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Research Article
Effects of *Zingiber officinale* Essential Oil as a Feed Additive on Zootechnical Performance and Some Biochemical Parameters in Broiler Chickens

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Abstract
Objective: To reduce problems induced by the use of antibiotics as feed additives in broiler diets and improve their digestive nutrient utilization capacity, the present study was set out to evaluate the effects of *Zingiber officinale* essential oil as feed additive on zootechnical performance and some biochemical parameters in broilers. **Materials and Methods:** The trial was conducted from January to June 2023 on 144 COBB 500 chicks (3-week-old with an average weight of 490±34.09 g). Chicks were divided into 4 groups of 36 birds each, in a completely randomized design. Each group was then subdivided into 3 sub-groups of 12 birds (6 males and 6 females), corresponding to the replicates. Within 28 days, the birds were gavaged with 0, 20, 40 and 60 µL of ginger rhizome essential oil per kg body weight corresponding to the 4 groups (LH0, LH20, LH40 and LH60, respectively). **Results:** Results indicated that live weight gain and average daily gain (56.09±2.21 g/day, 59.37±3.75 g/day 62.97±5.27 g/day and 64.83±3.66 g/day for LH0, LH20, LH40 and LH60, respectively) increased significantly ($p<0.05$) with increasing levels of *Zingiber officinale* essential oil on the one hand. On the other hand, the use of essential oil led to a decrease in the feed conversion ratio. No significant differences ($p<0.05$) were observed for feed consumption, carcass characteristics and biochemical parameters studied at any essential oil level compared to the control diet. In economic terms, a significant reduction ($p<0.05$) in the feed cost per kilogram of chicken live weight was recorded with the use of *Z. officinale* essential oil. **Conclusion:** Based on the results obtained, it can be concluded that the use of *Z. officinale* essential oil improved the zootechnical performance of broilers and could therefore be used as a feed additive in poultry farming specifically in broilers.

Key words: Biochemical parameters, broilers, plant extract, poultry feed, poultry production

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Over the past twenty years, global poultry numbers have increased while those of other species have grown at a much slower rate[1]. This is because poultry is the favourite meat for household menus, thanks to its low price and ease of production (short production cycle). So, to meet the ever-increasing demand, producers must reconcile chicken quality and price. Maximum productivity can only be achieved if the poultry farmer minimizes feed cost, which accounts for some 60-70% of production expenditure[2].

The Ministry of Livestock, Fisheries and Animal Industries reported that poultry meat production in Cameroon reached 52.6 thousand tons in 2021, up from 44.4 thousand tons, which is 18% higher than the last year 2020. Despite these efforts, the national production does not yet satisfy the population's demand[3]. In poultry production antibiotics were previously used as growth promoters, which improved growth by 3 to 10% and feed efficiency ratio by 3 to 5%. Since January 2006, European Union has banned the use of antibiotics in poultry production due to an increase in antibiotic resistance observed in both human and veterinary medicine. However, the cessation of their use has negatively affected the production, namely: deterioration in animal health, increase in mortality rates, drop in body weights, increase in feed conversion rates and consequently reduced the economic benefits of poultry farms[4].

These challenges have led to the development of numerous alternatives to growth-promoting antibiotics, including plant extracts such as essential oils, these oils are volatile and are highly concentrated in active molecules with diverse properties including antiparasitic, antifungal, antibacterial, anti-inflammatory, antioxidant and digestion-enhancing activities by stimulating endogenous enzymes[5-8]. In animal production, these properties are used to limit energy loss in favour of growth and reproduction. Given their zootechnical performance in recent years, their use has grown up considerably. Different essential oils have emerged, including ginger essential oil, which is enriched with flavonoids, phenolic compounds (gingerol, gingerol, gingerdione and shogaols), iron, magnesium, calcium and vitamin C[7-11]. In addition, Tchoffo *et al.*[12] indicated that female Japanese quail receiving 100 and 150 µL of ginger rhizome essential oil per kg of body weight by gavage significantly increased their fertility and the weight of chicks at hatching. Similarly, Mekuiko *et al.*[8] noted that the ability of Djallonké sheep to ingest dried matter, organic matter and a reduction in total cholesterol levels increased significantly when they received 100 and 200 mg of *Zingiber officinale* essential oil per kg of dry matter ingested. Also, The egg production of laying hens (Hy-Line W36) supplemented with ginger rhizome powder at 0.5 and 0.75% increased[13]. All these studies have shown the beneficial effects of ginger on animal production performance. In this context, the present study was conducted to evaluate the effects of ginger (*Z. officinale*) rhizome essential oil as a feed additive on zootechnical performance and some biochemical parameters in broilers.

