Research Article

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Avocado peel by-product in cattle diets and supplementation with oregano oil and effects on production, carcass, and meat quality

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Abstract: The objective of this work was to evaluate the effects of including a commercial avocado peel meal (Avomel) by-product as a feed source supplemented with *Lippia berlandieri* Schauer oregano essential oil (OEO) in cattle diets. Eighteen 22-month-old male Charolais x Angus crossbred cattle (334.96 ± 27.48 kg) were randomly distributed in three experimental groups (n = 6): Control, cattle fed with the control diet without Avomel and without OEO; Avomel, cattle fed 10% of Avomel in the diet; and Avomel + OEO, cattle fed 10% Avomel and 600 mg/kg of OEO in the diet. The evaluated variables were bulls' weight (BW), feed intake (FI), slaughter variables, carcass quality and the pH, water holding capacity (WHC), color and chemical composition of raw rib eye meat, as well as cooking loss (CL), shear force (SF), texture analysis and sensory evaluation of cooked meat. After 120 days of feeding, BW was highest (P < 0.10) for Avomel and lowest (P < 0.10) for Avomel + OEO. The Avomel + OEO group FI was low. Cattle slaughter variables, carcass quality variables, pH, and WHC did not show differences (P > 0.05). Lightness was highest (P < 0.05) for Avomel meat. Meat chemical composition was not affected (P > 0.05). SF of meat was different (P < 0.05) being highest for Avomel + OEO. On meat texture, springiness was different (P < 0.05), i.e., meat treated with Avomel was highest, but no differences (P > 0.05) were detected for hardness, adhesiveness, cohesiveness, gumminess, chewiness, and resilience. Odor, taste, softness, juiciness, and overall acceptability of cooked meat were not different (P > 0.05), data not shown. The commercial by-product avocado peel meal supplemented with OEO could be used in cattle diets without adversely affecting productive performance, carcass traits, and meat quality.

Keywords: beef, physicochemical, rib eye, sensory, texture, oregano essential oil

Abbreviations

BT	backfat thickness
BW	bulls' weight
CF	crude fiber
CFT	crude fat
CL	cooking loss
CP	crude protein
CW	cold carcass weight
EFN	extract free of nitrogen
FI	feed intake
KPHF	kidney, pelvic, heart fat of carcass
NDF	neutral detergent fiber
NFC	non-fiber carbohydrates
OEO	oregano essential oil
QG	quality grade
REA	rib eye area
SF	shear force
SW	slaughter weight
TPA	texture profile analysis
WHC	water holding capacity
YC	yield carcass
YG	yield grade

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1 Introduction

Cattle farming is an activity carried out for the production of meat destined for human consumption. Consequently, carcass production has increased significantly [1]. In 2021, the world's total beef production was 72.45 million tons, with the USA, Brazil, and China ranked as principal producers [2]. Increased production across the food industry presents problems related to food preservation. Among foods processed for human consumption, around 33% is wasted, with fruits and vegetables presenting the highest percentages of wastage (40–50%) [3]. Increased attention has been given in cattle farming to feed supplementation with commercial fruit by-products, due to the large quantities produced as human food but ultimately discarded [4]. Currently agri-food by-products, including fruits and vegetables, are being explored in animal feeding due to their high nutrient contents and as a strategy to reduce the environmental impact [5–7]. Studies have been conducted in cattle fed diets supplemented with fruit and vegetable wastes such as dried citrus pulp, grape pomace, and pumpkin [6,8–13]. While avocado peel and pit were assessed in animal feedlot diets for effects on sensory attributes, oxidative and color qualities were assessed in meat and milk [8,14–16]. Previous research has indicated that using avocado waste for animal feeding can have beneficial effects. Hernández-López et al. [14] conducted a study in which pigs were fed a formulation containing avocado waste and the results showed that the meat from treatment pigs had lower levels of intramuscular fat, reduced discoloration, and decreased rates of lipid and protein oxidation. Similarly, Galeano-Díaz *et al.* [17] concluded that rabbits fed with avocado waste in their diets exhibited enhanced growth and improved carcass traits. Furthermore, Bugarín-Prado *et al.* [18] used avocado meal in sheep diets and established that supplementation did not adversely affect growth performance. This suggests that avocado-supplemented diets improve growth performance and meat quality. However, in beef, avocado supplementation in diets have not been evaluated.

Natural compounds are also being developed and studied as substitutes for synthetic chemical compounds as feed additives, improving attributes for food quality [19,20]. Extracts of aromatic plants can be considered as natural alternatives to minimize processes affecting food product shelf life and physical deterioration, as well as improve growth performance in animal production [21–23]. *Lippia berlandieri* Schauer oregano essential oil (OEO) contains several compounds that can prevent food spoilage. Antioxidant and antimicrobial carvacrol and thymol are in the highest concentrations among components found in OEO; hence, it can be a natural option for synthetic chemicals in animal feed [24–27]. OEO could complement the use of avocado peel by-product in animal feed through application of the antioxidant and antimicrobial properties associated with carvacrol and thymol [28,29]. OEO added to avocado peel could improve its biological characteristics and nutritional properties and help to enhance animal production and meat quality [27,30–32]. Supplementation of ruminant diets with OEO could enhance growth performance [33], rumen digestive ability improving intestinal barrier and microbiota [32], and meat quality [34].

