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Effects of *Capsicum chinense* Phytogenic Additive on Growth Performance and Breast Muscle Pigmentation in Broiler Chickens

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ABSTRACT

The widespread use of antibiotic growth promoters (AGPs) in poultry production has contributed to the emergence of antimicrobial resistance, increasing the need for effective natural alternatives. The bioactive phenolic alkaloid present in *Capsicum* species has demonstrated antimicrobial, antioxidant, and digestive-stimulating properties. The present study aimed to evaluate the effects of a phytogenic additive derived from *Capsicum chinense* (oleoresin) on growth performance, survival rate, and breast muscle pigmentation in broiler chickens. A total of 2,400 one-day-old male broiler chickens with an initial body weight of 35.4 ± 0.43 grams were randomly allocated to 48 pens (50 chickens per pen) and assigned to four dietary treatment groups with 12 replicates each. The treatments included a basal balanced feed (BF) supplemented with 60 ppm of zinc bacitracin (T0). The second group received the BF with 300 g of *capsicum chinense* additives (ACC) per ton of feed (T300), the third group received the BF with 600 g of ACC per ton of feed (T600), and the fourth group received the BF with 1000 g of ACC per ton of feed (T1000). Growth performance parameters, including live weight (LW), average weight gain (AWG), feed intake, feed conversion ratio (FCR), and survival rate, were evaluated over a 42-day production period. At slaughter on day 42, breast skin pigmentation was evaluated using instrumental colorimetry based on the CIE Lab* system. The supplementation of *Capsicum chinense* significantly improved LW, AWG, and FCR during the first 21 days of age, with the best performance observed in Group T300 compared to the control group. Feed intake and survival rate were not significantly affected by the dietary treatments, although Group T600 experienced a lower survival rate. The current results indicated no significant differences in colorimetric parameters among dietary treatments, although Group T300 exhibited the highest redness (a*) values. The present findings indicated that supplementation with 300 g/ton of *Capsicum chinense* can improve growth performance in broiler chickens at 21 days of age, comparable to that of the group that received antibiotic growth promoters, without adversely affecting carcass pigmentation.

Keywords: Antibiotic, Efficiency, Feed intake, Phytogenic compound

INTRODUCTION

The use of antibiotic growth promoters (AGPs) in animal production was introduced in the mid-twentieth century, following significant improvements in feed conversion efficiency and productivity (Moore et al., 1946). However, a few years after the use of AGPs, initial signs of bacterial resistance were observed (Starr and Reynolds, 1951), prompting the development of international regulatory frameworks to restrict or eliminate their use. Evidence from recent decades, including global surveillance studies and meta-analyses (Tang et al., 2022), demonstrated that the non-therapeutic use of antimicrobials in animals promoted the emergence, persistence, and dissemination of antibiotic resistance genes that are significant for human health (Van Boeckel et al., 2015; Laxminarayan et al., 2020). The transfer of these genes to zoonotic pathogens, such as *Salmonella* spp., *Campylobacter* spp., and *Escherichia coli*, has contributed to higher rates of antimicrobial resistance, prolonged hospital stays, and reduced available therapeutic options (Döhne et al., 2012).

In Colombia, the regulation of AGP use in animal feed started in 1984 with the Colombian Agricultural

Institute's Resolution 1966 (ICA, 1984). In 1995, the use of three AGPs, including furazolidone, nitrofurazone, and furaltadone, in animal diets was officially banned (ICA, 1995). This restriction was later expanded to include two more substances (ICA, 2018; 2024). These regulations permitted the use of AGP in countries that lack therapeutic use of antibiotics in humans or animals, thereby increasing the risk of cross-resistance and its potential impacts on the antimicrobial treatments in veterinary and human medicine.

The utilization of AGPs was definitively banned in the European Economic Community at the beginning of this century. Regulation (EC) No. 1831/2003, enacted by the European Parliament and the Council of the European Union, emphasized the need to eliminate the use of AGPs that were or could be used in human or veterinary medicine. The interval between the enactment of the regulation and its implementation (approximately three years) was enough to replace AGP with alternatives such as acidifiers, phytochemicals, probiotics, prebiotics, and phytogenic compounds, thereby minimizing negative impacts on animal health (Rahman et al., 2022; Wickramasuriya et al., 2024). Therefore, considerable effort is now focused on finding effective alternatives to AGPs that preserve zootechnical performance while avoiding adverse side effects (AbdEl-Hack et al., 2022).

