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Article

Essential oil and bagasse of oregano (*Lippia berlandieri* Schauer) affect the productive performance and the quality of rabbit meat

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Abstract:

The present study assessed the effect of incorporating essential oil of oregano (EOO) and oregano bagasse (OB) into the diet on the productive parameters and on the variables sacrifice and quality of rabbit meat. A total of 100 rabbits (30 d of age) were distributed in six treatments T1: control, T2: 0.25 g/kg of EOO, T3: 0.40 g/kg of EOO, T4: 20% of OB, T5: 0.25 g/kg of EOO + 20% of OB, and T6: 0.40 g/kg of EOO + 20% of OB. The greatest live weight was that of T6 (*P*<0.0001). At d 37, 44 and 51, T3 exhibited the lowest food intake (*P*=0.0089), and T6 had the best weight gain (*P*=0.0172). Food conversion was best (*P*=0.0138) in T5 at d 37. The yield of the cold carcass and loin was highest in T2, T4 and T5 (*P*<0,001). The pH increased (P=0.0190) at 10 d *post mortem* in T1, T4, T5, and T6. The water retention capacity was greater (P=0.0500) in T2, T4, and T6; a* increased (*P*<0.0004) on d 10 *post mortem*, and b* was lower (*P*<0.0430) in T2 at 24 h and 1at 0 d *post mortem*. In conclusion, 0.25 and 0.40 g/kg of EOO with 20% of OB had a positive influence on the productive behavior and on the variables slaughter, carcass characteristics, and quality of rabbit meat.

Key words: Essential oil, Productive behavior, Slaughter, Carcass, Meat, Color.

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Introduction

Rabbit meat stands out for its characteristics and nutritional properties, being a low-fat, lean meat (60 % of the total fatty acids are unsaturated), rich in minerals (potassium, phosphorus and magnesium), proteins and amino acids of high biological value, low in cholesterol and sodium(1-4). Oregano is an aromatic plant whose essential oil (EOO) contains thymol and carvacrol, which confer it an antioxidant and antimicrobial effect(5,6). By removing the essential oil of oregano, a residue called oregano bagasse (OB) —rich in flavonoids, with antioxidant and antimicrobial activity— is obtained(7,8). In the industry of oregano, the marketing product is the essential oil, while the bagasse is considered as waste(9). Mexican oregano (*Lippia berlandieri* Schauer) is a species characterized by a strong odor and high yield of essential oils(10), characteristics ascribed to its high content of carvacrol, which exceeds that of *Origanum vulgare*(11). The main chemical compounds of the genus *Lippia* are carvacrol, thymol, cimene, pinene, and linalool. These components provide it with antibacterial, antioxidant, antiviral, anti-fungal, and insecticide activity(12).

EOO has been used in the production and fattening of rabbits(13,14,15,16), as have other plant extracts and essential oils. However, no effect of OB on the productive behavior and the quality of the rabbit meat has been reported. Even the effect of essential oils on the productivity of rabbits is controversial and is still being researched.

The rabbit is able to benefit from a wide variety of ingredients in its diet because of its digestive physiology(17,18), which makes it possible to include different ingredients in its diet in order to improve the productive characteristics and modify the characteristics of its meat(13,19). The objective of this study was to evaluate the effect of the essential oil of oregano and oregano bagasse on the production parameters and quality of rabbit meat.

Material and methods

Breeding and treatments

Mestizo rabbits (n= 100) of both sexes (44 females and 56 males) aged 30 ± 2 d and an initial weight of 0.778 ± 0.190 kg were utilized. The rabbits were randomly distributed into six treatments; T1: control (n=18), T2: 0.25 g/kg of EOO (n=14), T3: 0.40 g/kg of EOO (n=16), T4: 20% of OB (n=16), T5: 0.25 g/kg of EOO + 20% of OB (n=18), and T6: 0.40 g/kg of EOO + 20% of OB (n=18). The EOO was extracted from the leaves of oregano through dragging with water vapor, according to the protocol to the Biological Research Center of Northwest Mexico(20). The bagasse had the following composition: 11.5 7± 0.29 % of crude protein, 1.79 ± 0.18 % of ethereal extract, 14.05 ± 1.30 of fiber, 6.31 ± 0.25 of ashes, and 39.36 ± 0.25 of dry matter.

