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Utilization of *Terminalia catappa* L. leaf extract and orange (*Citrus sinensis*) waste as natural feed additives to improve performance, productivity, and meat quality of broiler chickens

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ABSTRACT

Feed additives such as phytobiotic feed additives originating from local waste materials which are abundantly available can be used to support livestock productivity. One of the wastes that is widely available and can be used as a feed additive for poultry is *Terminalia catappa* L. leaf extract and orange (*Citrus sinensis*) waste. This research aims to find local natural ingredients that are abundantly available and can be used as feed additives for broiler chickens. The research will be carried out in vivo on 252 broiler chickens with a design of 4 treatments and 7 replications with 9 chickens per replication. T0 (control, without administration of a mixture of extract and orange waste); T1 (Giving 3% mixture of *Terminalia catappa* L. leaf extract and orange waste); T2 (Giving 5% mixture of *Terminalia catappa* L. leaf extract and orange waste); and T3 (Administration of a 7% mixture of *Terminalia catappa* L. leaf extract and orange waste). Water and feed consumption, body weight gain, feed conversion ratio, IOFC, carcass traitt, meat moisture, meat crude protein and crude fat of broiler chicken were not significant ($P > 0.05$) among treatment. Phytobiotic feed additive from *Terminalia catappa* leave extract and orange waste in drinking water did not enhance performance, carcass trait, and meat quality of broiler chicken.

Introduction

The Indian almond tree, *Terminalia catappa*, has been the subject of much investigation on its potential as an antibacterial ingredient in the pharmaceutical sector. Due to its many medicinal benefits, this tree, which is indigenous to the tropics of Asia, Africa, and Australia, has been utilised in traditional medicine for millennia. It has been shown that *Terminalia catappa* contains a variety of bioactive substances, including as phenolic acids, flavonoids, and terpenoids, which add to its antibacterial action in the leaves, bark, and fruits.Numerous investigations have been conducted to find natural substances that can boost livestock production and growth in substitution of AGP. In tropical regions like Indonesia, ketatang leaves are frequently encountered. Usually, this plant is placed as shade along the side of the road. While dry leaves are reddish to brown, fresh leaves are green. *Terminalia catappa* L. leaves contain antibacterial and antioxidant compounds which can be used to support livestock productivity (Amata, 2011). The saponin, tannin and flavonoid content is a source of antioxidants and has natural antibacterial effects. Antioxidant activity was found in *Terminalia catappa* L. leaf extract, where the most powerful compounds came from fallen leaves (Baratelli *et al*., 2012). Essential oil from *Terminalia catappa* L. leaves obtained through decoction is antiseptic and can heal wounds (Nair and Chanda, 2008). The presence of several phytochemicals is thought to be responsible for the antibacterial actions of leaf extracts from *Terminalia catappa* L.. By interfering with the structure and function of bacterial cell membranes, these substances prevent bacterial growth and replication. The extracts are a good option for creating novel antibacterial agents because it has been demonstrated that they can stop the growth of both Gram-positive and Gram-negative bacteria (Darmawati *et al*., 2023). However, there has not been much research on the use of antioxidants and antibacterials from *Terminalia catappa* L. leaves for poultry.

Natural compounds such as saponins, tannins, flavonoids are sources of antioxidants and have natural antibacterial effects. Saponins are compounds found in several types of plants that can increase nutrient absorption through the intestinal epithelium and can be used as feed additives in poultry rations. Saponin can increase villus height and crypt depth, so that it can increase nutrient digestibility. Tannin is a potential natural antioxidant and is widely used as feed-additives. Tannins can ward off free radicals and inhibit prooxidative enzymes. Flavonoids have the ability to act as antioxidants by warding off free radicals and stopping oxidative stress. Saponin, tanin, flavonoid have a potential effect as feed additive. Feed additives originating from plants can function as antioxidants which can influence biological activity in the livestock body, including increasing digestion and absorption of nutrients, increasing digestive enzyme activity, reducing oxidative processes, reducing the growth of pathogenic bacteria, and being able to modify the histomorphology of the digestive tract. where this biological activity will cause physiological changes that will affect health status, nutrient absorption, improve carcass quality, and increase the shelf life of meat (Valenzuela-Grijalva *et al*., 2017). Feed additives from plants have a stable influence on performance even though they are processed in different ways and have different active substance compositions. The use of phytobiotic feed additives also has a positive influence on the digestive tract wall, biochemical profile, carcass characteristics, and digestive tract bacterial profile. Meanwhile, feed conversion increases with the use of feed additives from phytibiotics, but using more than 1500 mg/kg can reduce feed consumption.