Among natural alternatives for AGPs, capsaicin has emerged as a promising replacement in broiler chicken nutrition (Zhang et al., 2025). Capsaicin is a phenolic alkaloid extracted from chili pepper and can constitute up to 70% of the total capsaicinoid content of the genus *Capsicum* (Wang et al., 2021; Castaño et al., 2025). Although more than 30 *Capsicum* species have been identified, the most globally cultivated include *Capsicum annuum* L., *Capsicum baccatum*, *Capsicum pubescens*, *Capsicum frutescens*, and *Capsicum chinense* (Ortiz et al., 2010; Bosland and Votava, 2012; Mňahončáková et al., 2021). *Capsicum chinense* is one of the most commercially available species in Colombia for human consumption and is commonly known as the habanero pepper (Romero, 2018).

The biological activity of capsaicin and related capsaicinoids used in animal nutrition has been associated with enhanced intestinal morphology (Liu et al., 2021), improved nutrient utilization (Herrero-Encinas et al., 2023), increased antioxidant and immune responses (Liu et al., 2021), protection of gut integrity under inflammatory challenge conditions (Nunes et al., 2025), and improvement of the structure and functionality of the gastrointestinal tract (Zhang et al., 2024), thereby supporting their role as functional alternatives to AGPs. Lipid compounds such as carotenoids have been identified in *Capsicum* (Giuffrida et al., 2014). Capsanthin and capsorubin are present at higher concentrations in the extractable oleoresin of the fruit, which is responsible for the red/orange coloration of *Capsicum*, and are used as natural colorants in feeds to influence skin, meat, or egg yolk pigmentation (Martín et al., 2006).

Considering the increasing interest in promoting sustainability and enhancing the value of agricultural co-products in the food industry, countries such as China (Xiao et al., 2025), India (Phisitaukara et al., 2025), and Brazil (Nacimento et al., 2020) have developed additives for poultry from oleoresins derived from chili pepper. These additives are used at different dosages of capsaicinoids in animal feed, depending on the type of extract and formulation. While chili pepper (*Capsicum spp.*) exhibited significant potential in Colombia, its effectiveness as an alternative to AGPs in balanced feed formulations requires further evaluation.

The present study aimed to evaluate the effects of a phytogenic additive derived from *Capsicum chinense* (oleoresin) on growth performance, survival rate, and breast skin pigmentation in broiler chickens, and to assess its potential as a natural alternative to AGPs under commercial production conditions.

MATERIALS AND METHODS

Ethical approval

The experimental animals were handled in accordance with the Code of Good Poultry Practices (FENAVI–FONAV, 2011), and the experimental methodology was reviewed and approved by the Institutional Committee on Ethics for the Care and Use of Experimental Animals of ICESI University at Cali, Colombia (CIECUAE /2023).

Study location

The present study was carried out at the Nirvana Poultry Farm of Operadora Avícola, in the municipality of Caldas (Antioquia), at 1780 meters above sea level, with an average temperature of 19°C and a mean annual precipitation of 3000 mm, located in the premontane rainforest ecological zone (Espinal, 1992).

Preparation of *Capsicum chinense* additive

Commercial habanero peppers (*Capsicum chinense Jacq*.), provided by Hugo Restrepo and Cía S.A. (Yumbo, Valle del Cauca, Colombia), served as the source material for preparing the plant matter and chili paste used to formulate the additive. The peduncles were removed, and the whole fruits were homogenized for five minutes to obtain a chili paste containing placenta, seeds, and pericarp. The paste was dried in a convection oven at 60°C for three days, then ground in an industrial mill to obtain a dry, homogeneous chili powder (Avilés-Betanzos et al., 2023). The oleoresin was extracted from dry chili powder using a biomass to solvent ratio of 1:5, with 96% bioethanol in a conventional extraction process. The mixture was kept at 85°C under continuous stirring at 142.5 rpm until the extraction process was complete. The oleoresin was then dried and converted into a free-flowing powder to produce the granular additive with a specific capsaicinoid concentration, which was used as a diagnostic element for quality and reproducibility (Santamaría et al., 2000).

