The use of antibiotic growth promoters (AGPs) as feed additives for livestock has been banned by the Indonesian government through Ministerial Regulation No. 14 of 2017 due to concerns about antibiotic resistance. This issue poses a significant problem for the poultry industry, leading to increased morbidity and mortality rates in broilers during outbreaks (Untari et al., 2021). Consequently, there are side effects, such as residue accumulation on broiler carcasses and the emergence of antibiotic-resistant bacteria (Mehdi et al., 2018). The use of AGPs has been reported to increase nutrient utilization, reduce intestinal pH, reduce pathogen bacterial populations, and increase nonpathogenic bacterial populations (Natsir et al., 2017). Singh et al. (2020) emphasized the need to find alternatives to synthetic antimicrobial growth promoters (AGPs) because of their related issues. They highlighted natural growth promoters (NGPs) as promising options. These NGPs, which include *Andrographis paniculata*, *Moringa oleifera*, and their derivatives, are recognized for their beneficial effects on the health of broiler chickens. These benefits include antimicrobial, antioxidant, anti-inflammatory (Okhuarobo et al., 2014; Chhikara et al., 2021).

The chemical compounds found in *Moringa oleifera* include alkaloids, flavonoids, saponins, terpenoids, tannins, and steroids (Bhattacharya et al., 2018). According to phytochemical tests conducted by Oladeji et al. (2020), these compounds function as antibacterials, antioxidants, and anti-inflammatory agents. *Moringa oleifera* is known for its natural antioxidant content and is a rich source of dietary fiber and essential macro- and micronutrients (Islam et al., 2021). *Andrographis paniculata* contains orthosiphon glucose, essential oils, saponins, polyphenols, flavonoids, sapogenins, potassium salts, and myoinositol (Hossain et al., 2014). Flavonoids in *Andrographis paniculata* are known to reduce free radicals, flavonoids, such as chalcones, flavones, flavonols, flavanones, and catechins exhibit antioxidant activity (Ahmad et al., 2020), and they have also been reported to be important for antiviral activity (Nithya et al., 2021).

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Both *Andrographis paniculata* and *Moringa oleifera* can be extracted via nanoparticles to improve their poor bioavailability. Nanosized particles not only increase the surface area but also possess better physical and chemical characteristics, including enhanced reactivity and solubility (Martínez-Ballesta et al., 2018), which is due to the increased stability of the active compounds within the nanoparticles.

These issues highlight the need for alternatives to AGPs and improvements in carcass quality while exploring the potential of *Andrographis paniculata* and *Moringa oleifera* as replacements. The objective of this study was to evaluate the effects of administering *Andrographis paniculata* and *Moringa oleifera* at different concentrations on the performance and carcass quality of broiler chickens. This research was crucial for enhancing carcass quality affected by parasites through the use of active compounds from herbal plants and for identifying alternatives to antibiotic growth promoters (AGPs) in broiler chicken production.

MATERIALS AND METHODS

Ethics approval

This experiment was carried out in accordance with Brawijaya University regulations, and the Indonesian Animal Care and Utilization Committee gave ethical approval for this research with the number 099-KEP-UB-2023.

Experimental design and treatments

In the current study, day-old chick (DOC) of the Lohmann Japfa Platinum MB 202 strain, aged 1 day with an average body weight of 38 grams, was reared for 35 days without sex differentiation. The DOC Platinum strain was used to vaccinate against Newcastle disease (ND) and infectious bursal disease (IBD). A total of 128 DOC were allocated into four treatment groups, with each group being replicated four times and each replicate consisting of eight chicks. Throughout the study, lighting was maintained at a maximum intensity of 20-40 lux, and heating was provided during the 10-day incubation period, with six gasolec heaters positioned on the sides of the cage with a temperature range of 25-30°C and a humidity level of 50-70%. Tube feeders and drinkers were provided to ensure unlimited access to food and water. The feed additive used was a mixture of *Andrographis paniculata* and *Moringa oleifera*, which were extracted and nanoextracted in liquid form. These feed additives were mixed into the feed at concentrations of 0.25%, 0.50%, and 0.75% of the total feed given. The composition of the feed ingredients is detailed in Table 1, and the percentage of the phytogenic mixture is presented in Table 2.