Feed additives from plants contain many active compounds such as phenol which function as antioxidants and protect biomolecules such as proteins, nucleic acids, unsaturated fats and sugars from oxidative damage through reactions stimulated by free radicals. Phenol compounds can act as antioxidants because of their role in reducing hydrogen atoms, bond structures and atomic rings (Mahfuz *et al*., 2021). The synergy of several compounds from *Terminalia catappa* L. leaf extract makes this plant have good antibacterial and antioxidant properties. As an antibac-

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terial, *Terminalia catappa* L. leaf extract is expected to maintain the ecology of the digestive tract so that nutrient utilization can be maximized. As an antioxidant, *Terminalia catappa* L. leaf extract is expected to reduce stress, so that growth and productivity can increase. To determine the effectiveness and use of *Terminalia catappa* L. leaves as a growth promoting agent in poultry, it is necessary to research the compounds contained in *Terminalia catappa* L. leaves in vivo and in vitro. Combine *Terminalia catappa* L. leaves with other acidic materials, such acidifier sources, to maximise some of the chemicals found in the leaves. Acidifiers are organic acids that aid in digestion by decreasing the pH in the intestines, increasing the activity of digestive enzymes, and preserving the microbiological balance in the digestive tract. In Tajudin *et al*. (2021), Orange peel is one of the substances that can be utilised as an acidifier. Active ingredients found in orange peel (*Citrus sinensis*) include limonoids, flavonoids, steroids, phenolics, kumari, and saponins (Haroen, 2017). Orange wasteion yields a large number of carotenoids-rich essential oils. Essential oils can halt the formation of immature cell walls and membranes by interfering with this process.

Broiler chicken performance is predicted to increase when *Terminalia catappa* L. leaf extract and orange waste are combined in livestock drinking water. The research has the advantage of providing information on the best way to use *Terminalia catappa* L. leaf extract and orange waste together as a natural feed additive for broiler chickens. The study's objective was to assess the impact of adding a mixture of *Terminalia catappa* L. leaf extract and orange waste to drinking water on performance, productivity, and meat quality.

Materials and methods

The committe of Animal Ethics of the Faculty of Animal and Agricultural Sciences, Universitas Diponegoro approved the present study (Approval Number: 58-11/A-13/KEP-FPP).

The research used 252 broiler chicken. The experiment was arranged based on a completely randomized design with four treatment groups and seven replicates consisting of 9 chicks each. The treatments included T0 (control, without administration of a mixture of extract and orange waste); T1 (Administration of 3% mixture of *Terminalia catappa* L. leaf extract and orange waste); T2 (Administration of 5% mixture of *Terminalia catappa* L. leaf extract and orange waste); and T3 (Administration of 7% mixture of *Terminalia catappa* L. leaf extract and orange waste). Treatment was given add libitum to drinking water from 14 days to 42 days of age. Data measured include performance, carcass production, and meat quality. According to the feed label, the chicks were raised on commercial prestarter feed until day 14. in d 14 forward, the chicks were feed with self mixing ration that shown in Table 1. The birds were raised in an open-sided chicken coop using rice husks for the duration of the trial. In each pen, a hand feeder and drinker were used to provide ad libitum access to drinking water and feed. Throughout the day, there was constant illumination. A tarp and blowers were used to control the air flow inside the house during the examination. The chickens receive vaccinations against Newcastle Disease (ND), Infectious Bronchitis (IB), Avian Influenza (AI), and Infectious Bursal Disease (IBD).

The extraction process was carried out using the method of Alhadi *et al*. (2021) which modified the ratio of materials and solvents, where in that study turmeric and betel leaves used a ratio of 1: 4 and in this study it was modified to a ratio of 1: 5. The preparation of *Terminalia catappa* L. leaf extract begins with cleaning the *Terminalia catappa* L. leaves using running water then the *Terminalia catappa* L. leaves are air-dried for one night then the leaves are cut into pieces of about 1-2 cm then the *Terminalia catappa* L. leaves are ground. The dried, ground *Terminalia catappa* L. leaves are then soaked in aquades solution with a ratio of 1: 5 for 72 hours and stirred periodically, after which the extract is taken by filtering the soaking results using whatman filter paper. The extraction process uses the method of Alhadi *et al*. (2021) The preparation of orange waste begins with cleaning the orange peel then soaking it in a 1:5 aquadest solution and putting it in the refrigerator for 4 hours after which the extract is taken by filtering the soaking results using Whatman filter paper. *Terminalia catappa* L. leaf extract and orange waste are then combined in a 2:1 ratio and then put into a bottle to wait for use.