According to Food and Agriculture Organization [3], population growth will increase to ten billion people by 2050; hence, 73% of meat production will be necessary to meet the demands of human consumption. This forecast suggests that the agricultural sector related to beef cattle should increase production with the support of viable and natural sustainable alternatives to traditional and increased-demand feed sources. The objective of the current study was to evaluate the effect of avocado peel meal (Avomel) as a feed source supplemented with *Lippia berlandieri* Schauer OEO in cattle diets on production variables, carcass traits, and meat quality.

2 Materials and methods

2.1 Experimental design

The study was carried out in Nava, Coahuila, Mexico (28°32′ 27.4 N, 100°29′11.8 W, 320 m) and was approved by the Animal Care and Welfare Committee for ethical animal use with the protocol no. 031/2021. Eighteen 22-month-old male Charolais x Angus crossbred cattle were treated with Vigantol (Vigantol ADE, Bayer de México, S.A. de C.V.) and immunized against clostridioides, pasteurellosis, mannheimiosis, bovine viral diarrhea type 1 and 2, proinfluenza 3, bovine respiratory syncytial virus, campylobacteriosis, and leptospirosis, and implanted with Synovex Plus (Zoetis, Pfizer, New York, NY, USA) at 0 and 24 days during the feedlot period. Animals were randomly distributed in three experimental group pens (n = 6 per treatment): Control, cattle fed with the control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. The OEO was mixed with vegetable oil (as stated by the manufacturer, and containing two or more oils from canola, soybean, sunflower, safflower, and no greater than 0.02% antioxidant tertiary butylhydroquinone) then mixed with the avocado peel meal for incorporation in the diet. The cattle had an adaptation period of 15 days and

feedlotting was 120 days with four feeding periods starting with the grower diet (27 days) followed by development (33 days), maintenance (11 days), and finishing (49 days) diets (Table 1). The animals were individually weighed at the beginning of the experiment, day 0, as well as at 60 and 120 days.

Table 1: Experimental beef cattle feedlot diets

Phase/ingredients (kg)	Treatments[1]		
	Control	Avomel	Avomel + OEO
Grower (1–27 days)			
Corn	405	305	305
Cotton seed	100	100	100
Dried malt	180	180	180
Soybeans	30	30	30
Avomel	0	100	100
Forage	160	160	160
Molasses	100	100	100
Premix 3[2]	20	20	20
Vegetable oil	5	5	5
Development (27–60 days)			
Corn	495	380	380
Cotton seed	100	100	100
Dried malt	130	145	145
Soybeans	30	30	30
Avomel	0	100	100
Forage	120	120	120
Molasses	100	100	100
Premix 3	20	20	20
Vegetable oil	5	5	5
Maintenance (60–71 days)			
Corn	565	450	450
Cotton seed	90	90	90
Dried malt	120	135	135
Avomel	0	100	100
Forage	100	100	100
Molasses	100	100	100
Premix 3	20	20	20
Vegetable oil	5	5	5
Finishing (71–120 days)			
Corn	325	215	225
Rolled corn	280	280	280
Cotton seed	60	60	60
Dried malt	125	135	125
Avomel	0	100	100
Forage	85	85	85
Molasses	100	100	100
Premix 3	20	20	20
Vegetable oil	5	5	5

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet.
[2]Ingredients: Ash 57.50%, Calcium 15.00%, Moisture 3.18%, Phosphorus 0.61%.

Lippia berlandieri Schauer OEO (Natural Solutions S.M.I., Ciudad Jimenez, Chihuahua, Mexico) had a composition of 74.25% carvacrol, 8.01% p-cymene, 4.53% thymol, 2.55% caryophyllene, and 2.33% γ-terpinene. Avomel (avocado peel meal) was purchased from Comercializadora Mexicana MC S.A. de C.V. (Piedras Negras, Coahuila, Mexico) and had a chemical composition of 6.97% crude protein, 15.45% crude fat, 7.59% ash, 12.13% crude fiber, 42.85% neutral detergent fiber, 57.87% nitrogen free extract, and 27.15% non-fiber carbohydrates on a dry basis. The Premix 3 used in the diet had a content of 57.50% ash, 15% calcium, 3.18% moisture and 0.61% phosphorus (Insumos Alimenticios Agroalimentarios S.A. de C.V., Nava, Coahuila, Mexico). Cristal (Aceites Grasas y Derivados S.A. de C.V., Zapopan, Jalisco, Mexico) was used as the OEO carrier vegetable oil. The control diet was prepared based on the commercial diet produced by the Union Ganadera Regional de Coahuila feeding plant, furthermore, control and treated diets were formulated to contain similar levels of digestible energy (Mcal/kg) and were calculated according to National Academic of Science, Engineering, and Medicine [35] (Table 2). Diets were sampled in triplicate for bromatological analysis (Table 3). Feed intake was measured throughout grower, development, maintenance, and finishing phases to determine the feeding variables.

Table 2: Energy composition of diets offered to beef cattle

Phase/treatmeants[1]	Nutrient levels[2]		
	ME, Mcal/kg DM	NEm, Mcal/kg DM	NEg, Mcal/kg DM
Grower (1–27 days)			
Control	2.24	1.62	1.02
Avomel	2.23	1.62	1.03
Avomel + OEO	2.23	1.62	1.03
Development (27–60 days)			
Control	2.32	1.65	1.17
Avomel	2.30	1.65	1.23
Avomel + OEO	2.30	1.65	1.23
Maintenance (60–71 days)			
Control	2.30	1.65	1.08
Avomel	2.34	1.66	1.08
Avomel + OEO	2.34	1.66	1.08
Finishing (71–120 days)			
Control	2.46	1.76	1.14
Avomel	2.45	1.77	1.14
Avomel + OEO	2.45	1.77	1.14

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet.
[2]ME, metabolizable energy; NEm, net energy for maintenance; NEg, net energy for gain.