Animals

A total of 2,400 day-old male ROSS 308 AP genetic line broiler chickens, obtained from AVIAGEN Colombia S.A. (Ibagué, Tolima, Colombia), were utilized for the present study. The chickens were randomly assigned to 48 pens measuring 44 m², with 50 chickens per pen, resulting in 12 replicate pens per treatment. The bedding in each pen consisted of approximately 10 cm of previously disinfected wood shavings. One bell drinker and one manual feeder were assigned to each pen. The initial live weight of the chickens was 35.4 g ± 0.42 grams. From day 1 to day 7, the pens were maintained at 28.2 ± 0.2°C using infrared heaters. Between 8 and 14 days of age, the ambient temperature in the pens was gradually reduced to 22°C and subsequently maintained at 20 ± 1.5 °C until the end of the trial. Humidity was between 65 to 75% during the trial. The chickens were exposed to 24 hours of light on the first day. This was reduced to 16 hours of light until day 21, then increased to 23 hours of light until day 35, and remained at 23 hours until day 42. The chickens were vaccinated at birth against Gumboro, Newcastle, Marek, and Infectious Bronchitis (Boehringer Ingelheim S.A., Colombia) at AVIAGEN Colombia S.A., and received the second Newcastle (Colombia) dose at 10 days old.

Sample size

The sample size was calculated based on the average weight gain (AWG) following standard procedures for statistical power analysis in experimental studies (Zimmer et al., 2024). The calculation used a significance level (α) of 0.05 with two-sided tests, an expected AWG of 67.3 g at 42 days, and a standard deviation (SD) of 3.4 g (Gonçalves et al., 2022). Based on these parameters, 12 pens per treatment were required to detect a minimum difference of 1.05 × SD with 80% statistical power (Georgiev, 2025).

Study design

To assess the impact of the Capsicum chinense Jacq. Supplement, formulated as outlined above, on broiler growth performance, four experimental diets were tested across the starter (days 1-7), grower (days 8-21), and finisher (days 22-42) periods. The control group consisted of a balanced feed (BF) supplemented with 60 ppm zinc bacitracin (T0), representing a conventional commercial broiler diet without phytogenic additives. This inclusion level was selected as an intermediate dose within the range reported in previous studies (Ahiwe et al., 2019; Kwak et al., 2022) and commonly used in commercial poultry production systems. The remaining groups received BF supplemented with 300 g (T300), 600 g (T600), or 1000 g (T1000) of *Capsicum chinense* additive (ACC) per ton of feed (Table 1). Each experimental diet was analyzed for crude protein, ether extract, crude fiber, ash, calcium, and phosphorus according to AOAC (2016) methods (Table 2). Feed refusals were collected daily to estimate intake, and the formulated diets were subsequently distributed according to the age and number of animals. The mean live weight (LW) of the chickens in each pen was recorded at 1, 7, 21, and 42 days of age. The AWG, feed intake (FI), and feed conversion ratio (FCR) were subsequently calculated on days 7, 21, and 42. The weekly counts of chickens were recorded, including those discarded due to health issues.

On day 43, the chickens were slaughtered at an authorized processing facility using stunning followed by cervical dislocation. This procedure adhered to established operating procedures in poultry facilities and was based on animal welfare principles outlined in Decree 1500 of 2007 by the Ministry of the Interior and Justice of the Republic of Colombia. Color measurement of breast skin was conducted at the processing facility after the de-feathering stage, in a controlled environment maintained at 10°C. For color measurement, a Konica Minolta CR400 reflectance colorimeter (KONICA MINOLTA Inc., Tokyo, Japan), configured with the D65 illuminant, was used. The parameters of lightness (L*), redness (a*), and yellowness (b*) were measured using the CIE (1978) system with the integrated software (Utility Software SR-C4w). Measurements were taken from the dorsal surface of breast fillets from 935 chickens (T0: 252 chickens, T300: 225 chickens, T600: 226 chickens, and T1000: 233 chickens), selecting areas without visible defects, such as bruises or spots.