The experimental unit (EU) consisted of two rabbits of the same sex per cage; T1 (9 repeats), 4 EU females and 5 EU males; T2 (7 repeats), 3 EU females and 4 EU males; T3 (8 repeats), 3 EU females and 5 EU males; T4 (8 repeats), 4 EU females and 4 EU males; T5 (9 repeats), 5 EU females and 4 EU males, and T6 (9 repeats), 3 EU females and 6 EU males. The rabbits were housed in wire cages (45 x 60 x 40 cm) during 42 days in an environment with 16 h of light and 8 h of darkness and were offered feed and water *ad libitum (Table 1)*. The care and management of rabbits during the research were in accordance with the provisions of the Official Mexican Standard NOM-062-ZOO(21).

Table1: Experimental supplemented feed rations supplied to the rabbits

Treatment	Ingredients (%)										EOO	OB
	C	SM	WB	V&M	CC	DP	Salt	ME	LY	VO	(g/kg)	(%)
T1	74.10	19.50	2.60	0.60	2.20	1.00	0.50	0.40	0.00	16.00	0.00	0.00
T2	73.40	19.50	2.65	0.60	1.09	1.06	0.53	0.19	0.00	0.80	0.250	0.00
T3	73.10	19.80	2.65	0.60	1.09	1.06	0.53	0.19	0.00	0.80	0.400	0.00
T4	46.20	20.90	0.00	0.60	2.21	2.15	1.08	0.30	0.50	5.90	0.000	20.00
T5	45.71	21.12	0.00	0.50	2.23	2.23	1.09	0.30	0.50	5.90	0.250	20.00
T6	45.42	21.19	0.00	0.50	2.24	2.18	1.09	0.30	0.50	6.00	0.400	20.00

T1= control (n=18), T2= 0.25 g/kg of EOO (n=14), T3= 0.40 g/kg of EOO (n=16), T4= 20% of OB (n=16), T5= 0.25 g/kg of EOO + 20% of OB (n=18), T6= 0.40 g/kg of EOO + 20% of OB (n=18).

C= corn; SM= soybean meal; WB= wheat bran; V&M= premix of vitamins and minerals; CC= calcium carbonate; DP= dicalcium phosphate; ME== methionine; LY= lysine; VO= vegetable oil; EOO= essential oil of oregano; OB= oregano bagasse.

Productive behavior

The initial weight (IW, kg) of each rabbit was registered at the beginning of the experiment. The studied variables were the weight of the rabbit (WR, kg), and food intake (FI, kg) at days 37, 44, 51, 58, 65 and 72 of fattening. The data obtained were utilized to estimate the daily weight gain per week [WWG; (finalWR – initialWR - IW) / days] and the food conversion (FC; FI / WR) as food intake depending on the weight of the rabbits.

Slaughtering, carving of the carcass and the meat sampling

After the period of fattening, the rabbits were identified and transported to the Complex of Meat Science of the University for slaughtering according to the guidelines of the Official Mexican Standard NOM-033-SAG/ZOO[22] and Simonová *et al*[23]. The transportation time was less than 10 min. The rabbits were not given fasting time before being slaughtered. They were desensitized through dislocation of the atlanto-occipital joint, and immediately hung on slaughter hooks by the rear legs in the process line and quickly bled dry through a cut in the neck (jugular vein and carotid artery) during 3 min. Afterward, the front legs, the head, and the skin with the tail were carefully separated; immediately after, the rabbits were eviscerated, their rear legs were separated and the open carcasses were washed. Finally, the carcasses were drained during 5 min and stored at 4 ± 1.0 °C for 24 h. During this process, the weight at slaughtering (WS), the weight of the blood, the skin with the tail, the front and rear legs, the head, the viscera and the weight of the hot carcass (n= 100) were registered; thus, these weights were expressed as percentages of the WS and considered as slaughter variables: blood, skin, head, feet, viscera, and hot carcass yield (HCY). The weight of the cold carcass took 24 h *post mortem* to determine the cold carcass yield (CCY). The average weight at slaughtering was 1.86 ± 0.44 kg.

The primary cuts (quartering: spine, legs, arms and ribs) of the carcasses obtained (n= 100) were performed according to the harmonization criteria described by Blasco and Ouhayoub(24). The weights of the parts are expressed in terms of the WR. The carcass was devoid of the head, liver, kidneys and thoracic organs. Finally, the *Longissimus lumborum* muscles were separated and stored (4 ± 1.0 °C) until the quality of meat was assessed.