Table 3: Chemical composition of beef cattle diets

Phase/treatmeants[1]	Component[2]							
	Moisture	**Ash**	**CP**	**CFT**	**CF**	**NDF**	**EFN**	**NFC**
Grower (1–27 days)								
Control	9.59 ± 0.87	7.38 ± 0.59	15.01 ± 3.63	4.56 ± 0.43	13.11 ± 0.36	26.75 ± 0.59	59.95 ± 3.43	46.30 ± 4.37
Avomel	8.19 ± 0.54	8.40 ± 0.41	14.20 ± 0.20	6.38 ± 2.04	12.21 ± 1.59	30.66 ± 4.69	58.82 ± 1.05	40.35 ± 2.05
Avomel + OEO	9.84 ± 0.50	8.40 ± 0.02	14.42 ± 0.15	6.15 ± 0.01	13.07 ± 0.25	34.70 ± 1.32	57.98 ± 0.11	36.36 ± 1.19
Development (27–60 days)								
Control	10.55 ± 0.13	9.32 ± 1.76	11.25 ± 0.94	4.31 ± 0.07	10.09 ± 2.36	22.63 ± 5.11	65.04 ± 0.27	52.50 ± 2.48
Avomel	10.80 ± 0.23	7.06 ± 0.08	13.76 ± 0.47	3.63 ± 1.64	7.95 ± 1.13	23.78 ± 0.52	67.61 ± 0.04	51.78 ± 0.57
Avomel + OEO	10.55 ± 0.20	4.06 ± 3.56	14.36 ± 0.28	5.79 ± 0.42	10.15 ± 2.12	26.11 ± 1.74	65.64 ± 4.99	49.69 ± 4.60
Maintenance (60–71 days)								
Control	10.34 ± 0.08	5.88 ± 0.23	12.56 ± 0.01	3.99 ± 0.14	12.03 ± 1.46	26.91 ± 6.03	65.55 ± 1.84	50.67 ± 5.64
Avomel	9.77 ± 0.58	6.83 ± 0.76	12.60 ± 0.29	6.14 ± 1.41	10.87 ± 0.23	28.02 ± 0.39	63.56 ± 1.66	46.42 ± 1.50
Avomel + OEO	10.76 ± 0.22	6.68 ± 0.30	11.52 ± 0.45	6.08 ± 0.20	12.58 ± 0.35	30.36 ± 1.92	63.15 ± 0.90	45.36 ± 1.37
Finishing (71–120 days)								
Control	10.34 ± 0.69	5.89 ± 0.12	13.04 ± 0.93	4.39 ± 0.42	9.20 ± 1.82	21.18 ± 2.70	67.50 ± 0.36	55.52 ± 1.23
Avomel	10.43 ± 0.16	6.76 ± 0.33	14.15 ± 0.22	5.67 ± 0.33	8.61 ± 0.93	24.70 ± 0.91	64.83 ± 1.14	48.74 ± 1.12
Avomel + OEO	10.21 ± 0.01	6.18 ± 0.45	13.91 ± 0.57	5.55 ± 1.43	9.16 ± 1.40	25.71 ± 1.08	65.19 ± 2.95	48.65 ± 2.63

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet.
[2]CP, crude protein; CFT, crude fat; CF, crude fiber; NDF, neutral detergent fiber; EFN, extract free of nitrogen; NFC, non-fiber carbohydrates.

2.2 Feedlot and productivity evaluation

Each experimental group was fattened in pens (10 × 50 m) per treatment with six animals per pen. Animals were fed at 7:00 a.m. and 2:00 p.m.; feed and water were offered *ad libitum*. Bulls' weight (BW) were collected at 60 and 120 days and feed intake (FI) were calculated as cumulative feed to 60 and 120 days per group and then was calculated as mean per animal. The cattle initial weight was measured at the beginning of the experiment, at day 0, and was considered as a covariate effect in the productive data analysis statistical model.

2.3 Animal slaughter and sampling

Cattle were transported according to the NOM-051-ZOO [36] standard on humane treatment for animal transport. The slaughter weight (SW) was measured and then slaughter was performed according to NOM-033-SAG/ZOO [37] consisting of stunning, followed by exsanguination, bleeding, leg and head cutting, skin removal, evisceration, carcass cutting, and washing. The slaughter process was carried out at the Slaughterhouse-Federal Inspection Type, Muzquiz, Coahuila, Mexico. Carcasses were suspended from the Achilles tendon, cut longitudinally, weighed, labeled, and refrigerated at 4°C for 24 h. Carcasses were classified and samples were collected from the longissimus dorsi muscle (between the sixth and twelfth ribs) of the left half of the carcass of each beef cattle. Meat muscle sampling was carried out according to de Huidobro *et al.* [38] with some modifications (Figure 1): the muscle was sectioned every 2 cm and four sections (A, B, C, and D) were placed in Ziploc® bags for raw meat analysis (pH, color, and water holding capacity (WHC)); three sections (E, F, and G) were cooked in water at 75°C for 1.5 h for cooking loss (CL) and texture analysis; two sections (H and I) were used for chemical composition analysis; and one section (J) was used for sensory analysis.