Table 1. Composition of experimental diets containing *Capsicum chinense* for broiler chickens during the starter, grower, and finisher phases

Phase	Starter phase (1-7 days; %DM)				Grower phase (8-21 days; %DM)				Finisher phase (22-42 days; %DM)			
Treatments	**T0**	**T300**	**T600**	**T1000**	**T0**	**T300**	**T600**	**T1000**	**T0**	**T300**	**T600**	**T1000**
Animal fat	0.40	0.40	0.40	0.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Corn	61.00	60.94	60.99	61.06	60.94	61.07	61.03	60.90	62.62	62.59	62.54	62.41
Fish meal	2.00	2.00	2.00	2.00	-	-	-	-	-	-	-	-
Meat and bone meal	2.50	2.50	2.50	2.50	2.00	2.00	2.00	2.00	2.50	2.50	2.50	2.50
Processed soy (SBM + FFSB)	28.28	28.44	28.34	28.21	29.34	29.27	29.29	29.39	24.28	24.28	24.30	24.39
Sunflower meal 38%	2.00	2.00	2.00	2.00	3.00	3.00	3.00	3.00	6.00	6.00	6.00	6.00
Dicalcium phosphate	0.36	0.35	0.36	0.36	-	-	-	-	-	-	-	-
Calcium carbonate	0.40	0.40	0.40	0.40	0.80	0.80	0.80	0.80	0.40	0.40	0.40	0.40
Salt	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Premix*	1.73	1.61	1.62	1.63	1.60	1.50	1.50	1.50	1.59	1.59	1.59	1.59
L-Lysine	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.91	0.91	0.91	0.91
DL-Methionine	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.50	0.50	0.50	0.50
ACC	-	0.03	0.06	0.10	-	0.03	0.06	0.10	-	0.03	0.06	0.10

SBM: Soybean meal, FFSB: Full-fat soybean, ACC: Additive of *Capsicum Chinese*, T0: Balanced feed + AGP, T300: Balanced feed + 300 g/Ton of ACC, T600: Balanced feed + 600 g/Ton of ACC, and T1000: Balanced feed + 1000 g/Ton of ACC. * The mineral-vitamin premix was included in the experimental diets according to Aviagen Ross broiler recommendations, with supplementation adjusted by feeding phase (pre-starter, starter, and grower/finisher). The premix supplied copper (16 mg/kg), iodine (1.25 mg/kg), iron (20 mg/kg), selenium (0.30 mg/kg), manganese (120 mg/kg), and zinc (120 mg/kg) across all phases, whereas vitamin inclusion levels varied by phase as follows: Vitamin A, 13,000, 11,000, and 10,000 IU/kg, Vitamin D3, 5,000, 4,500, and 4,000 IU/kg, Vitamin E, 80, 65, and 55 IU/kg, vitamin K, 4.0, 3.6, and 3.2 mg/kg, thiamine, 5, 4, and 3 mg/kg, Riboflavin, 9, 8, and 7 mg/kg, Niacin, 70, 65, and 50 mg/kg, Pantothenic acid, 25, 20, and 15 mg/kg, Pyridoxine, 5, 4, and 3 mg/kg, Biotin, 0.35, 0.28, and 0.22 mg/kg, Folic acid, 2.5, 2.0, and 1.8 mg/kg, Vitamin B12, 0.02, 0.018, and 0.016 mg/kg, Choline chloride to provide minimum total choline levels of 1700, 1600, and 1500 mg/kg for pre-starter, starter, and grower/finisher diets, respectively.