Physical-chemical properties of the meat

The physical-chemical evaluation of the meat was made by triplicate, using for this purpose the *Longissimus lumborum* muscle, at 24 h and 10 d *post-mortem*. The pH was measured with a potentiometer with a puncture electrode (Sentron® Integrated Sensor Technology, Model 101); these values were converted to antilogarithm for analysis. The water retention capacity (WRC) was determined according to the technique described by Owen *et al*(25); 0.3 g of meat were compacted under a weight of 5 kg per 10 min; the WRC was calculated based on the difference in weight before and after the pressure, expressed as a percentage. The color was assessed using the CIE Lab(26) system, L* (luminance), a* (tendency to red), and b* (tendency to yellow) with a spectrophotometer (Konica Minolta®, Tokyo, Japan; CIE standard illuminant/Observer: D65/10).

Statistical analysis

The data for the productive behavior were analyzed with the PROC MIXED(27), and the initial weight of rabbits was used as a covariate. The variables slaughter, carving and meat quality (24 h and 10 d) were analyzed using the general linear model(27). When there was difference ($P \leq 0.05$) between treatments, the averages of the variables were analyzed with Tukey's statistical test.

Results and discussion

Table 2 shows the productive behavior of rabbits supplemented with essential oil and bagasse of Mexican oregano. The rabbits supplemented with OB had higher weights. At the age of 37 ds (*P*<0.0001), the rabbits of the T4 exhibited the highest weight (1.12 kg), while the rabbits with the control diet (T1) had the lowest weighs (0.90 kg). At 44, 51, 58, 65 and 72 d of age (*P*<0.0001), the highest live weights were found in T6 (1.38, 1.51, 1.79, 1.88 and 2.08 kg), and the lowest, in T3 (1.03, 1.08, 1.32, 1.57 and 1.67 kg). The results obtained at 37 d of age may be associated with the fact that the adaptation period of the intestinal flora of the rabbits with oregano was still ongoing(28), so that a lower dose and the biological activity of the OB led to better weights. The above can be confirmed by the results of the subsequent periods, where the higher weights occurred in the rabbits supplemented with 400 ppm of EOO + OB; at this stage, the rabbits were already adapted to the dose of EOO, whose biological activity coupled with that of OB was expressed as positive. Abdel-Khalek(29) pointed out that supplementation of rabbits with antioxidants such as alpha tocopherol acetate and vitamin C has a positive effect on the production parameters. On the other hand, the supply of fiber from the OB was able to contribute to the balance of the intestinal flora, positively influencing the feed efficiency(30). T1 and the treatments with essential oil (T2 and T3) behaved in a similar way (*P*=0.9403). These results coincide with those obtained by Cardinali *et al*(15), who found no difference in the live weight of the rabbits when adding essential oils to their diet.

Table 2: Productive behavior of rabbits supplemented with essential oil of oregano and oregano bagasse (the least-squares mean ± standard error)