2.4 Slaughter variables and carcass quality

SW was measured (n = 6) after the slaughter process, and cold carcass weight (CW) was determined to estimate yield carcass (YC = (CW/SW) × 100). The kidney, pelvic, heart fat (KPHF) and yield grade (YG) of carcasses (n = 6) were measured according to united states department of agriculture (USDA) [39] guidelines. Carcass quality variables (n = 6 per treatment) were evaluated in the rib eye muscle between the 6th and 12th ribs. The rib eye was measured (in^2) with a grid to estimate the rib eye area (REA) and to classify the degree of carcass marbling (Figure 1). Marbling was evaluated with a 6-point scale: (1) practically devoid and traces; (2) slight; (3) small; (4) modest; (5) moderate; and (6) slightly abundant. The quality grade (QG) was evaluated with a 6-

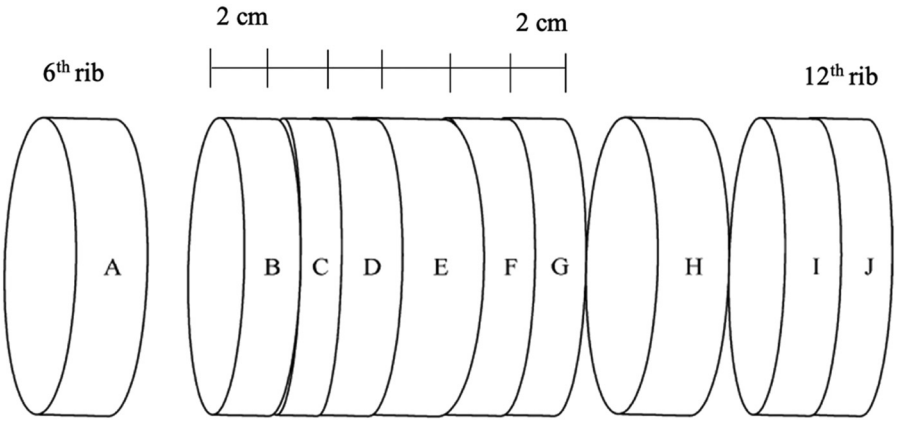

Figure 1: Sampling of longissimus dorsi muscle [38].

point scale: (1) standard (−, °, and +); (2) select (− and +); (3) choice−; (4) choice°; (5) choice+; and (6) prime-, according to USDA [39] grading with some modification. In the experiment, a 6-point scale for QG was selected because the values obtained were not greater than prime-quality. Backfat thickness (BT) was measured on fat that surrounded the central part of rib eye.

2.5 Meat physicochemical traits

The pH (n = 24 per treatment; 4 samples per each carcass cut) was measured in the meat with a puncture electrode (HI 99163, Hanna Instruments, Woonsocket, RI, USA). The WHC (n = 24; 4 samples per carcass cut) was determined by the compression method according to Barraza-Santos *et al.* [31]; 300 mg of meat was weighed and placed between two pieces of filter paper, between two acrylic-plastic plates and a force of 4 kg was applied for 20 min and the samples were weighed again. The free water was absorbed by the filter paper and the following equation was used: WHC = 100 − [((Initial$_{weight}$ − Final$_{weight}$)/Initial$_{weight}$) × 100]. Meat color was determined (n = 24 per treatment; 4 samples per carcass cut) with a colorimeter (CR-400 Konica Minolta®, Tokyo, Japan; Illuminant/Observer: D65/10) and L^* (lightness), a^* (green to red component), b^* (blue to yellow component), Chroma (saturation index), and Hue value (tonality) were measured.

2.6 Meat chemical composition

Raw meat (n = 12 per treatment; 2 samples per carcass cut) was cut into 1.0 cm cubes and placed into aluminum trays and were pre-dried at 65°C for 3 days. Subsequently, the samples were removed and allowed to cool to room temperature for analysis. Dry matter and moisture were determined by drying the samples in an oven at 100–110°C for 1 h, considering the initial and final weights (method 934.01). Ash was measured by the ash method in a muffle at 550°C (method 942.05). Crude fat was measured using the Goldfish method (method 920.30) and crude protein was measured with the Kjeldahl method (954.01) [40].

2.7 Cooking loss and meat texture

For CL and texture analysis (n = 18 per treatment; 3 samples per carcass cut), meat was vacuum-packed (Koch 800, Kansas City, MO, USA) in vacuum bags (Zubex Industrial SA de CV, Monterrey, Nuevo Leon, Mexico) and cooked by immersion in water at 75°C for 90 min followed by cooling at room temperature for 30 min. The meat was completely drained, reweighted, and CL was estimated as [(weight$_1$ − weight$_2$)/weight$_1$] × 100. Similarly, after cooking (75°C for 90 min) and draining, the samples were prepared for evaluation of shear force (SF) and texture profile analysis (TPA). SF and TPA were carried out with a TA.XT.Plus texturometer (Stable Micro Systems, Surrey, England). SF (Newton, N) was performed using the V-shaped-Warner Bratzler blade adapted to the texturometer. Rectangular samples (3.0 cm long × 1.0 cm wide × 1.0 cm high; n = 18) were cut parallel to the direction of the muscle fibers. Test velocities used in the instrument were 2 mm/s pre-test, 2 mm/s during the test, 5 mm/s post-test, and a distance of 15 mm. TPA was performed using standardized cylindrical samples (2.0 cm high and 2.5 cm in diameter; n = 18), oriented perpendicular to the direction of the muscle fibers. A cylindrical piston (75 mm in diameter) was used to compress the cylindrical samples during two test cycles,

compressing the sample up to 60% of the original height within a time span of 5 s between cycles; the velocities used were 2 mm/s pre-test, 2 mm/s during the test, and 5 mm/s post-test, with a distance of 25 mm. The variables determined were hardness (N), adhesiveness (g/s), springiness (mm), cohesiveness (dimensionless), gumminess (g), chewiness (g/mm), and resilience (dimensionless).