Table 1. Nutritional contents of the basal feeds of starter and finisher in broiler chickens, after the addition of nanolnano-iquid extracts of *Andrographis paniculata* and *Moringa oleifera*

Nutrients of starter	
Crude Protein	21.00-22.00%
Fat	4.00-8.00%
Crude Fibre	3.00-5.00%
Ash	5.00-7.00%
Calcium	0.90-1.20%
Phospor	0.70-0.90%
ME	2950-3050 Kcal/kg
Nutrients of finisher	
Moisture	12%
Crude Protein	19%
Crude Fat	5%
Crude Fibre	5%
Calx	7%
Calsium	0.8-1.1%
PhosporUS	0.45%
Enzyme	Phytase 400 FTU/kg
Aflatoxin	50 ppb

Table 2. Percentage of phytogenic blend produced by the addition of nanolnano-iquid extracts of *Andrographis paniculata* and *Moringa oleifera* to broiler chickens' diet

Treatment	
T0: *Andrographis Paniculata* + *Moringa Oleifera*	Basal feed
T1: *Andrographis Paniculata* + *Moringa Oleifera*	Use 0.25% nanoliquid extract mixture
T2: *Andrographis Paniculata* + *Moringa Oleifera*	Use 0.50% nanoliquid extract mixture
T3: *Andrographis Paniculata* + *Moringa Oleifera*	Use 0.75% nanoliquid extract mixture

T: treatment

Moringa oleifera and *Andrographis paniculata* nano liquid preparation

The feed additive used was a combination of *Andrographis paniculata* and *Moringa* extracted in a nanoliquid form. This feed additive was mixed with the feed at concentrations of 0.25%, 0.50%, and 0.75% of the total feed provided to the broilers from day 1 to day 35. *Andrographis paniculata* and *Moringa oleifera* extracts were prepared in the Nutrition Laboratory of the Faculty of Animal Husbandry, Brawijaya University, via a maceration process. The process involved soaking *Andrographis paniculata* and *Moringa oleifera* in a 1:1 ratio in a container and then adding 70% ethanol at a ratio of 1:5 (100 grams of sambiloto powder and 500 ml of ethanol; Prasetyaningrum et al., 2022). This mixture was stirred at room temperature for 24 hours. Extraction was then performed via microwave-assisted extraction (MAE) at a temperature of 50-60°C for 15 minutes. Once extraction was complete, the mixture was allowed to settle briefly and then filtered through filter paper to obtain the filtrate. The filtrate was subsequently distilled via a microwave at a controlled temperature for 30 minutes until all the ethanol had evaporated. Finally, nanoparticle-based extraction was conducted via ultrasonic assisted extraction (UAE) for 10 minutes, which was repeated three times, for a total of 30 minutes. The detailed process of extracting nano-liquid of the feed additive was illustrated in Figure 1.

Figure 1. The process of extracting a nano liquid of the feed additive used was a combination of *Andrographis paniculata* and *Moringa,* and microwave-assisted extraction (MAE) was performed at a temperature of 50-60°C for 15 minutes. Nanoparticle-based extraction was conducted via ultrasonic-assisted extraction (UAE) for 10 minutes, which was repeated three times, for a total of 30 minutes.

Preparation of the cage and equipment

The first stage of cage preparation involved cleaning the remaining dirt from the previous broiler chicken farm and trimming the bushes around the cage. The cage floor was then mopped until it was clean and dry for 1 week. The cage used was an open-house type with bamboo slats, partitions made of bamboo, and sacks measuring 100 cm × 100 cm × 70 cm, creating a total of 28 plots, each containing 8 broiler chickens. A sack was placed as a base, and the rice husks were evenly spread to a height of 5-10 cm in the treatment cages. Tarpaulins were placed around the plots to regulate the temperature and air conditions in the cage during the starter phase (Zhai et al., 2020). The number of feed and water containers provided was in accordance with the number of plots, totaling 28, with sizes adjusted according to the age of the livestock. Baby chick feeders were used for DOC (1-14 days), and feed containers with a capacity of 7 kg were used for older chickens. Drinking containers with a 2-liter capacity were also provided. The cage of the *in vivo* experiment can be seen in Figure 2. The heater system used 6 gas molecules, which were placed on the sides of the cage. The light was provided for 12 hours per day, from 18:00 to 06:00. Once all the equipment was set up, the gas was turned on for 3 hours before introducing the DOC to ensure that the cage temperature was adequately warm. A solution of brown sugar was prepared to prevent dehydration and minimize stress. During the starter phase, the broiler chickens were arranged in 5 separate plots, each designated for a different treatment, without any replication. After the brood hens were released, they were distributed according to the research cage repetitions for 35 days.

