frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 12 January 2026
DOI 10.3389/fsufs.2025.1651648

Check for updates

OPEN ACCESS

EDITED BY
Ahmed Kablan,
United States Agency for International Development, United States

REVIEWED BY
Oyegunle Emmanuel Oke,
Federal University of Agriculture, Abeokuta, Nigeria
Shivaun Leonard,
CutRight, United States

*CORRESPONDENCE
Gerardo Mendez-Zamora
✉ gerardo.mendezzm@uanl.edu.mx

RECEIVED 22 June 2025
REVISED 15 December 2025
ACCEPTED 16 December 2025
PUBLISHED 12 January 2026

CITATION
Cuevas JAS, Kawas JR, Rico-Costilla DS, Villalobos-Martínez YD, Ramos-Zayas Y, Aguirre-Arzola VE, Soto-Domínguez A, Sinagawa-García SR and Mendez-Zamora G (2026) Oregano oil supplementation over different production phases of grow-out and effects on broiler chicken breast meat yield, physicochemical traits, and quality.
Front. Sustain. Food Syst. 9:1651648.
doi: 10.3389/fsufs.2025.1651648

Oregano oil supplementation over different production phases of grow-out and effects on broiler chicken breast meat yield, physicochemical traits, and quality

Judith A. S. Cuevas[1,2], Jorge R. Kawas[1], Daniela S. Rico-Costilla[2], Yuri D. Villalobos-Martínez[3], Yareellys Ramos-Zayas[2], Victor E. Aguirre-Arzola[1], Adolfo Soto-Domínguez[4], Sugey R. Sinagawa-García[1] and Gerardo Mendez-Zamora[1]*

[1]Facultad de Agronomía, Universidad Autónoma de Nuevo León, General Escobedo, Nuevo León, Mexico, [2]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nuevo León, General Escobedo, Nuevo León, Mexico, [3]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Sinaloa, Culiacán, Sinaloa, Mexico, [4]Facultad de Medicina, Universidad Autónoma de Nuevo León, Monterrey, Nuevo León, Mexico

Introduction: Mexican oregano essential oil (OEO) has been shown to improve the breast meat quality of broilers when supplemented for 42 days. However, it is necessary to evaluate the effects of OEO supplementation during different grow-out phases on meat yield, physicochemical traits, and sensory quality of broiler breast meat.
Methods: The experiment considered three production phases (starter, 1-2 wk; grower, 3-4 wk; and finisher, 5-6 wk) to establish five treatments: OEO0, control diet without OEO (0 mg/kg); OEO12, diet with 100 mg/kg of OEO only in weeks 1 and 2; OEO34, diet with 100 mg/kg of OEO only in weeks 3 and 4; and OEO56, diet with 100 mg/kg of OEO only in weeks 5 and 6; and OEO16, diet with 100 mg/kg of OEO from weeks 1 to 6.
Results and Discussion: OEO supplementation significantly affected ($p < 0.05$) hot carcass yield and pH of the chicken breasts. Cooking loss was lower in OEO56. OEO0 resulted in the highest ($p < 0.05$) values for yellowness, saturation, and tonality, whereas these traits were lowest in OEO16. All OEO treatments (OEO12, OEO34, OEO56, and OEO16) increased ($p < 0.05$) shear force in chicken breast meat. Meat from OEO34 was the softest. OEO12 showed the lowest ($p < 0.05$) scores for juiciness and softness ($p < 0.05$), while OEO56 improved ($p < 0.05$) both attributes. These findings suggest that dietary inclusion of OEO at 100 mg/kg during the grower or finishing phases may be a suitable strategy to enhance processing yield, physicochemical properties, and sensory quality of broiler chicken breast meat.

KEYWORDS

breast meat, color, sensory, softness, texture

1 Introduction

In the poultry food industry, production phases (starter, grower, and finisher) are critical to ensure optimal physiological development and meet commercialization requirements (Babatunde et al., 2022). However, bacterial resistance to antimicrobials and the persistence of residues in the environment have become major concerns (Medeot et al., 2023). These issues pose risk to human health and limit antimicrobial use in poultry production. Consequently, the FAO and WHO have recommended a 50% reduction in antibiotic use (Mulchandani et al., 2023). In response, alternatives such as probiotics, organic acids, and essential oils from aromatic plants (EOAP) are being investigated.

EOAP has been shown to enhance production, feed digestibility, and chicken meat quality (Al-Hijazeen, 2021). EOAP from ajai, cinnamon, and oregano exhibit antimicrobial and antioxidant properties while strengthening the chicken immune system (Zeng et al., 2015; Chowdhury et al., 2018). For instance, Chang-Song et al. (2017) reported improved growth and antioxidant capacity in broilers fed 150 mg/kg of oregano powder from 1 to 41 days, while oregano essential oil (OEO) has demonstrated positive effects on productivity and meat quality (Al-Hijazeen, 2021).

In Mexico, OEO from *Lippia berlanderi* Schauer and *Poliomintha longiflora* Gray have been evaluated in broiler chickens, showing improvements in yield and quality (Méndez-Zamora et al., 2017; Cázares-Gallegos et al., 2019; Hernández-Coronado et al., 2019; Sánchez-Zamora et al., 2019). These studies, however, applied OEO continuously for 6 weeks (41 or 42 d) across all production phases. Continuous supplementation may not be necessary, as OEO could be effective when provided in one or two phases. Targeted supplementation may reduce costs while improving performance, yield, and meat quality.