Variable/ Age (days)	Treatments						*P*-value
	T1	T2	T3	T4	T5	T6	
	Live weight (kg)						
37	0.90 ± 0.08[bc]	0.92 ± 0.08[c]	0.94 ± 0.08[bc]	1.12 ± 0.08[a]	1.10 ± 0.08[ab]	1.09 ± 0.08[ab]	< 0.0001
44	1.07 ± 0.08[abc]	1.07 ± 0.08[bc]	1.03 ± 0.08[c]	1.31 ± 0.08[ab]	1.33 ± 0.08[ab]	1.38 ± 0.08[a]	< 0.0001
51	1.16 ± 0.09[ab]	1.21 ± 0.08[bc]	1.08 ± 0.08[c]	1.45 ± 0.08[ab]	1.44 ± 0.08[ab]	1.51 ± 0.08[a]	< 0.0001
58	1.44 ± 0.09[bc]	1.37 ± 0.08[bc]	1.32 ± 0.08[c]	1.69 ± 0.08[ab]	1.62 ± 0.08[ab]	1.79 ± 0.08[a]	< 0.0001
65	1.53 ± 0.09[ab]	1.52 ± 0.09[b]	1.57 ± 0.08[b]	1.78 ± 0.08[ab]	1.77 ± 0.08[ab]	1.88 ± 0.08[a]	0.0002
72	1.72 ± 0.09[ab]	1.68 ± 0.09[ab]	1.67 ± 0.08[b]	1.97 ± 0.08[ab]	1.99 ± 0.08[ab]	2.08 ± 0.08[a]	0.0031
	Feed intake (kg)						
37	0.34 ± 0.10[b]	0.37 ± 0.10[b]	0.39 ± 0.10[b]	0.79 ± 0.10[a]	0.72 ± 0.10[a]	0.74 ± 0.10[a]	< 0.0001
44	0.26 ± 0.10[b]	0.27 ± 0.10[ab]	0.19 ± 0.10[b]	0.32 ± 0.10[ab]	0.35 ± 0.10[ab]	0.47 ± 0.10[a]	0.0089
51	0.36 ± 0.11[ab]	0.42 ± 0.10[a]	0.20 ± 0.10[b]	0.39 ± 0.10[ab]	0.45 ± 0.10[a]	0.45 ± 0.10[a]	0.0170
58	0.54 ± 0.11	0.32 ± 0.10	0.41 ± 0.10	0.42 ± 0.10	0.35 ± 0.10	0.44 ± 0.10	0.4518
65	0.40 ± 0.12	0.53 ± 0.11	0.76 ± 0.11	0.35 ± 0.11	0.51 ± 0.10	0.39 ± 0.10	0.0520
72	0.74 ± 0.11	0.59 ± 0.11	0.39 ± 0.11	0.63 ± 0.10	0.73 ± 0.10	0.70 ± 0.10	0.6343

T1= control (n=18), T2= 0.25 g/kg of EOO (n=14), T3= 0.40 g/kg of EOO (n=16), T4= 20% of OB (n=16), T5= 0.25 g/kg of EOO + 20% of OB (n=18), and T6= 0.40 g/kg of EOO + 20% of OB (n=18).

[abc] Different letters between columns indicate significant difference (*P*<0.05).

The food intake was influenced by the effect of the treatments (*P*<0.0001). At 37 d of age, the highest intake (0.79 kg) occurred in the T4 rabbits. At d 44 (*P*=0.0089), the rabbits of T6 exhibited a higher intake (0.47 kg), while the rabbits of T3 had the lowest intake (0.19 kg). At 51 d of age (*P*=0.0170), the animals of T2, T5 and T6 exhibited the highest consumption (0.42, 0.45 and 0.45 kg, respectively); in the same period, the rabbits of T3 had the lowest food intake (0.20 kg). From d 58 to d 72, the treatment did not influence the food intake (*P*=0.4518, 58 d; *P*=0.0520, 65 d; *P*=0.6343, 72 d). The results could be due to the fiber type provided by the OB; Marguenda *et al*(31) mentioned that the level and type of fiber are important factors to regulate the retention time in the caecum and, therefore, the food intake. On the other hand, Bakkali *et al*(5) indicated that some components of essential oils do not have specific cellular targets, but can cause some degree of membrane toxicity similar to the mechanism of bactericidal action. In eukaryotic organisms, they cause depolarization of the mitochondrial membranes, decreasing the membrane potential, which affects certain ion channels, and, as a result, the pH decreases and modifies the digestive enzyme activity. In this regard, it has been noted[32] that phenolic compounds present in the oregano favor the absorption of nutrients and stimulate the secretion of digestive enzymes. This may have caused the animals fed with OB to have, at d 37, 44 and 51, a higher intake and live weight, while in the rest of the periods there was no difference between treatments, probably because the animals were already accustomed to the food and increased their intake with respect to previous periods.

The weekly weight gain was influenced by effect of the treatments (Table 3). At d 37 (P<0.0001), the rabbits supplemented with OB (T4) exhibited the greatest gains (0.34 kg), while those of T1 and T2 had lower gains (0.13 kg). At 44 d of age, (P=0.0172) the best weight gain (0.28 kg) was observed in T6, whereas the lowest was found in T3 (0.09 kg). At d 51 (P=0.0126), the highest weight gains were registered in T2, T4 and T6 (0.14 kg), and lowest, in T3 (0.05 kg). At d 65 (P=0.0257), the rabbits of T3 had the greatest weight gain (0.23 kg), while the animals of T6 were the ones that gained the least weight (0.10 kg). At d 58 (P=0.3752) and 72 (P=0.7100), no difference in weight gain was found; this is consistent with the food intake during these periods, which was similar in all treatments. The greater weight gains at d 37, 44 and 51 of T6 can be accounted for by the higher food intake observed in this treatment during the same period. The results show a clear relationship between food intake and weight gain, suggesting that supplementation with oregano influences weight gain.