2.8 Sensory evaluation

An affective sensory test of meat attributes (n = 6 per treatment; 1 sample per carcass cut) was carried out with 23 semi-trained consumers (those who declare that they consumed beef meat more than 3 days per week). Six meat samples per treatment were vacuum-packed and cooked by immersion in water at 75 ± 0.1°C for 90 min. Consumers received three 1.0 cm cut cubes of meat samples from each treatment placed in plastic cups labeled with three random numbers. The attributes evaluated were odor, flavor, softness, juiciness, and overall acceptability. A 5-point hedonic scale was used, where 1 = disliked much and 5 = liked much. The sensory test was performed in individual booths, each equipped with a sink, light, table, and chair in the Universidad Autonoma de Nuevo Leon at Sensory Laboratory [41].

2.9 Statistical analysis

For data analysis, treatment effect (τ_i) was considered as fixed effect and initial weight of cattle was considered as covariate effect (λ) in the statistical model to evaluate the treatment effects on variables. The GLM statistical model was $y_{ij} = \mu + \tau_i + \lambda + \varepsilon_{ij}$, where y_{ij}: BW, slaughter variables, carcass quality (REA and BT), and meat quality, μ = general mean, τ_i = treatment effect, λ (covariate effect of the initial weight of cattle), and ε_{ij} = experimental error with normal distribution, mean zero, and variance σ^2 (($\varepsilon_{ijk} \sim N$) (0, σ^2)). Analysis of variance (GLM; Minitab®, 2013; version 17.1.0) was carried out, and H_0 was rejected when the probability value was less than 0.05 ($P < 0.05$), and when H_0 was rejected, mean comparisons was performed with the Tukey statistic test. For analyses of whole-body weights at 120 days, carcass SW, a^*, and Chroma variables, a Fisher comparison was used ($P < 0.10$) when the P-value was >0.05 and <0.10 (trend). Data analysis of carcass quality variables (marbling and QG) and sensory evaluation were analyzed with Friedman non-parametric test (GLM; Minitab®, 2013; version 17.1.0).

3 Results

3.1 Weight and FI

Weight performance (BW) for cattle supplemented with Avomel and OEO over 120 days of feeding are given in Table 4. Initial weight as well as BW at 60 days were not different ($P > 0.05$). At 120 days, BW was highest ($P < 0.10$) in the Avomel treatment and lowest ($P < 0.10$) in Avomel + OEO. Descriptive statistics of FI for pens at 60 days showed that Avomel was high and Control was low (Table 5). At 120 days, Avomel + OEO FI was low and Control was high for FI.

3.2 Steer slaughter variables

SW was different ($P < 0.10$) between experimental groups. SW was highest for Avomel and lowest for Avomel + OEO

Table 4: Weights of cattle supplemented with avocado peel meal and OEO over 120 days of feeding

Treatments[1]	Weight (kg)		
	0 days	60 days	120 days
Control	233.00	336.56	424.90[ab]
Avomel	240.10	349.07	431.00[a]
Avomel + OEO	232.40	330.01	393.00[b]
SEM	10.33	6.84	12.57
P-value	0.848	0.174	0.088

[1]Control, cattle fed with control diet (without Avomel and without OEO; Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[a–b]Mean values (n = 6) in columns and with different superscripts indicate statistical difference between treatments ($P < 0.05$); weight 120 days with Fisher comparison ($P < 0.10$).

Table 5: Feed intake of cattle supplemented with avocado peel meal and OEO over 120 days of feeding

Treatments[1]	Feed intake (kg)[2]	
	60 days	120 days
Control	526.88	625.00
Avomel	572.86	608.57
Avomel + OEO	534.50	523.75

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet.
[2]Feed intake cumulative for each pen (per animal) containing six animals was determined at 60 and 120 days.

Table 6: Slaughter variables of beef cattle supplemented with avocado peel meal and OEO over 120 days of fattening

Treatments[1]	Variables[2]				
	SW (kg)	CW (kg)	YC (%)	KPHF (%)	YG
Control	462.10[ab]	262.00	57.38	1.75	1.76
Avomel	466.70[a]	264.20	56.38	1.83	1.78
Avomel + OEO	426.50[b]	243.70	56.68	1.83	1.70
SEM	12.72	10.30	1.44	0.82	0.94
P-value	0.084	0.332	0.881	0.108	0.170

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[2]SW: slaughter weight; CW: carcass weight; YC: yield carcass; (1: <52.4% of lean meat cuts; 2: 50.1–52.3% of lean meat cuts; 3: 47.8–50.0% of lean meat cuts; 4: 45.5–47.7% of lean meat cuts; 5: represents a percentage of <45.5% of lean meat cuts); KPHF: kidney, pelvic, and heart fat; YG: yield grade.
[a–b]Mean values (n = 6) in columns and with different superscripts indicate statistical difference between treatments (P < 0.05); SW with Fisher comparison (P < 0.10).