Therefore, the objective of this study was to evaluate OEO supplementation during individual production phases and across to entire grow-out period, analyzing processing yield, physicochemical traits, and sensory quality of breast meat. This represents a first effort to assess OEO application across different stages of broiler production, potentially generating new hypothesis regarding metabolic pathways, growth, performance, and overall health, with implications for meat production and quality.

2 Materials and methods

The experiment was carried out at the Marin Farm of the Facultad de Agronomia (FA) of the Universidad Autonoma de Nuevo Leon (UANL), Marin, Nuevo Leon, Mexico. Marin is located at latitude 23° 53′, longitude −100° 2′W, and altitude of 400 m, with temperature ranging 18 °C to 32 °C, and annual precipitation of 600–800 mm (INEGI, 2025). The study (ID 046/2023) was approved by the bioethics and animal welfare committee of the Facultad de Medicina Veterinaria y Zootecnia, UANL. In addition, the guidelines of the Official Mexican Standard NOM-062-ZOO-1999 (1999) on the production, care, and use of laboratory animals were considered in the experiment.

2.1 Experimental design and diets

Mexican oregano oil from *Lippia berlandieri* Schauer was used in the study. A total of 300 1-d-old Ross-308 broiler chicks (49.40 ± 1.30 grams) were randomly assigned to five treatments with six replicates (pens) and 10 chicks for each. The experiment considered the production phases of grow-out (starter, 1–2 wk.; grower, 3–4 wk.; finisher, 5–6 wk) to establish the treatments: OEO_0, control diet without OEO (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; and OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6. The broiler chicks were allocated in iron pens (1.0 × 1.20 × 0.75 m) with a feeder, waterer, and fresh wood shavings. Feed and water were offered *ad libitum*. Oregano oil was extracted by steam distillation (Natural Solutions S.M.I., Ciudad Jimenez, Chihuahua, Mexico) from leaves of *L. berlandieri* Schauer and was composed of 76.16% carvacrol, 10.07% thymol, 2.01% α-pinene, and 9.05% other compounds (Clarus 600 and MS SQ8 Perkin Elmer Inc., Waltham, MA; Silva-Vázquez et al., 2017). The diets were formulated according to Ross-308 Broiler Nutrition Specifications (Aviagen®, 2022) and the nutrient compositions are presented in Table 1.

2.2 Meat yield

On day 42, bird slaughter was according to the Official Mexican Standard NOM-033-SAG/ZOO-2014 (2014) and Hernández-Coronado et al. (2019). A total of six chickens per replicate per treatment were randomly selected (n = 36 per treatment). After the slaughter and evisceration processes, slaughter weight (SW; weight was recorded before slaughter), hot carcass weight, and cold carcass weight were recorded to estimate the hot carcass yield (HCY; weight was recorded after slaughter; 36 °C) and cold carcass yield (CCY; weight was recorded after cold storage; 4 °C) according to Sánchez-Zamora et al. (2019). The carcasses were stored at 4 °C for 12 h. The breast was then separated from the carcass, and its weight was recorded to estimate the breast yield (BY) and to prepare them for quality analyses.

2.3 Physicochemical traits of breast meat

Physicochemical analysis of breast meat was performed on both sides (measured in each side of the breast). For pH, water holding capacity (WHC), and color, 12 samples per treatments were used [n = 12; 2 breasts per replicate (pen) per treatment]. The pH was measured with a potentiometer (Orion® 3-star Thermo Fisher Scientific, PA, USA) using a puncture electrode introduced directly into the samples.

The WHC was carried out in accordance with the modifications established by Méndez-Zamora et al. (2015) and Cázares-Gallegos et al. (2019). Breast meat samples were weighed (0.30 ± 0.01 g) and placed between two pieces of filter paper, next between acrylic-plastic plates (12 × 12 cm), applying a force of 4 kg for 20 min. The initial (Wi) and final weight (Wf) of samples were recorded to estimate the WHC:

$$\mathrm{WHC} = 100 - \left[\left(\mathrm{Wi} - \mathrm{Wf} \right) / \mathrm{Wi} \right] \times 100$$

Color was measured directly on the surface on both sides of the breast samples. A colorimeter (CR-400, Konica Minolta®, Tokyo, Japan) was

TABLE 1 Composition of diets (as fed basis) supplemented with oregano essential oil for the production phase of grow-out.