Table 1. Ingredients and nutrient contents of feeds for broilers.

Items	Finisher (day 14-42)
Yellow maize (%)	61
Soybean meal (%)	32
Palm oil (%)	2.95
DL-methionine (%)	0.19
Bentonite (%)	0.75
Limestone (%)	1
Monocalcium phosphate (%)	1.3
Premix[2] (%)	0.34
Chlorine chloride (%)	0.07
Salt (%)	0.4
Analysed nutritional compositions:	
Metabolizable energy (kcal/kg)[1]	3,438.71
Crude protein	16.22
Crude fibre	0.71
Crude fat	5.93
Ash	12.35

[1]Metabolizable energy was calculated according to Bolton's (1967) formula: 40.81 {0.87 [crude protein + 2.25 crude fat + nitrogen-free extract] + 2.5}
[2]Premix contained (per kg of diet) of Vitamin A 7750 IU, Vitamin D3 1550 IU, Vitamin E 1.88 mg, Vitamin B1 1.25 mg, Vitamin B2 3.13 mg, Vitamin B6 1.88 mg, Vitamin B12 0.01 mg, Vitamin C 25 mg, folic acid 1.50 mg, Ca-d-pantothenate 7.5 mg,

Weighing of feed and remaining rations is done once a day in the morning. Body weight was measured at the beginning before treatment and once a week during treatment, namely on days 1, 7, 14, 21, 28, 35 and 42. The increase in body weight of each broiler chicken is calculated from the body weight at the end of maintenance minus the initial body weight. The meat's chemical quality was assessed using standard proximate analysis, which included the oven method for measuring water content, the Kjeldahl method for measuring protein content, the Soxhlet method for measuring fat content, and the dry ashing method for measuring ash content (AOAC, 2007). Data collected from this study were statistically analyzed based on analysis of variance (steel and Torrie, 1997) using SPSS (IBM Corp., New York). Duncan's multiple-range test was conducted when remarkable differences ($p<0.05$) were found among the treatment groups.

Results

The effect of Administration of *Terminalia catappa* L. leaf extract and orange waste (TCO) on the growth performance of broiler chicken is shown in Table 2. Water consumption, feed consumption, body weight gain, feed conversion ratio, and income over feed cost (IOFC) was not significant ($P > 0.05$) among treatment. Administration of TCO did not show a significant effect ($P > 0.05$) on the carcass percentage and meat quality of broiler chickens.

Discussion

The supplementation of *Terminalia catappa* L. leaf extract and orange waste was studied to determine its effects on the growth performance of broiler chickens. However, the supplementation did not have significant impacts on performance parameters such as water consumption, feed consumption, body weight gain, and feed conversion ratio. Research has evaluated alternative supplements as potential enhancers of growth per-

Table 2. Growth performance of broilers chicken with administration of *Terminalia catappa* L. leaf extract and orange waste.

Variables	T0	T1	T2	T3	SEM	*P*-value
Water Consumption (ml/bird)	8.340.24	7.790.68	8.099.35	7.966.43	0.07	0.08
Feed Consumption (g/bird)	3.109.81	3.136.67	3.110.33	3.180.38	0.01	0.43
Body Weight Gain (g/bird)	1.859.14	1.888.86	1.875.00	1.821.71	0.02	0.76
Feed Conversion Ratio	1.69	1.67	1.67	1.74	0.11	0.67
IOFC (IDR/bird)	7.626.57	8.002.57	7.850.14	6.746.43	0.3	0.50

T0: control, without administration of a mixture of extract and orange waste, T1: Administration 3% mixture of *Terminalia catappa* L. leaf extract and orange waste, T2: Administration 5% mixture of *Terminalia catappa* L. leaf extract and orange waste, T3: Administration of a 7% mixture of *Terminalia catappa* L. leaf extract and orange waste, SEM: standard error of the means.

Table 3. Carcass traits of broilers chicken with administration of *Terminalia catappa* L. leaf extract and orange waste.