MATERIALS AND METHODS

Study area: This study was conducted between January and June 2023 on a farm in the peri-urban area of Ngaoundere. In Ngaoundere municipality, the climate is humid tropical. It is characterized by an annual average rainfall of 1,500 mL. Peak rainfall is usually recorded in August. The average temperature is 22°C and diurnal temperature variations are very wide during the dry season. Total monthly evaporation is very high between December and March. It can reach 1,982.4 mm. Between June and September, however, it decreases very rapidly and stabilizes between 34.6 and 40.4 mm, before rising again rapidly to reach its maximum in February.

Experimental birds: A total of 144 one-day-old Cobb 500 chicks with an average weight of 42 g were used in this study over 49 days. They were reared in a single flock under standard broiler rearing conditions until 21 days of age. Birds were distributed in a completely randomized design that consisted of 4 groups of 36 chickens each, repeated 3 times with 12 (6 male and 6 female) chicks each. They were reared under the same conditions on a litter made of white wood shavings at a density of 20 chicks/m^2 at the starting phase (1-21 days) and 10 chickens/m^2 at the growth and finishing phase (22-49 days). Water and feed were provided to the animals *ad libitum*.

Sanitary protection: Two weeks before the arrival of chicks, the livestock building and various equipment were cleaned and disinfected using Javel and Cresyl solutions (20 mL per 1 litter of water). The floor and walls of the room was equally disinfected by applying calcium carbonate. After disinfection, a crawl space of two weeks was allowed before the introduction of the birds. The room and equipment used were cleaned daily.

Birds were vaccinated against Newcastle disease (Hitchner B1®) and infectious bronchitis (H120®) on the 4th day with a booster dose on the 18th day. The vaccine against Gumboro disease (IBA Gumboro®) was administered on the 11th day. From the second week, in drinking water,

Table 1: Experimental diet during the finishing phase (22-49 days)

Ingredients	Quantities (kg/100 kg)
Maize	58
Wheat bran	10
Soya bean cake	8
Groundnut seed cake	15
Concentrate (5%)	5
Oyster shells	3
Palm oil	1
Total	100
Analysis of nutritive values	
Moisture (%)	7.9
Dry matter (%)	92.1
Metabolizable energy (kcal/kg)	2910.70
crude ash (%)	6.8
Crude protein (%)	20.4
Fat (%)	5
Crude Fiber (%)	4.6
Starch (%)	37.9
Non nitrogenous extractive (%)	55.3

anticoccidial (Vetacox®) was administered three times per week. As soon as the birds entered the henhouse, they were given an anti-stress supplement via drinking water. Before and after vaccination, birds were weighed and transferred to the finisher house.

Plant material and essential oil extraction: Fresh and mature ginger rhizomes were obtained in December 2022 from Dang, Ngaoundere municipality, Cameroon. In order to extract essential oils, they were washed and crushed to release their tissues by hydro-distillation using the method described by Wang and Weller[14] and this process was done in the laboratory of Physiology and Animal Health of the Faculty of Agronomy and Agricultural Science, University of Dschang (Cameroon). After this, *Z. officinale* plant material is placed in an alembic and heated to 200°C with water. The intense heat released by the explosion of oil containing saccules of *Z. officinale* releases oil that spreads through water vapour. Oil water vapor was then channeled in a condenser and cooled to be liquefied again. At the end, essential oil was separated from water and dehydrated using anhydrous sodium sulphate and stored in a dark bottle away from light.