Ingredients	Diets (kg/ton)		
	Starter	Grower	Finisher
Corn, ground	523.06	572.92	623.42
Soybean meal	406.00	354.00	302.00
Soybean oil	26.00	32.00	35.00
Calcium carbonate	14.00	12.00	12.00
Monocalcium phosphate	9.75	8.50	7.25
Salt	4.10	4.40	4.40
L-lysine	1.18	1.00	1.00
DL-methionine	2.98	2.63	2.38
L-Threonine	0.43	0.05	0.05
Starter premix[1]	12.50		
Grower premix[2]		12.50	
Finisher premix[3]			12.50
Nutrient composition			
Moisture, %	10.34	11.82	11.79
ME, Kcal/kg[4]	3,004	3,081	3,146
Crude protein, %	23.00	21.40	19.00
Crude fiber, %	2.48	2.84	2.64
Ash, %	5.86	5.59	5.30
Crude fat, %	3.91	4.46	5.60
NDF, %	8.55	8.87	9.18
Calcium, %	1.07	0.97	0.88
Phosphorus, %	0.72	0.6	0.56
Magnesium, %	0.27	0.26	0.23
Lysine, %	1.43	1.28	1.17
Digestible lysine, %[4]	1.30	1.16	1.06
Methionine + cysteine, %[4]	1.05	0.98	0.9
Digestible methionine + cysteine, %[4]	0.98	0.91	0.84
Methionine, %[4]	0.68	0.63	0.58
Digestible methionine, %[4]	0.67	0.61	0.56
Threonine, %[4]	0.97	0.87	0.79
Digestible threonine, %[4]	0.86	0.77	0.69

[1]Starter premix: Mg, 4.64%; Ca, 4.25; Mn, 9,750 mg/kg; Zn, 8,888 mg/kg; Fe, 1,600 mg/kg; Cu, 1,300 mg/kg; I, 100 mg/kg; Se, 24 mg/kg; vitamin A, 1,040,000 IU/kg; vitamin D3, 400,000; vitamin E, 6,400 IU/kg; vitamin K3, 320 IU/kg; thiamin, 400 mg/kg; riboflavin, 720 mg/kg; niacin, 5,600 mg/kg; pantothenic acid, 2,000 mg/kg; pyridoxine, 400 mg/kg; Biotin, 80 mg/kg; folic acid, 200 mg/kg; vitamin B12, 1.6 mg/kg; choline, 136,000 mg/kg, Phytase, 80,000 PTU/kg.
[2]Grower premix: Mg, 4.64%%; Ca, 5.61%; Mn, 4,875 mg/kg; Zn, 4,444 mg/kg; Fe, 1,600 mg/kg; Cu, 650 mg/kg; I, 100 mg/kg; Se, 24 mg/kg; vitamin A, 880,000 IU/kg; vitamin D3, 360,000; vitamin E, 5,200 IU/kg; vitamin K3, 288 IU/kg; thiamin, 320 mg/kg; riboflavin, 640 mg/kg; niacin, 5,200 mg/kg; pantothenic acid, 1,600 mg/kg; pyridoxine, 320 mg/kg; Biotin, 22.4 mg/kg; folic acid, 160 mg/kg; vitamin B12, 1.44 mg/kg; choline, 128,000 mg/kg; Phytase, 80,000 PTU/kg.
[3]Finisher premix: Mg, 4.32%; Ca, 4.5%; Mn, 4,875 mg/kg; Zn, 4,444 mg/kg; Fe, 1,600 mg/kg; Cu, 650 mg/kg; I, 100 mg/kg; Se, 24 mg/kg; vitamin A, 880,000 IU/kg; vitamin D3, 320,000; vitamin E, 4,400 IU/kg; vitamin K3, 256 IU/kg; thiamin, 240 mg/kg; riboflavin, 560 mg/kg; niacin, 4,000 mg/kg; pantothenic acid, 1,200 mg/kg; pyridoxine, 240 mg/kg; Biotin, 17.6 mg/kg; folic acid, 144 mg/kg; vitamin B12, 1.28 mg/kg; choline, 120,000 mg/kg; Phytase, 80,000 PTU/kg.
[4]Calculated analyses.

used to determine the lightness (L*), redness (a*), yellowness (b*), saturation index (Chroma), and tonality (Hue angle). Cooking loss (CL) was determinate in 12 breasts ($n = 12$; 2 breasts per replicate per treatment) according to Sánchez-Zamora et al. (2019). The breasts were deboned then packed in vacuum bags and cooked in hot water (75 ± 0.1 °C) for 90 min. Afterwards, samples were pre-cooled at 20 °C for 30 min. Next, the samples were stored at 4 °C for 12 h. Finally, the weight of cooked breast was recorded. The CL was estimated:

$$CL\% = \left(\begin{array}{l}(\text{fresh breast weight} - \text{cooked breast weight})\\ /(\text{fresh breast weight})\end{array}\right) \times 100$$

2.4 Texture analysis

The texture analysis was carried out with the cooked breasts used to estimate the CL according to Sánchez-Zamora et al. (2019). The analysis was done for each side of the breast ($n = 12$; 2 breasts per replicate per treatment). Shear force (SF; N) and texture profile analysis (TPA) were obtained with a texturometer (TA.XT. Plus, Stable Micro Systems®, Surrey, United Kingdom). In the SF test, a Warner Bratzler knife was attached to the texturometer. The sample dimensions were 1 cm wide and high and 3 cm long, cut parallel to the muscle fibers. The test speeds were pre-test 1 mm/s, during test 2 mm/s, and post-test 5 mm/s, and 15 mm high. In the TPA test, cylindrical samples were used (1.8 cm in diameter and 1.5 cm in height); samples were cut perpendicularly to the muscle fibers. A 75-mm diameter of cylindrical piston was used to compress the sample in two cycles, 50% of the sample height. The test speeds were pre-test 1 mm/s, test 2 mm/s, and post-test 5 mm/s, obtaining force-time deformation curves. The variables measured were hardness (N), adhesiveness (g/s), cohesiveness (dimensionless), springiness (mm), gumminess (g), chewiness (g mm), and resilience (dimensionless) (Cázares-Gallegos et al., 2019; Hernández-Coronado et al., 2019).