Figure 2. The open house type of cage used in the present study. A total of 28 plots, each containing 8 broiler chickens

Data collection

The initial data collection was conducted when the DOC arrived at the poultry house. All DOCs were weighed together to obtain the average body weight. Subsequent average body weight measurements were taken weekly. Feed consumption was also recorded weekly by subtracting the amount of feed remaining from the amount of feed given during weighing. At 35 days of age, two broiler chickens from each experimental unit, whose weight was close to the average weight of the unit, were then marked on their legs according to the treatment they received so that a total of 28 broiler chickens were used as samples. Broiler chickens were first weighed to determine their live weight and then slaughtered by hanging them upside down and severing three neck vessels, including the esophagus, carotid artery, and jugular vein. After slaughter, the blood was drained as much as possible, and the broiler chickens were immersed in hot water for 10 seconds to facilitate manual feather plucking. The head and feet were detached, the internal organs were removed, and the weights of the broiler chicken carcasses were recorded. A breast meat sample, measuring 5 cm in length, 3 cm in width, and 0.5 cm in thickness, was collected for texture and color analysis. The procedures for assessing color, texture, and cooking loss were conducted in the Laboratory of Animal Product Technology at the Faculty of Animal Science, Brawijaya University.

Statistical analysis

The software used was Microsoft Excel, and the data obtained were then analyzed via analysis of variance (ANOVA) with respect to the percentage of date pit flour usage. When different results were observed between treatments, Duncan's multiple range test was performed. Significantly different results were considered at the level of $p < 0.05$, and highly significantly different results were considered at the level of $p < 0.01$.

RESULTS

Effects of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* on broiler chicken performance

The average effects of the treatments on the feed conversion ratio (FCR), income-over-feed cost (IOFC), body weight, and feed consumption of broiler chickens are shown in Table 3. Statistical analysis revealed that the liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* had a significant effect ($p < 0.05$) on the feed conversion ratio (FCR), income over feed cost (IOFC), and body weight of broilers. The highest FCR was observed in the T0 (control) treatment at 1.57%, whereas the lowest FCR was found in the T1 treatment (0.25% nanoliquid extract mixture of *Andrographis paniculata* and *Moringa oleifera*) at 1.49%. The highest IOFC was recorded in the T1 treatment (9,530/kg), whereas the lowest IOFC was recorded in the T0 treatment (6,036/kg). The highest body weight was achieved in the T1 treatment (3,833.33 g/head), whereas the lowest body weight was achieved in the T0 treatment (3,553.9 g/head). The effects of nano *Andrographis paniculata* and *Moringa oleifera* did not significantly affect ($p > 0.05$) the feed consumption of broilers chicken. The highest feed consumption occurred in the T1 treatment (3.57 kg/broiler), whereas the lowest feed consumption occurred in the T2 treatment (3.45 kg/broiler).

Effects of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* on broiler chicken carcass quality

The average impact of the treatments on broiler chicken carcass quality was presented in Table 4. According to the statistical analysis, the liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* did not have a significant effect ($p > 0.05$) on carcass percentage, meat color ($L^*a^*b^*$), water holding capacity, or meat texture. The highest carcass percentage was observed in the T1 treatment (75.52%), whereas the lowest carcass percentage was observed in the T0 treatment (67.83%). The highest value for meat color was recorded in the T3 treatment (5.75), whereas the lowest a value was recorded in the T0 treatment (3.18). The highest b value for meat color was found in the T3 treatment (13.61), whereas the lowest b value was found in the T0 treatment (11.56). The highest WHC was observed in the T2 treatment (44.85%), whereas the lowest WHC was observed in the T0 treatment (41.44%). The highest meat texture was found in the T0 treatment (4.59 N), whereas the lowest meat texture was found in the T3 treatment (3.65 N). The effects of the liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* on broiler chicken carcass quality significantly affected ($p < 0.05$) cooking loss and meat color L. The highest cooking loss was in the T3 treatment (36.25%), whereas the lowest cooking loss was in the T0 treatment (33.37%). The highest L value for meat color was recorded in the T3 treatment (54.79%), whereas the lowest L value was recorded in the T0 treatment (50.36%).