(Table 6). CW, YC, KPHF, and YG were not different (P > 0.05).

3.3 Steer carcass quality

Carcass quality: REA, BT, marbling, and QG showed no differences (P > 0.05; Table 7).

3.4 Meat physicochemical traits

Meat pH and WHC were not different (P > 0.05) between treatments (Table 8). However, Avomel + OEO had a relatively high WHC value.

Values for steer meat color L^* improved (P < 0.05) for meat from the Avomel group and was lowest (P < 0.05) in the Control group (Table 9). At a 10% error comparison (P < 0.10), a^* and Chroma was highest for Avomel + OEO meat and lowest for Control meat.

3.5 Meat chemical composition

Steer meat composition was not affected (P > 0.05) by Avomel and OEO supplementation in the diets (Table 10).

Table 7: Carcass quality variables of steers supplemented with avocado peel meal and OEO over 120 days of fattening

Treatments[1]	Variables[2]		Quality[3]	
	REA (in^2)	BT (in)	Marbling	QG
Control	11.55	0.167	3.00	2.00
Avomel	11.62	0.150	3.00	2.00
Avomel + OEO	11.05	0.133	2.50	2.50
SEM	0.49	0.02	—	—
P-value	0.673	0.626	0.373	0.373

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[2]REA: rib eye area; BT: backfat thickness; QG: quality grade.
[3]Marbling: 1, practically devoid and traces; 2, slight; 3, small; 4, modest; 5, moderate; and 6, slightly abundant; Quality grade: 1: standard (−, °, and +), 2: select (− and +), 3: choice−, 4: choice°, 5: choice+, 6: prime-USDA [39]. Analyzed with the Friedman nonparametric test.

Table 8: Meat pH and water retention in meat of steers supplemented with avocado peel meal and OEO over 120 days of feeding

Treatments[1]	pH	WHC[2] (%)
Control	5.77	60.78
Avomel	5.76	59.75
Avomel + OEO	5.72	61.43
SEM	0.02	0.85
P-value	0.153	0.374

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[2]WHC: water holding capacity.

3.6 Cooking loss and texture analysis

The CL and SF of meat from cattle fed diets supplemented with Avomel and OEO is shown in Table 11. Meat SF was different (P < 0.05), being highest in Avomel + OEO meat than in Control and Avomel-only meat. But CL was not affected (P > 0.05) by treatment.

Meat springiness was affected (P < 0.05) by treatments, but not (P > 0.05) for hardness, adhesiveness, cohesiveness, gumminess, chewiness, and resilience (Table 12). Meat springiness of the Avomel group was highest (P < 0.05) and lowest (P < 0.05) for Control.

Table 9: Meat color of steers supplemented with avocado peel meal and OEO in diets over 120 days of feeding

Treatments[1]	Color[2]				
	*L**	*a**	*b**	Chroma	Hue value
Control	46.69[b]	26.91[b]	12.60	29.76[b]	25.22
Avomel	48.03[a]	27.61[ab]	15.74	30.60[ab]	25.39
Avomel + OEO	47.76[ab]	27.96[a]	13.29	30.96[a]	25.37
SEM	0.37	0.33	1.49	0.38	0.21
P-value	0.028	0.077	0.303	0.079	0.819

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[2]*L**: lightness; *a**: green to red component; *b**: blue to yellow component; Chroma: saturation index; Hue: tint angle (tone).
[a–b]Mean values (n = 24) in columns and with different superscripts indicate statical difference between treatments ($P < 0.05$); *L** with Tukey comparison ($P < 0.05$); *a** y Chroma with Fisher comparison ($P < 0.10$).

Table 11: Cooking loss and shear strength of meat from steers supplemented with avocado peel meal and oregano oil over 120 days of feeding

Treatments[1]	Variables[2]	
	CL (%)	SF (N)
Control	36.75	44.44[b]
Avomel	37.73	48.96[b]
Avomel + OEO	36.49	57.09[a]
SEM	0.94	2.40
P-value	0.641	0.003

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[2]CL: cooking loss; SF: shear force.
[a–b]Mean values (n = 18) in columns and with different superscripts indicate statical difference between treatments ($P < 0.05$).

3.7 Sensory evaluation

Meat sensory attributes evaluation revealed no differences ($P > 0.05$) between experimental groups. Sensory attributes (data not shown) received a score of 4 (like) and juiciness had a score of 3.5 (>neither like nor dislike).

4 Discussion

Initial steer weights in the current study were similar to results obtained by da Luz *et al.* [42] and Ran *et al.* [43] with 235.43 and 279.00 kg, respectively. Pukrop *et al.* [44] and Ran *et al.* [43] did not find differences at 151 and 112 days, respectively, for yield and carcass traits of cattle supplemented with essential oils and naturally sourced feed additives that consisted of *Lactobacillus* fermentation products, plant-based enzymes, and prebiotics. Prior works have documented the effectiveness of adding 10% avocado waste in diets to increase the final weight in rabbits [17] and the inclusion of 10% avocado meal in diets of lambs [18], in contrast to those animals that were not fed with avocado waste. However, Zhang *et al.* [32] found positive effects in rumen microbiota and improvement in rumen epithelium increasing the relative abundance of Bacteroidetes and Firmicutes with OEO dietary supplementation. Torres *et al.* [45] reported that metabolic benefits of supplementation of OEO decrease over the feeding period. Our results provide evidence of some limitations of adding Avomel meal + OEO, which could be negative interactions between Avomel and OEO molecules.