2.5 Sensory evaluation

An affective sensory test for attributes (Hernández-Coronado et al., 2019) was conducted to measure the satisfaction level of 30 semi-trained consumers. One breast per replicate per treatment ($n = 6$ breasts) was used for evaluation of cooked breast meat (75 °C ± 0.1 °C; 90 min). Each consumer received four cubes (1.5 cm) per treatment placed in cups coded with three random numbers. The attributes evaluated were odor, taste, juiciness, softness, and overall acceptability. A five-point hedonic scale was used for evaluation, where 5 = liked very much and 1 = disliked very much.

2.6 Statistical analysis

The general linear model (GLM) used to analyze the meat yield and quality was as follows:

$$y_{ij} = \mu + T_i + \varepsilon_{ij}$$

where: y_{ij} = response variables, μ = general mean; T_i = effect of the ith treatment (OEO_0, OEO_{12}, OEO_{34}, OEO_{54}, OEO_{16}) and ε_{ij} = random error. A significance level of 0.05 was used to find significant differences between treatments ($p < 0.05$). When H_0 was rejected, the means were compared with the Tukey test ($\alpha = 0.05$). The sensory analysis was carried out with the non-parametric Friedman test, considering the consumer as a block effect in the analysis; when H_0 was rejected ($p < 0.05$), the mean comparisons were carried out according to Nemenyi test (Núñez-Colín, 2018). Orthogonal polynomial contrasts (OPC) were performed to evaluate the trend effects (linear, quadratic and cubic) of treatment on the response variables. Minitab® (2013) 17.1.0 statistical software was used for data analyses.

3 Results

3.1 Meat yield

Table 2 shows the carcass traits variables at 42 d for broilers supplemented with oregano oil at 100 mg/kg of diet over the prescribed production phases. The HCY showed differences ($p < 0.05$) between treatments with OEO_{16} having the highest yield and OEO_{34} the lowest. The SW, CCY, and BM variables did not show differences ($p > 0.05$). The analysis of orthogonal polynomial contrasts (OPC) for meat yield variables was not significant ($p > 0.05$).

TABLE 2 Meat yield of broilers supplemented with oregano oil during different production phases of grow-out.

Treatments[1]	Variables[2]			
	SW (kg)	HCY (%)	CCY (%)	BY (%)
OEO_0	2.51	74.87[b]	73.05	29.56
OEO_{12}	2.48	74.86[b]	72.14	30.00
OEO_{34}	2.52	74.72[b]	72.81	29.89
OEO_{56}	2.55	75.57[a,b]	72.91	30.73
OEO_{16}	2.54	76.33[a]	72.98	29.81
SEM	0.05	0.34	0.31	0.33
p-values/OPC	0.851	0.005	0.266	0.130
Linear	0.582	0.887	0.134	0.729
Quadratic	0.518	0.946	0.127	0.399
Cubic	0.536	0.680	0.151	0.300

[1]OEO_0, control diet without oregano essential oil (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6. SEM: standard error of the mean; OPC: orthogonal polynomial contrasts.
[2]SW = slaughter weight; HCY = hot carcass yield; CCY = cold carcass yield; BY = breast yield.
[a,b]Means ($n = 36$; 6 chickens per replicate per treatment) in columns and with different superscripts are significantly different ($p < 0.05$).

TABLE 3 pH, water retention, and cooking loss of breast meat from chickens supplemented with oregano during different production phases of grow-out.

Treatments[1]	Variables[2]		
	pH	WHC (%)	CL (%)
OEO_0	5.88[c]	60.31	22.49[a]
OEO_{12}	6.05[b]	60.78	23.10[a]
OEO_{34}	6.03[b]	59.68	21.47[a,b]
OEO_{56}	6.05[b]	61.29	20.38[b]
OEO_{16}	6.15[a]	61.47	22.13[a,b]
SEM	0.02	0.88	0.50
p-values/OPC	0.001	0.624	0.005
Linear	0.000	0.917	0.094
Quadratic	0.000	0.978	0.012
Cubic	0.000	0.862	0.006

[1]OEO_0, control diet without oregano essential oil (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6. SEM: standard error of the mean; OPC: orthogonal polynomial contrasts.
[2]pH = hydrogen potential; WHC = water holding capacity; CL = cooking loss.
[a,b]Means [$n = 12$; 2 breast per replicate per treatment measured on each side; $n = 12$ (2 breast per replicate per treatment)] in columns and with different superscripts are significantly different ($p < 0.05$).

TABLE 4 Effect of oregano oil on breast meat color variables of chickens supplemented with oregano oil during different production phases of grow-out.