Table 3. Effects of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* on the feed conversion ratio, income over feed cost, body weight and feed consumption in broiler chickens

Treatments	T0	T1	T2	T3	*p-value*
Feed Consumption (g/broiler)	3494 ± 59.32	3579 ± 26.33	3455 ± 83.97	3510 ± 40.04	0.096
Body Weight (g/broiler)	2221.19 ± 45.33	2351.41 ± 71.12	2283.61 ± 58.65	2215.19 ± 59.59	0.044
IOFC (IDR/kg)	6036 ± 1046.08^{a}	9530 ± 1154.85^{b}	6053.13 ± 1430.22^{a}	6584.37 ±1360.59^{a}	0.009
FCR	1.57 ± 0.04^{b}	1.49 ± 0.04^{a}	1.55 ± 0.01^{b}	1.55 ± 0.03^{b}	0.019

Superscripts with different letters in the same columns indicate significant differences ($p < 0.05$). FCR: Feed conversion ratio, IOFC: Income-over-feed cost. T0: basal feed, 0% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, T1: 0.25% of of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, T2: 0.50% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, and T3: 0.75% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract.

Table 4. Effects of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* on the carcass quality of broiler chickens

Treatments		T0	T1	T2	T3	*p-value*
Carcass percentage (%)		67.83 ± 0.46^{a}	75.52 ± 1.27^{c}	72.57 ± 1.52^{b}	72.16 ± 1.37^{b}	2.81E-06
Cooking loss (%)		33.37 ± 0.24^{a}	34.09 ± 0.83^{ab}	35.69 ± 1.91^{bc}	36.25 ± 1.30^{c}	0.016
Meat color	L*	50.36 ± 0.34^{a}	52.67 ± 1.34^{ab}	53.24 ± 2.44^{b}	54.79 ± 2.09^{b}	0.020
	a*	3.18 ± 0.28^{a}	5.18 ± 1.07^{b}	5.66 ± 0.90^{b}	5.75 ± 0.29^{b}	0.0005
	b*	11.56 ± 0.66	11.95 ± 0.57	12.89 ± 2.55	13.61 ± 0.36	0.181
Water holding capacity (%)		41.44 ± 0.44^{a}	42.77 ± 1.01^{ab}	44.85 ± 0.38^{b}	43.4 ± 0.34^{b}	9.39E-06
Meat texture. (N)		4.59 ± 0.44^{b}	4.6 ± 0.29^{b}	4.46±0.24^{b}	3.65±0.29^{a}	0.002

Superscripts with different letters in the same columns indicate significant differences ($p < 0.05$). T0: basal feed, 0% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, T1: 0.25% of of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, T2: 0.50% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract, and T3: 0.75% of *Andrographis paniculata* and *Moringa oleifera* nanoliquid extract.

DISCUSSION

Performance

The success of broiler production was evaluated based on performance indicators such as feed consumption, final body weight, and the feed conversion ratio (FCR; Shafey et al., 2014). Research findings have shown that a nano mixture of *Andrographis paniculata* and *Moringa oleifera* contains active compounds with natural antimicrobial and antioxidant properties. An evaluation of performance factors against specific livestock parameters, such as FCR, revealed the ratio between the feed consumed and the weight gained by broiler chickens (Pierozan et al., 2016). A lower FCR value signified greater efficiency, which was evident from the FCR values in the T2 treatment, where T2 had a lower value than the control and was similar to T1. Nevertheless, all the treatments achieved a targeted low average feed conversion ratio (FCR) because the liquid nano extracts of *Andrographis paniculata* and *Moringa oleifera* have pharmacological activities as natural antibiotics, antivirals (Udikala et al., 2017), antimicrobials, anti-inflammatory agents, anti-cholesterol agents, anticancer agents, appetite stimulants, and digestive enhancers for broilers (Bagheri et al., 2020). The addition of liquid nano extracts of *Andrographis paniculata* and *Moringa oleifera* resulted in relatively high feed conversion ratios due to the physical and chemical properties of *Moringa oleifera*. As mentioned, the concentration of antinutritional factors such as tannins and saponins led to reduced feed consumption (Steven et al., 2015), making the feed more efficient, as observed in T2.