Table 2. Chemical composition of the experimental diets formulated for broiler chickens during 42 days

Phase / Percentage of dry matter	Treatment	CP (%)	EE (%)	CF (%)	Ash (%)	Ca (%)	P (%)	ME (Kcal/kg)
Starter (1-7 days)	**T0**	22.35	3.65	3.74	5.03	0.90	0.63	2926
	T300	22.40	3.65	3.75	5.03	0.90	0.63	2928
	T600	22.37	3.65	3.74	5.03	0.90	0.63	2927
	T1000	22.33	3.65	3.74	5.02	0.90	0.63	2927
Grower (8-21 days)	**T0**	20.99	5.27	3.81	4.45	0.81	0.49	2955
	T300	21.00	5.24	3.81	4.45	0.80	0.49	2958
	T600	20.99	5.26	3.81	4.45	0.80	0.49	2957
	T1000	21.00	5.29	3.81	4.45	0.80	0.49	2955
Finisher (22-42 days)	**T0**	19.01	7.72	3.64	3.86	0.69	0.57	2978
	T300	19.01	7.72	3.63	3.86	0.70	0.51	2977
	T600	19.00	7.73	3.63	3.86	0.70	0.51	2975
	T1000	19.01	7.76	3.64	3.86	0.70	0.51	2973

CP: Crude protein, EE: Ether extract, CF: Crude fiber, Ca: Calcium, P: Available phosphorus, ME: Metabolizable energy

Statistical analysis

The response variables, production and survival (transformed by the logarithm of the original value), were analyzed using a completely randomized design in a factorial arrangement with PROC GLM in SAS v 8.0 (SAS Inc., 1999; Release 8.0, SAS Inst., Inc., Cary, NC, USA), using the following formula.

$Y_{ijk} = m + T_i + E_j + (T \times E)_{ij} + e_{ijk}$

where Y_{ij} is the response variable, m is the overall mean, T_i is the effect of the i-th treatment, E_j is the effect of age at the j-th measurement age, $(T \times E)_{ij}$ is the interaction between treatment and measurement age, and e_{ijk} is the residual variability associated with the k-th experimental unit. When statistical differences were found, a mean analysis was performed using Duncan's test using the SAS statistical software. The variables associated with breast skin color at 42 days were analyzed under a completely randomized design using the following formula.

$Y_{ij} = m + T_i + e_{ij}$

where Y_{ij} is the response variable, m is the overall mean, T_i is the effect of the i-th treatment, and e_{ij} is the residual variability associated with the j-th experimental unit. When statistical differences were found, a mean analysis was performed using Duncan's test. Statistical differences were considered significant at a p-value equal to or less than 5% ($p < 0.05$).

RESULTS

The effects of different levels of ACC supplementation on productive performance and survival rate are presented in Table 3. Food consumption and cumulative consumption during each evaluation period did not differ significantly ($p > 0.05$). The FCR was significantly lower in the ACC-supplemented groups compared to T0 during the first 21 days of age ($p < 0.05$). However, the average FCR was lower in Group T300. The survival rate decreased with age and was significantly lower in Group T600 than in other treatment groups ($p < 0.05$). The parameters associated with the breast skin color of the experimental animals at day 42 are presented in Table 4. Group T1000 exhibited significantly higher luminosity compared to groups T300 and T600 ($p < 0.05$), but did not differ significantly from Group T0 ($p > 0.05$). Additionally, Group T300 exhibited the highest red color intensity, whereas Group T600 displayed the lowest yellow color intensity among the treatment groups.

Table 3. Effects of supplementing *Capsicum chinense* on the productive performance and survival rate of broiler chickens from 1 to 42 days of age

Age (day)	Treatment	LW (g/bird)	AWG (g/bird/d)	AFI (g/bird/per)	CAFI (g/bird/per)	FCR (g:g)	Survival rate (%)
7	T0	152^{ab}	16.7^{ab}	141	140	1.20	99.5
7	T300	155^{a}	17.2^{a}	138	137	1.15	99.2
7	T600	148^{c}	16.1^{c}	133	133	1.18	98.7
7	T1000	151^{bc}	16.5^{bc}	136	136	1.18	98.3
21	T0	755^{b}	34.3^{b}	886	1026	1.43^{a}	99.2
21	T300	849^{a}	38.8^{a}	902	1040	1.28^{b}	98
21	T600	835^{a}	38.1^{a}	892	1025	1.28^{b}	95.5
21	T1000	836^{a}	38.2^{a}	899	1036	1.29^{b}	97.7
42	T0	2737	64.3	3277	4303	1.59	96.5
42	T300	2768	65.1	3295	4335	1.59	93.3
42	T600	2781	65.4	3358	4383	1.60	91
42	T1000	269	63.3	3251	4287	1.62	93.8
Average							
7	-	152	16.6	137	137	1.18	98.9
21	-	819	37.3	849	1031	1.32	97.4
42	-	2745	64.5	3296	4327	1.60	93.7
-	T0	1215^{B}	38.4^{C}	1434	1823	1.40^{B}	98.1^{A}
-	T300	1258^{A}	40.4^{A}	1445	1837	1.34^{A}	96.8^{A}
-	T600	1255^{A}	39.9^{AB}	1461	1847	1.36^{B}	95.1^{B}
-	T1000	1227^{AB}	39.3^{B}	1429	1819	1.36^{B}	96.6^{A}