Treatments[1]	Variables[2]				
	L*	a*	b*	Chroma	Hue
OEO_0	63.29	12.38	11.74[a]	17.17[a]	43.53[a]
OEO_{12}	62.80	12.43	11.34[a,b]	16.89[a,b]	42.72[a,b]
OEO_{34}	62.30	11.61	10.60[a,b]	15.81[b]	42.54[a,b]
OEO_{56}	63.05	12.43	11.19[a,b]	16.77[a,b]	41.94[a,b]
OEO_{16}	63.14	12.34	10.24[b]	16.07[a,b]	38.61[b]
SEM	0.35	0.29	0.36	0.31	1.18
p-values/OPC	0.372	0.239	0.033	0.013	0.041
Linear	0.198	0.454	0.087	0.065	0.364
Quadratic	0.394	0.736	0.151	0.182	0.305
Cubic	0.589	0.947	0.169	0.271	0.216

[1]OEO_0, control diet without oregano essential oil (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6. SEM: standard error of the mean; OPC: orthogonal polynomial contrasts.
[2]L* = lightness, a* = redness, b* = yellowness, Chroma = saturation index, Hue = hue angle (tonality).
[a,b]Means ($n = 12$; 2 breast per replicate per treatment measured on each side) in columns and with different superscripts are significantly different ($p < 0.05$).

3.2 Physicochemical traits

The effect of 100 mg/kg of dietary OEO on physicochemical properties is shown in Table 3. The pH and CL were different ($p < 0.05$) between the experimental groups. The pH of breast meat was highest in OEO_{16} and lowest for OEO_0. Cooking loss was highest in OEO_{12}, while OEO_{56} showed improvement. The WHC did not show differences ($p > 0.05$) between the experimental groups. The OPC showed significant effects for pH and CL ($p < 0.05$). For pH, linear, quadratic and cubic components were significant, indicating that the response pattern ranged from linear to cubic. For CL, significant quadratic and cubic effects were observed.

The color analysis of breast meat from chickens supplemented with OEO showed differences ($p < 0.05$) for yellowness (b*), saturation (Chroma), and tonality (Hue angle) (Table 4). b* was highest for OEO_0 and lowest for OEO_{16}, while saturation was highest for OEO_0 and lowest for OEO_{34}. In relation to tonality, OEO_0 was highest and OEO_{16} was lowest. Lightness (L*) and redness (a*) were not different ($p > 0.05$) between the treatments. The OPC showed no significant effects ($p > 0.05$) for the color variables.

3.3 Texture analysis

Table 5 presents the texture analysis data for breast samples from broilers supplemented with OEO at 100 mg/kg of diet during production phases. The SF and hardness (H) were different ($p < 0.05$) between the experimental groups. OEO_0 was the treatment with the lowest SF compared to the those supplemented with 100 mg/kg of OEO. OEO_{12} exhibited the highest hardness, while OEO_{34} showed the lowest. The variables adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience did not differ significantly ($p > 0.05$) between treatments. Likewise, these variables were not significant ($p > 0.05$) in the contrast analysis.

3.4 Sensory evaluation

The sensory attributes of chicken breasts meat are presented in Table 6. Juiciness and softness differed significantly ($p < 0.05$) among treatments. OEO_0, OEO_{34}, OEO_{56}, and OEO_{16} were scored as the juiciest, whereas OEO_{12} was least preferred. In the meat softness attribute, OEO_{56} received the highest scores, while OEO_{12} was rated lowest.

4 Discussion

4.1 Meat yield

According to results obtained in meat yield, similar results for HCY were obtained by Cázares-Gallegos et al. (2019). Those authors found differences when using Mexican oregano oil at 200 mg/kg in broiler chicken diets. Meat yield in the current study was higher than that obtained by Cázares-Gallegos et al. (2019). Forte et al. (2018) obtained higher BY with the use of 200 mg/kg in the diet using an aqueous extract of oregano. Better processing yield in meat can be attributed to the antioxidant activity of plant extracts (Arif et al., 2022). This assertion can be attributed to OEO_{16} with improved CCY, while OEO_{12} and OEO_{56} showed improved BY. Possibly, OEO may increase the number of muscle myofibril (via cell division) when this natural additive is administrated during weeks 1 to 6.

4.2 Physicochemical traits

The pH and CL were different among treatments. The pH results are somewhat similar to those found by Méndez-Zamora et al. (2015) with pH 5.8 to 6.05. He et al. (2023) indicated that a pH lower than 6.0 affects the quality, texture, and flavor of meat. Breast

TABLE 5 Texture analysis of breast meat from chickens supplemented with oregano oil during different production phases of grow-out.