Experimental diet: Nutritional values of ingredients were considered when the experimental diet for broilers was formulated according to their needs and ages. The chemical composition of the diet was determined using the method of AOAC[15]. It was carried out at the Masterlab of Nutrico Company (Douala). The centesimal composition of ingredients and the chemical composition of the experimental diet are presented in Table 1.

Experimental design: A total of 144 3-week-old birds with an average weight of 490±34.09 g were divided in a completely randomized design consisting of 4 treatments (LH0, LH20, LH40 and LH60) of 36 birds each. Each group was subdivided into 3 sub-groups of 12 birds corresponding to treatment's repetitions. Feed was distributed twice a day at regular intervals, in the morning between 6 and 7 a.m. and in the evening between 4 and 5 p.m. Feed and water were provided *ad libitum* during the trial. The essential oil was distributed among birds by gavage. Each sub-group was regularly distributed throughout the henhouse. Birds in each group received one of the following treatments for 28 days:

- **Control group:** Consisting of 36 birds receiving a base diet without essential oil (LH0)
- **Group 1:** Consisting of 36 birds receiving a base diet with 20 µL of *Z. officinale* essential oil/kg body weight/day (LH20)
- **Group 2:** Consisting of 36 birds receiving base diet with 40 µL of *Z. officinale* essential oil/kg body weight/day (LH40)
- **Group 3:** Consisting of 36 birds receiving base diet with 60 µL of *Z. officinale* essential oil/kg body weight/day (LH60)

Data collection:

Growth performance: every 7 days, feed intake, live weight, average weight gain and feed conversion ratio were recorded. Feed was weighed and distributed to animals daily and at the end of each week, the leftovers were collected and weighed. Feed intake was calculated as the difference between the quantity served and the leftover in each experimental group. At the beginning of the trial and every 7 days thereafter, birds in each experimental group were weighed and weekly weight gain was calculated as the difference between two consecutive week's weights. Feed conversion ratio (FCR) was calculated as the ratio of the amount of feed intake during the week as well as the weight gain of the same week.

Carcass characteristics: After 49 days, 12 chickens (06 males and 06 females) per treatment were randomly selected and fasted for 24 hrs, then weighed, slaughtered, plucked and eviscerated for carcass evaluation[16]. The relative weight of each organ (gizzard, liver, heart, legs, abdominal fat and intestinal weight) was calculated by dividing the weight of the carcass or that of corresponding organs by the live body weight of the bird.

Biochemical parameters: At the end of the trial, blood samples were obtained from 24 birds (2 per sub-group) by puncture of the jugular vein and shifted to labelled dry tubes test. Serum samples were collected after blood centrifugation and frozen at -20°C until the day of analyses. They were carried out at the SUNSHINE laboratory (in the Ngaoundere town). All the biochemical analyses were carried out using commercial kits (RANDOX for glucose, total protein and CHOLESTEROL LS for cholesterol). The experimental protocol which permitted the determination of the serum concentration of glucose, total protein and cholesterol was described by the manufacturer of each kit. Proportioning was colorimetric and the readings of absorbance were done using a spectrophotometer.

Evaluation of feed production cost: Based on the average feed conversion ratio for each treatment, the cost of feed production per kg of live weight was evaluated during the growth and finishing periods (4th and 7th week). The feed cost per kg live weight of chicken was estimated by multiplying the price per kg feed by the feed conversion ratio (FCR).

$$Cx\ (cfaF) = FCRx \times (cfaF)$$

Cx = Cost per kg live weight (cfaF)
FCRx = Feed conversion ratio
Px = Price per kg diet (cfaF)
x = Period considered

Data analysis: Data were analyzed using one-way (level of essential oil) analysis of variance (ANOVA). When there was a significant difference between treatments, Duncan's multiple range test at a 5% threshold was used to separate means. SPSS 20.0 (Statistical Package of Social Sciences) software was used for the analyses.