Variables	T0	T1	T2	T3	SEM	*P*-value
Live weight (g/bird)	2.117.14	2.235.00	2.220.71	2.224.28	27.54	0.19
Carcass weight (g/bird)	1.501.00	1.552.85	1.575.00	1.562.71	18.81	0.53
Breast and Thigh Meat ratio	1.16	1.17	1.17	1.19	0.01	0.93

T0: control, without administration of a mixture of extract and orange waste, T1: Administration 3% mixture of *Terminalia catappa* L. leaf extract and orange waste, T2: Administration 5% mixture of *Terminalia catappa* L. leaf extract and orange waste, T3: Administration of a 7% mixture of *Terminalia catappa* L. leaf extract and orange waste, SEM: standard error of the means.

Table 4. Meat quality of broilers chicken with administration of *Terminalia catappa* L. leaf extract and orange waste.

Variables	T0	T1	T2	T3	SEM	*P*-value
Moisture (%)	76.12	75.99	75.88	76.21	27.54	0.19
Crude Protein (%)	19.98	19.62	20.24	19.54	0.11	0.07
Crude Fat (%)	1.83	1.71	1.55	1.63	0.04	0.19

T0: control, without administration of a mixture of extract and orange waste, T1: Administration 3% mixture of *Terminalia catappa* L. leaf extract and orange waste, T2: Administration 5% mixture of *Terminalia catappa* L. leaf extract and orange waste, T3: Administration of a 7% mixture of *Terminalia catappa* L. leaf extract and orange waste, SEM: standard error of the means.

formance and meat quality in broilers. For example, Spirulina platensis, a blue-green alga, has shown improvements in growth performance, meat quality, immune function, and antioxidant status in broilers by providing high protein, mineral, and vitamin content (Irshad *et al*., 2024). Another study highlighted the benefits of phytobiotics, which are plant-derived feed additives that possess antimicrobial, antioxidant, immune-modulating, and growth-promoting properties. These have emerged as promising alternatives to synthetic antibiotics, promoting gut health and enhancing growth performance (Abd El-Ghany *et al*., 2024). The use of a commercial citrus extract feed additive (CEFA) has also been discussed as a method to improve environmental sustainability of broiler production, demonstrating enhanced growth performance and reduced environmental impacts through more efficient feed conversion (Bui *et al*., 2023).

Although statistically the treatment did not significantly affect drinking water consumption, in this case there was a tendency that drinking water consumption was higher (275.34–297.86 ml/head/day) than the standard drinking water consumption for broilers, which is around 190 ml/head/day in finisher phase chickens (Janmohammadi *et al*., 2009). This is thought to be due to the temperature being too high during the study, which reached 30-31˚C during the day, so that the chickens experienced stress and consumed more water. This statement is in line with the opinion of Bruno *et al*. (2011) who stated that water consumption increases if the poultry experiences stress due to excessively high temperatures. Water consumption in broiler chickens has a certain standard and broiler chickens will drink water continuously when under stress due to excessive temperatures. According to Zhang *et al*. (2012), the optimal temperature in broiler chicken maintenance is 23-24ºC. Drinking water consumption will increase by 5% when the environmental temperature increases by 1˚C.

The statistical analysis results show no significant difference (P>0.05) between the combination supplementation treatments of *Terminalia catappa* L. leaf extract and orange waste on feed consumption parameters. Administration levels up to 7% did not have an effect, presumably due to the low bioactive substances in the extract not having a positive effect on increasing ration consumption. This is similar to the study by Attia *et al*. (2017) on the use of turmeric in drinking water given at a dose of 0.5% was unable to improve broiler chicken ration consumption. However, this is not the case with the study by Hashemi *et al*. (2008) where the administration of medicinal plant extracts consisting of ginger, Javanese turmeric, lesser galangal, and turmeric at a dose of 0.5% added to drinking water at a dose of 0.02–0.03% was able to improve ration consumption.