The results revealed that the nano mixture of *Andrographis paniculata* and *Moringa oleifera* presented the highest IOFC in the T1 treatment. The results from the T1 treatment demonstrated that higher levels of herbal mixture usage were associated with increased feed costs. According to Utami et al. (2023), factors influencing IOFC include broiler chicken body weight, feed intake, feed costs during the rearing period, and the selling price of the broiler chicken at harvest. Improved management practices lead to a higher IOFC, which implies more efficient broiler chicken rearing. The T2 treatment demonstrated that the average IOFC value was similar to that of T0 and T3, with nearly identical body weights, indicating that more efficient conversion of nutrients into meat results in better IOFC values. This result was related to the advantages of the liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera*, which include greater particle absorption in the form of nanoparticles. Greater surface area for improved interactions, extending their time in the intestines, minimizing intestinal cleansing processes, enhancing tissue penetration, and improving penetration of the epithelial layer, resulting in more effective cellular absorption (Cao et al., 2019).

The results of the present study indicated that the T1 treatment, which involved the liquid nano extracts of *Andrographis paniculata* and *Moringa oleifera* leaves, resulted in the highest body weight. However, this result led to high IOFC. Therefore, the most stable treatment was T2, owing to its efficient feed conversion ratio, which reduced feed costs and contributed to body weight formation. Owoade et al. (2021) reported that low feed consumption was influenced by the antioxidant compounds present in *Andrographis paniculata* and *Moringa oleifera*, which affected organ performance and growth promoters in broilers, thus improving nutrient absorption and resulting in better body weight (Alwaleed et al., 2020). Compared with the other treatments, the addition of 0.50% nano *Andrographis paniculata* and *Moringa oleifera* resulted in slightly lower feed consumption but higher body weight again because *Andrographis paniculata* and *Moringa oleifera* were recognized as excellent sources of nutrients with high protein content and many benefits for monogastric livestock (Astuti and Irawati, 2022).

The results of the present study indicated that the consumption of 0.50% liquid nanoextracts from *Andrographis paniculata* and *Moringa oleifera* was the most effective, as it resulted in increased body weight gain in broiler chickens and decreased feed consumption. This was balanced by a lower feed conversion ratio, lower IOFC, and increased body weight. The addition of *Andrographis paniculata* and *Moringa oleifera* to the diet could reduce feed consumption. Oraibi and Ali (2021) noted that bioactive compounds in nano *Andrographis paniculata* and *Moringa oleifera* could reduce feed consumption compared with normal levels. Secondary compounds such as tannins and saponins, which have a bitter taste, were found to reduce palatability (Kholif et al., 2018). However, from a biological perspective, feed consumption, the protein efficiency ratio, and the feed conversion ratio were optimal in the T2 treatment. The bioactive compounds present in *Andrographis paniculata* and *Moringa oleifera* were present at optimal dosages within the herbal mixture. Additionally, the synergistic effects of the combined ingredients positively influenced various performance parameters.

Carcass quality

The average carcass percentage values with the addition of the nanoliquid additive extracts of *Andrographis paniculata* and *Moringa oleifera* were, in descending order, 75.52% for the 0.25% addition (T1), 72.57% for the 0.50% addition (T2), 72.16% for the 0.75% addition (T3), and 67.83% for the control (T0). In the present study, the ideal carcass percentage value was achieved with the addition of 0.25% nanoliquid to *Andrographis paniculata* and *Moringa oleifera*. This result was due to the advantages of nanoparticles, which have an increased surface area (Alkhtib et al., 2020). According to Abd El-Hack et al. (2018), greater particle absorption in the form of nanoparticles was due to their larger surface area, which allows for better interactions, prolongs the residence time in the intestines, reduces intestinal cleansing mechanisms, increases tissue penetration, and enhances epithelial layer penetration, leading to more efficient cellular absorption.

The cooking loss values in this study ranged from an average of 33.37% to 36.25%, which was considered normal. This aligns with the findings of Sari et al. (2021), who reported that broiler meat with a cooking loss of approximately 35% was of very good quality because of its relatively low cooking loss. Meat with a cooking loss of less than 35% was deemed to have acceptable quality, as it reflects minimal nutrient loss during cooking. The cooking loss values in this study were very similar, indicating that the addition of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* did not result in significant differences.