RESULTS

Effects of *Z. officinale* essential oil on growth performance and carcass characteristics of broilers: Table 2 shows that the use of *Z. officinale* essential oil as a feed additive in broiler diet did not significantly influence the feed consumption and carcass characteristics independently at different levels of incorporation. However, birds receiving 60 µL essential oil/kg body weight had the highest carcass weight and yield values. The broilers receiving essential oil of *Z. officinale* showed a significant improvement ($p<0.05$) in average daily weight gain (ADWG) as compared to the control. However, the highest ADWG was recorded in birds receiving 40 and 60 µL of essential oil/kg live weigh. On the other hand, the lowest ADWG was recorded in the control group. Furthermore, the feed conversion ratio of birds receiving 40 and 60 µL of essential oil/kg body weight remained comparable and significantly ($p<0.05$) lower than that of the control group.

Effects of *Zingiber officinale* essential oil on biochemical parameters of broiler chickens: Table 3 shows that the use of ginger rhizome essential oil in the diet had no significant effect ($p>0.05$) on all biochemical parameters studied in broilers. However, in comparison with the control group,

Table 2: Effects of *Z. officinale* essential oil on growth performance and carcass characteristics of broilers

	Diets				
	LH 0	LH 20	LH 40	LH 60	p-value
Feed intake (g/day)	118.03±1.79	115.00±5.05	112.82±1.42	121.87±9.59	0.286
ADWG (g/day)	56.09±2.11^{a}	59.37±3.75^{ab}	62.97±5.27^{ab}	64.83±3.66^{b}	0.034
FCR	2.16±0.12^{a}	1.95±0.11^{ab}	1.82±0.08^{b}	1.83±0.11^{b}	0.015
Carcass weight (g)	1545.00±17.00	1468.00±10.28	1481.00±21.51	1750.33±18.38	0.692
Carcass yield (%)	74.33±1.52	73.33±0.57	68.33±5.85	75.67±3.05	0.160

^{a,b}Means within line with different superscripts differ at $p<0.05$, ADWG: Average daily weigh gain, FCR : Feed conversion ratio, LH0: Control (0% additive), LH20: Control diet containing 20 µL, LH40: Control diet +40 µL, LH60: Control diet +60 µL of *Z. officinale* essential oil/kg body weight, respectively.

Table 3: Effects of *Z. officinale* essential oil on biochemical parameters of broilers

	Diets				
Biochemical parameters	LH 0	LH 20	LH 40	LH 60	p-value
Total cholesterol (mg/dL)	131.15±5.53	122.37±0.70	118.960±2.52	118.49±3.06	0.501
Glucose (mg/dL)	308.12±4.11	303.00±3.10	300.360±7.83	300.74±0.95	0.203
Total Protein (mg/dL)	2.66±0.06	2.72±0.03	2.791±0.03	2.69±0.09	0.267

LH0: Control (0% additive), LH20: Control diet containing 20 µL, LH40: Control diet +40 µL, LH60: Control diet +60 µL of *Z. officinale* essential oil/kg body weight, respectively