Feed intake is an important factor to consider in food animal production. Even minor differences due to treatment can translate into important expenditure savings during production. FI in the current study was similar to those of Gomes *et al.* [46], Lee *et al.* [47], and Herd *et al.* [48]. Likewise, Marcos *et al.* [16] studying goat ruminal *in*

Table 10: Percentage chemical composition of meat from steers supplemented with avocado peel meal and oregano oil over 120 days of feeding

Treatments[1]	Moisture	Protein	Fat	Ash	Carbohydrates
Control	74.97	17.93	2.16	0.94	3.95
Avomel	75.46	17.40	2.19	0.90	3.37
Avomel + OEO	75.49	17.82	2.01	0.93	3.96
SEM	0.38	0.39	0.21	0.02	0.40
P-value	0.554	0.584	0.811	0.175	0.497

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.

Table 12: Meat texture of steers fed diets supplemented with avocado peel meal and oregano oil over 120 days of feeding

Treatments[1]	Hardness (N)	Adhesiveness ($g\ s^{-1}$)	Springiness (mm)	Cohesiveness	Gumminess (g)	Chewiness ($g\ mm^{-1}$)	Resilience
Control	118.44	−1.41	0.3995[b]	0.4671	58.62	24.70	0.1632
Avomel	118.09	−1.55	0.4310[a]	0.4814	61.97	26.04	0.1744
Avomel + OEO	108.98	−1.39	0.4237[ab]	0.4766	58.11	26.80	0.1651
SEM	3.97	0.20	0.0079	0.0067	3.91	1.50	0.004
P-value	0.193	0.844	0.019	0.315	0.736	0.624	0.156

[1]Control, cattle fed with control diet (without Avomel and without OEO); Avomel, cattle fed with 10% Avomel in the diet; Avomel + OEO, cattle fed with 10% Avomel and 600 mg/kg of OEO in the diet. SEM: standard error of the mean.
[a–b]Mean values (n = 18) in columns and with different superscripts indicate statical difference between treatments ($P < 0.05$).

vitro fermentation with avocado peel and pulp suggested that avocado by-products could be used for ruminant feeding and improved productivity. The current results indicated that diet supplemented with Avomel and OEO could improve cattle FI at 60 days. Although at 120 days, OEO decreased FI, this could be because ruminants are sensitive to the taste and smell of food [49,50]. OEO modifies the feeding behavior and intake of food probably due to the strong smell and taste of essential oils attributable to high volatility might decrease feed palatability and animal FI [51].

The SW in the current study was similar to that obtained by de Oliveira *et al.* [52], and YC was similar to findings of da Luz *et al.* [42]. Mialon *et al.* [53] found comparatively higher cattle SW when using low-fiber and high-fat diets. In the current study, the Avomel group had higher amounts of ash, crude protein, and crude fat in the diet; hence, it was possible that due to their nutritional content during the fattening finishing period, there was improved muscle development. Likewise, avocado peel is rich in carotenes, which can improve metabolism in cattle because they are precursors of vitamin A and improve muscle development at the physiological level [54–57].

Purevjav *et al.* [58], Condron *et al.* [59], and Vellini *et al.* [60] obtained higher values (2.10–5.35%) for KPHF grades in Angus Nellore breed and Angus crossbreeds. In contrast, Garmyn *et al.* [61] obtained similar values (1.34–2.14%) to those in the current study. According to USDA [39], a QG value close to 1 represents a higher cut grade of the final carcass; hence, carcass QG in the current study indicated a high level for the carcass cuts due to values being between 1.70 and 1.76.

The REA was similar to the values obtained by da Luz *et al.* [42] but contrasted with those of Smith *et al.* [62] and de Oliveira *et al.* [52], who obtained higher values. The backfat thickness of cattle analyzed in the current study was lower than that obtained by da Luz *et al.* [42] and de Oliveira *et al.* [52], but higher than REA of Smith *et al.* [62]. The carcass marbling classification had similar results to findings of da Luz *et al.* [42]; however, Smith *et al.* [62] and de Oliveira *et al.* [52] found higher marbling values of slight, small, modest, and moderately abundant. According to criteria of Smith *et al.* [62], the QGs of steer carcasses supplemented with Avomel and OEO were prime, choice, and select. According to NMX-FF-078-SCFI [63], carcasses were classified as a standard QG, white to creamy fat color, with a cherry red to intense muscle tone, a backfat thickness conformation of 25% and upwards having a standard level classification, with trace to little marbling and a firm firmness with fine texture. At physiological maturity, carcasses were classified in the select and standard categories. Likewise, considering the relationship between maturity and marbling, the carcasses were classified as select B and standard B at the commercial level [63].