LW: Live weight, AWG: Average weight gain, AFI: Average feed intake; CAFI: Cumulative average feed intake, FCR: Feed conversion rate, [a,b,c] The different superscript letters indicated a significant difference in the columns at $p < 0.05$ for each day. [A,B,C] The different superscript letters indicated a significant difference in the columns at $p < 0.05$ for mean parameters.

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Table 4. Effects of dietary *Capsicum chinense* supplementation on breast skin coloration of broiler chickens at 42 days of age

Experimental treatment (g/Ton)	Color parameters		
	L	a	b
T0	73.8 ± 2.22[ab]	4.15 ± 1.88[c]	7.13 ± 2.29[a]
T300	73.4 ± 2.15[b]	5.07 ± 2.13[a]	7.33 ± 2.04[a]
T600	73.6 ± 2.17[b]	4.68 ± 2.14[b]	6.64 ± 1.99[b]
T1000	74.1 ± 2.12[a]	4.51 ± 1.96[b]	7.45 ± 2.13[a]

L: Luminance, a: Red color intensity; b: Yellow color intensity. Data are presented as Mean ± standard deviation. [a,b,] The different superscript letters indicated a significant difference in the column at $p < 0.05$.

DISCUSSION

The daily AWG and LW increased through 21 days of age in chickens fed ACC, indicating that *Capsicum chinense* could be a more effective alternative to AGP. Additionally, Liu et al. (2021) reported higher AWG up to 21 days of age in broiler chickens fed a diet supplemented with *Capsicum* extract, compared to those receiving AGP. Consistent with the current findings, Liu et al. (2021) observed that after 21 days of age, there were no remarkable differences in AWG among different treatment groups. These results were attributed to the fact that *Capsicum annuum* extract elicited an immune response in the gastrointestinal tract similar to that produced by AGP. These mechanisms decreased cytokines (TNF-α and IL-1β) and produced effects similar to those of chlortetracycline, thereby reducing inflammation and supporting intestinal health. Furthermore, Afolabi et al. (2017) demonstrated that adding *Capsicum annuum* meal to chickens' diets improved feed conversion efficiency by increasing FI and weight gain. Similarly, Zanotto et al. (2023) reported improved feed efficiency in turkeys supplemented with *Capsicum annuum* extract, which was attributed to the reduced FI without adversely affecting weight gain.

The natural origin of *Capsicum* suggested that it would not cause adverse effects in animals or humans. This beneficial impact was particularly striking during the initial weeks of life, a crucial period marked by rapid growth of the gastrointestinal system (Sklan, 2002) and maturation of the enteric immune system (dos Santos et al., 2020; Wickramasuriya et al., 2022). There is limited evidence indicating that the initial posthatch phase is a crucial period in broiler chickens' development, during which rapid gastrointestinal maturation occurs. This phase includes the initiation of nutrient transporter expression, the proliferation and differentiation of stem cells, and the activity of secretory cells, all of which establish the foundation for long-term immunity, growth, metabolism, and overall health (Ravindran and Abdollahi, 2021).