Table 4: Relative proportion of organs according to treatment

Organs	Treatments	Proportion of organs (%)	p-value
Gizzard	LT	1.990±0.11	0.189
	LH20	1.900±0.42	
	LH40	2.060±0.32	
	LH60	2.030±0.03	
Head	LT	2.460±0.12	0.912
	LH20	2.650±0.42	
	LH40	2.280±0.35	
	LH60	2.380±0.10	
Legs	LT	4.640±0.26	1.004
	LH20	4.610±0.55	
	LH40	4.096±0.60	
	LH60	4.530±0.18	
Liver	LT	1.890±0.31	0.064
	LH20	1.830±0.03	
	LH40	1.840±0.35	
	LH60	1.810±0.10	
Abdominal fat	LT	1.120±0.18	1.144
	LH20	1.280±0.27	
	LH40	1.490±0.27	
	LH60	1.230±0.26	
Heart	LT	0.410±0.02	1.450
	LH20	0.460±0.05	
	LH40	0.470±0.01	
	LH60	0.460±0±0.03	
Intestinal mass	LT	5.430±1.05	1.330
	LH20	4.620±0.24	
	LH40	4.580±1.06	
	LH60	5.610±0.51	

LH0: Control (0% additive), LH20: Control diet containing 20 μL, LH40: Control diet +40 μL, LH60: Control diet +60 μL of *Z. officinale* essential oil/kg body weight, respectively

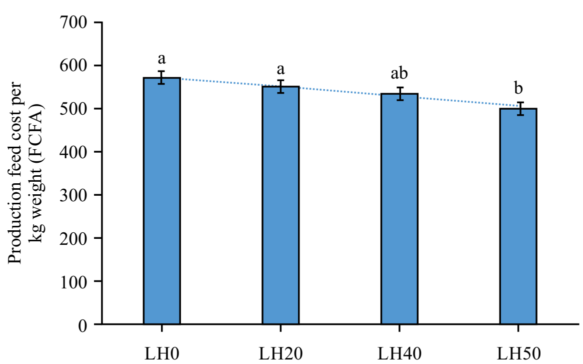

Fig. 1: Feed production costs according to treatments
^{a,b}Means with different superscripts differ at p<0.05, LH0: Control (0% additive); LH20: Control diet containing 20 μL, LH40: Control diet +40 μL, LH60: Control diet +60 μL of *Z. officinale* essential oil/kg body weight, respectively

birds receiving essential oil had a slight reduction in total cholesterol, although no significant differences (p>0.05) were observed throughout the study period.

Effects of *Zingiber officinale* essential oil on the relative proportion of organs: No significant difference (p>0.05) was recorded between the relative weight of different organs irrespective of treatment (Table 4).

Effects of *Zingiber officinale* essential oil on feed production costs: Figure 1 shows that the addition of *Z. officinale* essential oil significantly (p<0.05) influenced the feed production cost of broilers in the growing and finishing phases. The cost of producing 1 kg of feed per live weight was higher for animals in the control group than for those whose basic diet was supplemented with essential oil. On the other hand, the lowest production costs were recorded in the LH60 groups.

DISCUSSION

The essential oil of ginger rhizomes administered by gavage to broilers of the Cobb 500 strain as a feed additive did not significantly affect the feed consumption of the broilers whatever the dose used. These results are in line with the findings of Akbarian *et al.*[13], who reported that the addition of ginger rhizome essential oil to the diet of Japanese quail had no significant effect on their feed intake. In a similar study, Saleh *et al.*[17] added ginger rhizome powder at the rates of 0.25, 0.5 and 0.75% to the diet of Hy-Line W36 layers and did not observe any significant difference in feed intake. These results could be explained by the doses used, which did not significantly affect feed intake capacity.

Experimental results showed a significant improvement in the average daily weight gain and total weight gain of Cobb 500 broilers receiving a diet supplemented with the essential oil of *Z. officinale* rhizomes. Microorganisms in the intestinal flora might be responsible for the better utilization of nutrients in the ration. Due to its antimicrobial activity the powdered of *Z. officinale* rhizomes as an additive in broiler rations inhibits the growth of harmful bacteria such as *E. coli* in the intestinal tract, thus improving nutrient utilization[18]. Similar results were obtained by Kairalla *et al.*[19], who used ginger rhizome powder at 0, 0.2, 0.4 and 0.6% incorporation rates in the diet of Ross 308 chickens. Umatiya *et al.*[20] also obtained similar results who added a mixture of the aqueous extracts of ginger rhizomes (0.1%) and garlic (0.2%) to the drinking water of broilers of the Cobb 400 strain and recorded significantly higher average daily gains and total weight gain compared to the control group. On the other hand, Dieumou *et al.*[5] added 10, 20 and 40 mg essential oil of *Z. officinale* rhizome per kg body weight per day in the diet of Arbor Acres strain and obtained opposite results. This difference in results could be attributed to the incorporation rates or to the form in which ginger is incorporated into the diet; or it could be related to the strains of subjects used, which vary from one study to another.