The results showed that the treatment did not affect the growth of chicken body weight (P>0.05). The value of body weight gain was also in line with the results of the average ration consumption which was not significantly different. This is in accordance with the opinion of Abouelezz *et al*. (2019), body weight gain has a relationship in line with ration consumption, because if ration consumption is not significantly different, the nutritional requirements of chickens to produce body weight gain are also not significantly different. In addition, the protein and energy content of the feed are the most important factors affecting body weight gain. This is in accordance with the opinion of Abouelezz *et al*. (2019) who stated that metabolic energy and protein contained in feed affect poultry feed consumption. The use of a combination of TCO has not shown a significant effect on activity in the digestive tract so that it does not affect the consumption of rations and body weight gain of broiler chickens, where the resulting feed conversion also does not show a significant difference. The best income over feed cost (IOFC) value was found in treatment T1, with a 4.9% higher profit percentage compared to T0. This was due to the higher weight of the chickens produced and the more efficient use of feed, resulting in a higher IOFC value. Therefore, administering *Terminalia catappa* L. leaf extract and orange waste at a dose of 3% can be recommended to broiler chickens because it has been proven to improve performance by demonstrating low feed conversion values and high IOFC values.

Mixed supplementation of TCO had no significant effect (P>0.05) on live weight parameters, one of the factors being feed consumption. Ration consumption supports the supply of nutrients to form body tissues and growth of live weight of broiler chickens (Bagno *et al*., 2021). The treatment given in this study did not have an effect up to the 7% level, suspected to be caused by the presence of bioactive substances in the extract that did not have a positive effect on increasing ration consumption. The administration of a mixture of TCO did not affect carcass weight

(P>0.05). This occurs because the bioactive substances, such as flavonoids contained in the TCO mixture, have not been able to improve muscle tissue growth as a carcass builder due to the inappropriate administration level. This is consistent with research by Ko *et al*. (2002) regarding the administration of herbal extracts, which showed that administering 10% Dayak onion extract in drinking water containing flavonoids is very effective in improving digestive performance. This occurred because ration consumption, live weight, and carcass weight did not show a significant effect. This is because consumption supports the process of nutrient absorption for body tissue formation, growth, and better carcass production, so that consumption can indirectly affect the carcass percentage obtained (Bagno *et al*., 2021). According to Biswas and Wakita *et al*. (2001), carcass percentage is influenced by body weight and ration consumption. Administration TCO in drinking water did not show a significant effect (P>0.05) on the ratio of breast and thigh meat in broiler chickens due to the low acidic content as an acidifier in TCO which still cannot provide a significant effect on live weight and carcass weight. Acidic compounds from orange waste that can function optimally in helping increase muscle tissue growth in broiler chickens is 1.2% (Szymczyk*et al*., 2001). Acid plays a role in acidifying the digestive tract and helps reduce the number of pathogenic bacteria and increases the growth of optimal lactic acid bacteria so that nutrient absorption increases, especially protein absorption (Kumar *et al*., 2017).

The similar moisture content between the control treatment (T0) and the extract mixture supplementation treatments (T1, T2, and T3) is likely due to the low dose level, which means the consumed bioactive substances were not yet able to affect the moisture content of broiler chicken meat. This is supported that administering a mixture of *Terminalia catappa* L. leaf extract and orange waste had no significant effect (P>0.05) on the protein content of broiler chicken meat. This difference in results may be due to the consumption of bioactive substances such as tannins in the mixture of *Terminalia catappa* L. leaf extract and orange waste. This aligns with the opinion of Choi and Kim (2020), who stated that tannins can act as antibacterials but can also act as antinutritional substances because they inhibit the absorption of nutrients, particularly protein, in the small intestine. According to Swallah *et al*. (2020), the presence of antinutritional substances such as tannins can inhibit the digestive process, thereby reducing protein absorption in the small intestine. The results of the study showed that the mixture of *Terminalia catappa* L. leaf extract and orange waste had no significant effect (P>0.05) on the fat content of broiler chicken meat, possibly due to the relatively low content of dissolved bioactive substances in the mixture of *Terminalia catappa* L. leaf extract and orange waste. 31 Research conducted by Septinar *et al*. (2021) stated that adding mangosteen peel powder to drinking water at a level of 3%, containing the same bioactive compound, saponin, did not significantly affect meat fat content. According to Hidayat *et al*. (2021), tannins, saponins, and flavonoids are known to reduce fat and cholesterol levels in meat and improve carcass quality in broiler chickens.

Conclusion

Phytobiotic feed additive from *Terminalia catappa* L. leaf extract and orange waste in drinking water did not enhance performance, carcass trait, and meat quality of broiler chicken. Administration in 3% level of mixture give a beneficial in highest body weight gain and most efficiency in feed convertion.

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Conflict of interest

The authors have no conflict of interest to declare.

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