Treatments[1]	Variables[2]							
	SF	H	A	S	Co	G	C	R
OEO_0	12.92[b]	37.24[a]	−8.58	0.535	0.455	16.34	7.89	0.181
OEO_{12}	13.53[a]	37.44[a]	−8.18	0.534	0.442	16.48	8.50	0.171
OEO_{34}	16.09[a]	30.76[b]	−8.12	0.528	0.466	17.44	8.42	0.184
OEO_{56}	16.18[a]	31.45[a,b]	−7.07	0.528	0.467	14.97	7.21	0.184
OEO_{16}	15.74[a]	36.77[a,b]	−9.93	0.529	0.479	15.55	7.90	0.185
SEM	0.90	1.58	1.01	0.01	0.01	0.77	0.41	0.01
p-values/OPC	0.029	0.003	0.369	0.974	0.231	0.239	0.197	0.338
Linear	0.948	0.855	0.587	0.847	0.316	0.745	0.529	0.315
Quadratic	0.344	0.202	0.341	0.947	0.158	0.366	0.268	0.218
Cubic	0.174	0.072	0.232	0.979	0.135	0.211	0.171	0.216

[1]OEO_0, control diet without oregano essential oil (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6. SEM: standard error of the mean; OPC: orthogonal polynomial contrasts.
[2]SF, shear force; H, hardness; A, adhesiveness; S, springiness; Co, cohesiveness (dimensionless); G, gumminess; C, chewiness; R, resilience (dimensionless).
[a,b]Means ($n = 12$; 2 breast per replicate per treatment measured on each side) in columns and with different superscripts are significantly different ($p < 0.05$).

TABLE 6 Sensory attributes of breast meat from broiler chickens supplemented with oregano oil during different production phases of grow-out.

Treatments[1]	Sensory attributes				
	Odor	Taste	Juiciness	Softness	Overall acceptability
OEO_0	4.00	4.00	4.00[a]	4.10[a]	4.00
OEO_{12}	4.00	3.80	3.00[b]	3.30[b]	4.00
OEO_{34}	4.00	3.90	4.00[a]	4.00[a,b]	4.00
OEO_{56}	4.00	4.00	4.00[a]	4.20[a]	4.00
OEO_{16}	4.00	4.30	4.00[a]	3.90[ab]	4.00
p-value	0.833	0.246	0.000	0.038	0.706

[1]OEO_0, control diet without oregano essential oil (0 mg/kg); OEO_{12}, diet with 100 mg/kg of OEO in weeks 1 and 2; OEO_{34}, diet with 100 mg/kg of OEO in weeks 3 and 4; OEO_{56}, diet with 100 mg/kg of OEO in weeks 5 and 6; and OEO_{16}, diet with 100 mg/kg of OEO from weeks 1 to 6.
[a,b]Medians ($n = 30$ semi-trained consumers) in columns and with different superscripts are significantly different ($p < 0.05$).

meat pH values were higher in treatments where broilers were supplemented with OEO, indicating improved meat quality (pH > 6.0). This effect may be attributed to regulation of ante-mortem physiological processes related to stress or natural metabolic reactions, which can influence the rate of pH decline while the muscle is still warm (36 °C) (Hernández-Coronado et al., 2019). Conversely, Hernández-Coronado et al. (2019) did not find difference for CL in chicken breasts meat supplemented with oregano oil at 400 mg/L, although those authors reported relatively high pH values ($p = 0.0605$) in meat from chicks supplementing with OEO. However, their results differed from those of the current study possibly because they supplemented OEO in water and in this study OEO was presented in the diet. OEO may enhance metabolic pathways involved in amino acid synthesis, thereby improving molecular interactions between water and protein, and reducing water loss (lower CL) during heat treatment.

Regarding color, Al-Hijazeen (2021) found differences for L*, a*, and b* compared to the current study, being that the treatment supplemented with oregano oil 100 mg/kg exhibited the least yellowness. Chang-Song et al. (2017) did not obtain difference in color variables with oregano powder at 150 mg/kg. Color can be influenced by the manner in which OEO is supplemented, depending on diet and environmental conditions (Teixeira et al., 2013). The results of the current study indicated that supplementing the diet with 100 mg/kg of OEO throughout the six-week production period (OEO_{16}) reduced b* values in broiler chicken breast meat. With respect to the orthogonal polynomial contrast, the results indicate that pH and CL of breast meat exhibited complex variation, which may be associated with curvature responses or inflection points when OEO levels are increased across broiler production phases.

4.3 Texture analysis

The shear force and hardness of breast meat from broiler chickens supplemented with oregano oil were affected. Compared with the control treatment (without supplementation of OEO), Salama et al. (2023) found lower SF in broilers supplemented with OEO at 300 and 600 mg/kg. Furthermore, Hernández-Coronado et al. (2019) did not obtain differences for hardness in chicken breast meat when supplementing OEO at 400 mg/kg in the drinking water. The findings of the current study with 100 mg/kg in diet showed that meat was softer (decreased hardness) when OEO was supplemented during weeks 3 and 4 (grower phase). The results for texture were similar to those of Herrera-Balandrano et al. (2020), who did not obtain an effect of oregano oil on adhesiveness, cohesiveness, gumminess, chewiness, and resilience of marinated chicken breasts. The findings of the current study indicated that OEO supplementation at different stages affects the shear force and hardness of breast meat.

4.4 Sensory evaluation

In the current study, sensory parameters of breast meat had effect on juiciness and softness. Forte et al. (2018) found differences in flavor, softness, and global acceptability when broilers were supplemented with 200 mg/kg of European OEO in the diet. Likewise, Cázares-Gallegos et al. (2019) found improved consumer preference for breast meat from chickens supplemented with OEO. Hong et al. (2012) also obtained differences in preference for meat softness in meat form broilers supplemented with essential oils containing carvacrol. Al-Rawashdeh et al. (2022) found that oregano oil affected odor and global acceptability of chicken meat supplemented with natural additives. The effect observed in the current study may indicate that OEO supplementation during different periods affects the juiciness and softness of breast meat.