Gavage of Cobb 500 broilers with the essential oil of ginger rhizomes for 28 days significantly influenced the feed conversion ratio. These results are in line with the findings of Khan *et al.*[21], who used aqueous ginger rhizome extracts at the rate of 0.4 and 0.6% in the drinking water of Ross 208 broilers. Similarly, Akbarian *et al.*[13] obtained comparable results using ginger rhizome essential oil at doses of 30 and 40 mg/kg dry matter in male broilers selected at twenty-one days of age. Opposite results were obtained by Ampode[11] in layers who used the doses of 60 and 100 µL of ginger essential oil per kg of feed. Much higher feed conversion ratios had been recorded by Tchoffo *et al.*[12] in Japanese quail using essential oil from ginger rhizomes at concentrations of 50; 100 and 150 µL/kg body weight by gavage. Variations between these results could be due to the doses used, the form in which the additive was presented to the subjects (powder, essential oil, aqueous extract......), the administration method, poultry strains used as well as experimental conditions (duration of treatments, rearing conditions, varieties of ginger used...).

The use of ginger essential oil at any dose had no significant effect on of the biochemical parameters studied in the subjects. Throughout the study, a non-significant reduction in total serum cholesterol levels was observed in broilers receiving ginger essential oil, compared with the control group. Similar outcomes were recorded by Tchoffo *et al.*[12] in Japanese quails using ginger rhizome essential oil at concentrations of 50, 100 and 150 µL/kg body weight by gavage. These results can be explained by the fact that ginger is thought to exert a hypocholesterolemic action through the coenzyme A (HMGCoA) involved in cholesterol synthesis.

The results of the present study revealed that the administration of the essential oil at the doses considered had no significant effects on carcass yield and the relative proportions of the various organs. These results are in agreement with those of Zhai *et al.*[22] who added ginger rhizome powder in the ration of arbor-acres broilers at a dose of 5 g/kg dry matter. Dieumou *et al.*[5] added 10, 20 and 40 mg of *Z. officinale* rhizome essential oil per kg live weight per day in the diet of Arbor Acres broilers and found that carcass yield was not affected but a reduction in head, gizzard and abdominal fat proportions compared with the control batch was observed.

The cost of broiler feed production was significantly lower for birds gavaged with ginger essential oil than for control birds. This low cost of feed production is thought to be linked to the lower feed conversion ratio recorded in the broiler receiving these diets. According to financial analysis, live weight production cost of subjects gavaged with ginger essential oil was much lower than that of control subjects. These production costs are lower than those obtained by Kairalla *et al.*[19] who incorporated ginger and garlic powder into the diet of Ross 308 and Cobb 400 strain chickens respectively. These differences in the production cost can be linked to the variations in prices of the ingredients, ginger doses as well as the broiler strains used.

CONCLUSION

Total live weight gain, average daily gain, feed conversion ratio and feed production cost of growing-finishing broilers were significantly improved by using ginger (*Z. officinale*) rhizome essential oil in growing-finishing broilers. Feed consumption, carcass weight and yield, relative organ weights and biochemical parameters were not significantly influenced by using *Z. officinale* essential oil. Although the results of this study were satisfactory with 40 and 60µl of essential oil per kg of body weight, it would be envisaged to extract the bioactive molecules from this oil and assess their individual effects on poultry production performances.

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