In contrast to the present findings, El-Deek et al. (2012) observed no differences in daily weight gain between diets supplemented with AGPs and those supplemented with *Capsicum annuum* extract over 42 days, indicating that *Capsicum annuum* extract was adequately replaced by AGP without compromising animal growth. Although there were no improvements in AWG, El-Deek et al. (2012) reported enhanced feed conversion efficiency up to 21 days in chickens given *Capsicum annuum* extract. This effect was associated with a decrease in FI without any adverse effects on AWG. The differences between the present results and those of El-Deek et al. (2012) might be due to differences in the *Capsicum* extract used, the quantity included in the diet, and the experimental conditions. A notable enhancement in FCR was observed in the groups treated with ACC during the initial three weeks. This improvement was associated with an increase in AWG rather than a reduction in FI. This effect was likely due to the positive impact of *Capsicum chinense* extract on preserving the health and integrity of the gastrointestinal epithelium, thereby improving nutrient absorption and supporting the animals' growth requirements (Afolabi et al., 2017; Liu et al., 2021). Similarly, El-Deek et al. (2012) reported no differences in cumulative feed conversion at 42 days between chickens fed *Capsicum annuum* extract and those receiving AGP.

Due to the presence of carotenoids in ACC, it was expected to have a positive effect on the skin coloration of supplemented animals, which is an important economic trait in the broiler chicken industry (Jácome et al., 2024). In the present experiment, the a* (red) to b* (yellow) color intensity ratio in chicken breast skin at 42 days aligned with the findings of Castañeda et al. (2005) and Sirri et al. (2010). However, the effect of ACC supplementation was observed only in red color (a* value), particularly in chickens that received 300 g of ACC. In contrast, Liu et al. (2021) found that *Capsicum annuum* extract primarily increased meat brightness in broiler chickens without altering red or yellow color parameters.

It is believed that red skin coloration in broiler chickens is an unreliable indicator of the effects of natural or artificial colorants because it can be mistaken for superficial blood vessels when observed *in vivo* (Castañeda et al., 2005). However, this confusion did not occur in the current experiment. Afolabi et al. (2017) found no impact of *Capsicum* flour dietary supplementation on hemoglobin levels or hematocrit in broiler chickens. Consequently, the effect observed in the present study might be due to natural colorants that affect the color of breast skin. Extracts of the *Capsicum* genus are known to contain substantial levels of canthaxanthin, a carotenoid that imparts a reddish color in avian tissues (Moura et al., 2016; Giehl et al., 2024). This characteristic might explain the increase in the reddish color of the breast skin in chickens *in vivo* following dietary supplementation with *Capsicum* extract in the current study.

CONCLUSION

Dietary supplementation with *Capsicum chinense* extract improved broiler chicken performance, particularly during the first 21 days of age, by increasing live weight, weight gain, and feed conversion efficiency without altering feed intake. The present findings revealed a dose-dependent effect, with the 300 g/ton inclusion level of *Capsicum chinense* being the most effective dosage, offering an optimal balance of growth performance, feed efficiency, survival rate, and enhanced breast skin pigmentation. Conversely, higher inclusion levels adversely affected the survival rate. The current findings highlighted the potential of *Capsicum chinense* extract as a phytogenic alternative to AGPs for improving carcass quality. Nevertheless, further long-term and dose-response studies, including economic analyses and evaluations under commercial production conditions, are needed to elucidate the physiological and molecular mechanisms underlying intestinal health, immune function, and nutrient absorption and to confirm its practical applicability.

DECLARATIONS

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Authors' contributions

Ligia Jaimes and Alexandra Torres conceptualized the study, acquired funding, and managed the project. Laura Salgado and Yesica Alzate carried out the trial and curated the data. Ligia Jaimes analyzed the data and wrote the initial draft. Ligia Jaimes, Alexandra Torres, Laura Salgado, and Yesica Alzate reviewed and edited the manuscript. All authors have read and confirmed the final edition of the manuscript.

Availability of data and materials

The dataset is available from the corresponding author upon reasonable request.

Competing interests

The authors declared no conflicts of interest.

Ethical considerations

The authors declared that this study was conducted in accordance with ethical research standards, without participation in plagiarism, scientific misconduct, fabrication or falsification of data, intervention of entities or persons with an interest in the results, or duplicate submission or publication, and that all authors have given their consent for the publication of this article. The authors confirmed that no AI tools were used to conduct and prepare the present study.

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