5 Conclusion

Hot carcass yield at (36 °C) increased in chickens supplemented with oregano oil during the finisher phase. Breast meat yellowness and tonality decreased with oregano supplementation throughout the trial. Juiciness was most preferred in breast meat from chickens supplemented during grower and finisher phases, whereas tenderness was most favored in the finisher phase. Supplementation with 100 mg/kg oregano oil is recommended during grower and finisher phases. Economic evaluation is needed to determine its impact on performance, meat yield, and quality. If the costs are high, the use of oregano oil should be weighed against potential improvements in meat quality and market value.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The animal study was approved by Bioethics and animal welfare committee; Facultad de Medicina Veterinaria y Zootecnia. The study was conducted in accordance with the local legislation and institutional requirements.

Author contributions

JC: Investigation, Methodology, Resources, Writing – original draft. JK: Investigation, Methodology, Resources, Validation, Writing – review & editing. DR-C: Investigation, Methodology, Resources, Writing – original draft. YV-M: Validation, Visualization, Writing – original draft. YR-Z: Conceptualization, Validation, Visualization, Writing – review & editing. VA-A: Conceptualization, Methodology, Visualization, Writing – original draft. AS-D: Conceptualization, Methodology, Resources, Writing – original draft. SS-G: Formal analysis, Investigation, Methodology, Writing – review & editing. GM-Z: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was supported by the Programa de Apoyo a la Publicacion Cientifica-UANL 2025 for publication.

Acknowledgments

The authors acknowledge Michael E. Hume Ph.D. for reviewing and editing the manuscript. Additionally, we acknowledge Facultad de Agronomia, UANL, for supporting this study with experimental areas.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that Generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Al-Hijazeen, M. (2021). The combination effect of adding rosemary extract and oregano essential oil on ground chicken meat quality. *Food Sci. Technol.* 42:e57120. doi: 10.1590/fst.57120

Al-Rawashdeh, M. S., Al-Hijazeen, M. A., and Al-Rabadi, G. J. (2022). Preservative effect of dietary oregano and germander on quality and storage stability of raw broiler meat. *J. Anim. Plant Sci.* 32, 1200–1210. doi: 10.36899/JAPS.2022.5.0526

Arif, M., Ur-Rehman, A., Naseer, K., Abdel-Hafez, S. H., Alminderej, F. M., El-Saadony, M. T., et al. (2022). Effect of Aloe vera and clove powder supplementation on growth performance, carcass and blood chemistry of Japanese quails. *Poult. Sci.* 101:101702. doi: 10.1016/j.psj.2022.101702

Aviagen®. 2022. Ross broiler management handbook. Available online at: https://aviagen.com/assets/Tech_Center/BB_Foreign_Language_Docs/Spanish_TechDocs/Ross-BroilerNutritionSpecifications2022-ES.pdf (Accessed June 20, 2025).

Babatunde, O. O., Bello, A., Dersjant-Li, Y., and Adeola, O. (2022). Evaluation of the responses of broiler chickens to varying concentrations of phytate phosphorus and phytase. II. Grower phase (day 12–23 post hatching). *Poult. Sci.* 101:101616. doi: 10.1016/j.psj.2021.101616

Cázares-Gallegos, R., Silva-Vázquez, R., Hernández-Martínez, C. A., Gutiérrez-Soto, J. G., Kawas-Garza, J. R., Hume, M. E., et al. (2019). Performance, carcass variables, and meat quality in broilers supplemented with dietary Mexican oregano oil. *Braz. J. Poult. Sci.* 21, 001–010. doi: 10.1590/1806-9061-2018-0801

Chang-Song, R., Xian-Ren, J., Myong-Ho, K., Jing, W., Hai-Jun, Z., Shu-Geng, W., et al. (2017). Effects of dietary oregano powder supplementation on the growth performance, antioxidant status and meat quality of broiler chicks. *Ital. J. Anim. Sci.* 16, 246–252. doi: 10.1080/1828051X.2016.1274243

Chowdhury, S., Prasad-Mandal, G., and Kumar-Patra, A. (2018). Different essential oils in diets of chickens: 1. Growth performance, nutrient utilisation, nitrogen excretion, carcass traits and chemical composition of meat. *Anim. Feed Sci. Tech.* 236, 86–97. doi: 10.1016/j.anifeedsci.2017.12.002

Forte, C., Branciari, R., Pacetti, D., Miraglia, D., Ranucci, D., Acuti, G., et al. (2018). Dietary oregano (*Origanum vulgare* L.) aqueous extract improves oxidative stability and consumer acceptance of meat enriched with CLA and n-3 PUFA in broilers. *Poult. Sci.* 97, 1774–1785. doi: 10.3382/ps/pex452

He, P., Lei, Y., Zhang, K., Zhang, R., Bai, Y., Li, Z., et al. (2023). Dietary oregano essential oil supplementation alters meat quality, oxidative stability, and fatty acid profiles of beef cattle. *Meat Sci.* 205:109317. doi: 10.1016/j.meatsci.2023.109317