According to NOM-004-SAGARPA [64], carcasses in the current study belong to the maturity group of 9–50 months, which can produce a final product of commercial classification between select and standard. Likewise, according to the marbling content, carcasses were classified as slight and trace marbling, obtaining a commercial product as standard or select [39]. Therefore, according to NOM-004-SAGARPA [64], the meat had a muscle maturity color of pale red hue, which produces a meat with moderately fine muscle texture and exhibits a separation of muscle fiber bundles with moderate changes in muscle texture, rendering supreme or select QGs. Hence, according to this carcass classification, in the current study, the fat covering the longissimus dorsi muscle was not affected by Avomel + OEO, since it did not differ from the Control group. Consequently, avocado meal can be used as a supplement in cattle diets without altering carcass traits.

Our results obtained for meat pH were similar to those from other meat quality studies [42,52,65,66,65]. WHC results were also similar to those found in other studies [67–69]. An increase in pH will increase in WHC by producing a balance in the charges and a juicer meat [69].

Meat color and appearance are often primary considerations of acceptability for consumers. The main color variables in meat are L^*, a^*, and b^* [70]. Similar trends in meat L^* in the current study were found by Hernández-López *et al.* [14] when evaluating avocado waste in pigs. Steer meat color values were high compared to those obtained by Muchenje *et al.* [70], da Luz *et al.* [42], and de Oliveira *et al.* [52]. The a^* variable is related to the meat myoglobin content and produces the bright red color; however, when oxygen reacts at the sixth active site of myoglobin, it is converted to oxymyoglobin, producing a higher red meat color in the final product [71]. In the current study, Avomel + OEO increased a^*. Simitzis *et al.* [72] found higher values for a^* in sheep meat with oregano supplementation in the diets. b^* values were similar to those of Muchenje *et al.* [70]. Results from the present study showed that when b^* increased, it was accompanied by increases in values for L^*. According to Khliji *et al.* [73], L^* and a^* values ≥35 and >21.7, respectively, are acceptable in meat color quality. Greater a^* values indicate a more red, fresh meat [74]. The increase in a^* may be due to Avomel and OEO supplementation, which could decrease myoglobin oxidation and activate antioxidant mechanisms in animal tissue, consequently, can modify pigment distribution in meat and maintenance of coloration.

The chemical composition of meat from steers supplemented with avocado peel meal and oregano were similar to those obtained by Tayengwa *et al.* [12], da Luz *et al.* [42], de Oliveira *et al.* [52], and Smith *et al.* [62]. Hernández-López *et al.* [14] used avocado peel and pulp waste. In the current study, no difference in total meat fat content was found.

Cooking loss is an important quality for final product acceptability due to meat's juiciness being affected by product cooking [75]; hence, low CL improves meat juiciness. In the current study, CL values are slightly higher than those obtained by de Oliveira *et al.* [52] and da Luz *et al.* [42].

SF indicates the resistance of meat fibers to SFs [76]; in other words, consumer palatability. Similar results were obtained for this variable in meat samples from Angus-Nellore heifers (48.45–49.86 N) [52] and from Charolais breed [77], while in a study that evaluated meat quality of Nellore and Angus breeds, those authors found higher results (61.09–82.10 N) [12,42]. According to this information, SF results from the current study were low and indicated lower resistance of muscle fibers to shearing for Control and Avomel treatments, but Avomel + AEO groups indicated higher resistance of muscle fibers to shearing. These results could indicate that Control and Avomel meats would feel softer which would improve palatability and consumer acceptance would be better than for Avomel + AEO meat which would appear less tender as we can see in the Chewiness value.

Meat hardness was higher than that obtained by de Huidobro *et al.* [38] and Pematilleke *et al.* [78]. Springiness according to Pematilleke *et al.* [79] is the speed at which a deformed sample returns to its original size and shape. Those authors found a significant correlation for meat springiness values with flavor. However, in the current study, consumers did not perceive differences in flavor between treatments, even though springiness was different. Pematilleke *et al.* [78] found that the variables of adhesiveness, springiness, and cohesiveness were similar to the values obtained in the current study with steers supplemented with Avomel and OEO. Nithyalakshmi and Preetha [80] and Caine *et al.* [81] had similar results when studying physicochemical properties and texture of emu meat and beef rib steaks. The increase in springiness for Avomel meat may be due to the intramuscular fat content, because more intramuscular fat improves meat texture [82].

Sensory evaluation average scores of 4 (like) were received for odor, flavor, tenderness, juiciness, and overall acceptability for the three treatments. These effects were similar to those obtained by de Huidobro *et al.* [38], Caine *et al.* [81], and Choe *et al.* [83]. Results indicated that neither the Avomel nor the Avomel + OEO supplementation influenced the sensory perception and acceptance of the meat.

5 Conclusion

Steers fed 10% Avomel avocado peel meal as a feed source in the diet exhibited the highest weight among treatments at 120 days, while the lowest weight was seen when Avomel was combined with oregano oil. The Avomel group saw relatively the highest FI at 60 days, while Control had the relatively highest FI at 120 days. Slaughter weight improved in Avomel cattle over the other treatment groups. Carcass variables and quality classification did not show differences between the experimental groups. pH and WHC of meat were not affected. Meat values for redness, lightness, and saturation index (Chroma) were highest with Avomel + OEO. Meat chemical composition and CL were not affected, but SF and springiness were highest for Avomel + OEO. Sensory attributes were not affected in meat from cattle given Avomel and OEO. Avocado peel meal by-product can be recommended as a feed source quality for use in diets for finishing cattle. Also, supplementation with OEO exhibits improvement in meat color; however, other studies are required to evaluate the mechanism of action of OEO on growth performance cattle.

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