Meat color was assessed via a Minolta Chromatometer Color Reader to obtain International Commission on Illumination (CIE) laboratory values (L*: Lightness, a*: Redness, b*: Yellowness). The average L* values in this study ranged from 50.36-54.79, which was considered to be within the normal range. This finding was consistent with that of Hayat et al. (2024), who reported that lightness levels showed significant sensitivity to color measurement fluctuations via three-dimensional color values, which were correlated with higher L* values. The use of high dimensions could induce the release of stress-related hormones, including adrenaline, noradrenaline, and corticosterone. Downing et al. (2017) categorized broiler breast meat with an L* value greater than 53 as pale. This occurred because the additives used, *Andrographis paniculata* and *Moringa oleifera*, did not significantly differ. However, the addition of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera*, which have much smaller particle sizes, resulted in a more stable L* value of 52.67 in the T1 treatment.

Compared with those of the control treatment, the a* color values of the addition of liquid nanofeed additives to *Andrographis paniculata* and *Moringa oleifera* were also greater. However, the addition of 0.25%, 0.50%, and 0.75% liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* did not result in significant differences. Additionally, the a* color values were related to the L* color values; in this study, both the a* and L* color values increased with increasing concentrations of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera*, because *Andrographis paniculata* can maintain erythrocyte levels in the body, and *Moringa oleifera* significantly increased the number of micronucleated polychromatic erythrocytes originating from the bone marrow of rodents (Bagri and Kumar, 2024). Myoglobin oxidation caused a decrease in a* values across all treatments, as iron atoms can oxidize or denature myoglobin molecules during oxidation, resulting in a negative color change in the product and conversion of myoglobin to methemoglobin (Çelebi, 2024).

In this study, the addition of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* did not have a significant effect on the b* values, because *Andrographis paniculata* and *Moringa oleifera* lack xanthophyll, which means that they do not affect the b* color of the carcass. Orkusz et al. (2024) reported that some bacteria can produce pigments through their metabolic processes, leading to alterations in meat color, such as an increase in yellowness to 58.59. Additionally, changes in meat color, including heightened yellowness, have been linked to bacterial spoilage, myoglobin autoxidation, and protein oxidation. With the addition of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera*, the water-holding capacity values, listed from highest to lowest, were 44.85% for the 0.50% addition (T2), 43.4% for the 0.75% addition (T3), 42.77% for the 0.25% addition (T1), and 41.44% for the 0% addition (T0). The WHC increased with the addition of nanoliquid extracts of *Andrographis paniculata* and *Moringa oleifera*, which was attributed to the presence of tannins in both *Andrographis paniculata* and *Moringa oleifera*, which can inhibit fat absorption. Shahlehi et al. (2024) reported that tannins react with mucosal and epithelial proteins in the intestines, thereby inhibiting the absorption of fats from ingested food.

The addition of liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera* to the feed resulted in texture values listed from highest to lowest as follows, including 4.6 for the 0.25% addition (T1), 4.4 for the 0.50% addition (T2), 4.5 for the 0% addition (T0), and 3.6 for the 0.75% addition (T3). The texture values of the *Andrographis paniculata* and *Moringa oleifera* extracts were greater than those of the control treatment, which was attributed to the alkaloid and tannin contents of *Andrographis paniculata* and *Moringa oleifera*, which inhibited fat absorption, leading to an increase in the meat protein content and consequently higher texture values (Ivanova et al., 2024).

CONCLUSION

The administration of 0.25% liquid nano extracts of *Andrographis paniculata* and *Moringa oleifera* effectively improved performance parameters, such as FCR, IOFC, body weight, and feed consumption and also effectively enhanced the carcass quality of broiler chickens. Moreover, additional studies were needed to explore the use of liquid and nanoliquid extracts of *Andrographis paniculata* and *Moringa oleifera* in feed to assess their potential for improving outcomes.

DECLARATIONS

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Authors' contributions

Ilham Fithrah Hasanain contributed to the data analysis and wrote the manuscript. Muhammad Halim Natsir and Osfar Sjofjan developed the research methodology and reviewed the manuscript. Yuli Frita Nuningtyas analysed the data. Filoza Marwi developed the technical research and edited the manuscript. Feri Eko Hermanto analyzed liquid nanoextracts of *Andrographis paniculata* and *Moringa oleifera*. All the authors performed the validation and investigation and approved the final manuscript.

Availability of data and materials

The authors of this article confirm that all the data supporting the findings of this research are available upon reasonable request from the authors.

Competing interests

The authors declare that they have no conflicts of interest.

Ethical considerations

Ethical issues (including plagiarism, consent to publish, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) have been checked by all the authors.

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