Hernández-Coronado, A. C., Silva-Vázquez, R., Rangel-Nava, Z. E., Hernández-Martínez, C. A., Kawas-Garza, J. R., Hume, M. E., et al. (2019). Mexican oregano essential oils given in drinking water on performance, carcass traits, and meat quality of broilers. *Poultry Sci.* 98, 3050–3058. doi: 10.3382/ps/pez094

Herrera-Balandrano, D. D., Martínez-Rojas, D., Luna-Maldonado, A. I., Gutiérrez- Soto, G., Hernández-Martínez, C. A., Silva-Vázquez, R., et al. (2020). Preserving chicken breasts with Mexican oregano essential oil. *Biotecnia* 22, 119–127. doi: 10.18633/biotecnia.v22i2.1253

Hong, J. C., Steiner, T., Aufy, A., and Lien, J. F. (2012). Effects of supplemental essential oil on growth performance, lipid metabolites and immunity, intestinal characteristics, microbiota and carcass traits in broilers. *Livest. Sci.* 144, 253–262. doi: 10.1016/j.livsci.2011.12.008

INEGI. 2025. Compendio de Información Geográfica Municipal. Available online at: https://www.inegi.org.mx/app/areasgeograficas/?ag=070000190034#collapse-Resumen (Accessed June 20, 2025).

Medeot, D., Nilson, A., Miazzo, R. D., Grosso, V., Ferrari, W., Jofré, E., et al. (2023). Stevia as a natural additive on gut health and cecal microbiota in broilers. *Vet. Anim. Sci.* 22:100322. doi: 10.1016/j.vas.2023.100322

Méndez-Zamora, G., Durán-Meléndez, L. A., Hume, M. E., and Silva-Vázquez, R. (2017). Performance, blood parameters, and carcass yield of broiler chickens supplemented with Mexican oregano oil. *Rev. Bras. Zootecn.* 46, 515–520. doi: 10.1590/S1806-92902017000600006

Méndez-Zamora, G., García-Macías, J. A., Santellano-Estrada, E., Durán-Meléndez, L. A., and Silva-Vázquez, R. (2015). Aceite de orégano sobre la calidad de pechuga de pollos de engorda. *Investigación y Ciencia de la Universidad Autónoma de Aguascalientes* 65, 5–12. doi: 10.33064/iycuaa2015653576

Minitab® (2013). Minitab 17 statistical software. State College, PA: Minitab, LLC.

Mulchandani, R., Wang, Y., Gilbert, M., and Van Boeckel, T. P. (2023). Global trends in antimicrobial use in food-producing animals: 2020 to 2030. *Glob. Public Health* 3:e0001305. doi: 10.1371/journal.pgph.0001305

NOM-033-SAG/ZOO-2014. 2014. Métodos para dar muerte a los animales domésticos y silvestres. Available online at: https://platiica.economia.gob.mx/normalizacion/nom-033-sag-zoo-2014/ (Accessed June 20, 2025).

NOM-062-ZOO-1999. 1999. Especificaciones técnicas para la producción, cuidado y uso de los animales de laboratorio. Available online at: https://www.dof.gob.mx/nota_detalle.php?codigo=762506&fecha=22/08/2001#gsc.tab=0 (Accessed September 1, 2025)

Núñez-Colín, C. A. (2018). Análisis de varianza no paramétrica: un punto de vista a favor para utilizarla. *Acta Agrícola y Pecuaria* 4, 69–79. doi: 10.30973/aap/2018.4.3/1

Salama, A., Belih, S., and Khedr, N. 2023 Impact of dietary oregano plant extract supplementation on carcass traits, physical and chemical meat quality of broilers J. Adv. Vet. Res. 13 1386–1393 Available online at: https://www.advetresearch.com/index.php/AVR/article/view/1467

Sánchez-Zamora, N., Silva-Vázquez, R., Rangel-Nava, Z. E., Hernández-Martínez, C. A., Kawas-Garza, J. R., Hume, M. E., et al. (2019). Inulina de agave y aceite de orégano mejoran la productividad de pollos de engorda. *Ecosis. Recur. Agrop* 6, 523–534. doi: 10.19136/era.a6n18.2197

Silva-Vázquez, R., Duran-Melendez, L. A., Mendez-Zamora, G., Santellano-Estrada, E., Xie, M., Dunford, N. T., et al. (2017). Antioxidant activity of essential oils from various Mexican oregano ecotypes and oil fractions obtained by distillation. *JSM Chem.* 5:1046. doi: 10.47739/2334-1831/1046

Teixeira, B., Marques, A., Ramos, C., Serrano, C., Matos, O., Neng, N. R., et al. (2013). Chemical composition and bioactivity of different oregano (Origanum vulgare) extracts and essential oil. *J. Sci. Food Agr.* 93, 2707–2714. doi: 10.1002/jsfa.6089

Zeng, Z., Zhang, S., Wang, H., and Piao, X. (2015). Essential oil and aromatic plants as feed additives in non-ruminant nutrition: a review. *J. Anim. Sci. Biotechnol.* 6, 7–10. doi: 10.1186/s40104-015-0004-5