Table 3: Productive efficiency of rabbits supplemented with essential oil and bagasse of Mexican oregano (least mean squares ± standard error)

Variable/ Age (days)	**Treatments**						***P*-value**
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	
			Weekly weight gain (kg)				
37	0.13 ± 0.05^{b}	0.13 ± 0.05^{b}	0.15 ± 0.05^{b}	0.34 ± 0.05^{a}	0.32 ± 0.05^{a}	0.31 ± 0.05^{a}	< 0.0001
44	0.17 ± 0.05^{ab}	0.16 ± 0.05^{ab}	0.09 ± 0.05^{b}	0.19 ± 0.05^{ab}	0.22 ± 0.05^{ab}	0.28 ± 0.05^{a}	0.0172
51	0.11 ± 0.05^{ab}	0.14 ± 0.05^{a}	0.05 ± 0.05^{b}	0.14 ± 0.05^{a}	0.12 ± 0.05^{ab}	0.14 ± 0.05^{a}	0.0126
58	0.37 ± 0.05	0.17 ± 0.05	0.25 ± 0.05	0.23 ± 0.05	0.18 ± 0.05	0.27 ± 0.05	0.3752
65	0.11 ± 0.05^{ab}	0.15 ± 0.05^{ab}	0.23 ± 0.05^{a}	0.09 ± 0.05^{b}	0.15 ± 0.05^{ab}	0.10 ± 0.05^{b}	0.0257
72	0.20 ± 0.05	0.17 ± 0.05	0.10 ± 0.05	0.19 ± 0.05	0.22 ± 0.05	0.20 ± 0.05	0.7100
			Feed conversion				
37	3.62 ± 0.26^{a}	2.91 ± 0.26^{ab}	3.00 ± 0.26^{ab}	2.35 ± 0.26^{b}	2.24 ± 0.26^{b}	2.69 ± 0.26^{ab}	0.0138
44	3.48 ± 0.26	3.64 ± 0.26	4.61 ± 0.26	3.82 ± 0.26	3.30 ± 0.26	3.52 ± 0.26	0.1764
51	3.76 ± 0.28	3.40 ± 0.26	4.09 ± 0.26	3.16 ± 0.26	3.97 ± 0.26	3.35 ± 0.26	0.1310

58	3.67 ± 0.29	3.88 ± 0.26	3.93 ± 0.26	4.00 ± 0.27	3.51 ± 0.26	3.94 ± 0.26	0.5642
65	4.08 ± 0.30	4.31 ± 0.27	3.57 ± 0.27	4.02 ± 0.27	4.04 ± 0.26	4.15 ± 0.26	0.2297
72	4.13 ± 0.28	3.87 ± 0.27	4.05 ± 0.27	3.64 ± 0.27	3.57 ± 0.26	3.72 ± 0.26	0.1695

T1= control (n=18), T2= 0.25 g/kg of EOO (n=14), T3= 0.40 g/kg of EOO (n=16), T4= 20% of OB (n=16), T5= 0.25 g/kg of EOO + 20% of OB (n=18), and T6= 0.40 g/kg of EOO + 20% of OB (n=18).

[ab] Different letters between columns indicate significant difference *P*<0.05).

The food conversion (FC) was influenced by effect of the treatments at the start of the study. At d 37 (*P*=0.0138), the best conversion occurred in T5 (2.24), while the control treatment had the highest FC (3.62). At d 44 (*P*=0.1764), 51 (*P*=0.1310), 58 (*P*=0.5642), 65 (*P*=0.2297) and 72 of age (*P*=0.1695), the treatment did not influence the FC. The results found may be due to the fact that, during the first days of study, the rabbits had been recently weaned and moved to their new accommodations, which may have caused them a certain level of stress. However, the rabbits that consumed oregano exhibited the best conversion, and, according to Abdel-Khalek(29), the addition of antioxidants to the diet of the rabbits helps to reduce the negative effects of stress. The above can be corroborated by the findings of the subsequent weeks, which showed that the rabbits were already accustomed to the external conditions, and, therefore, they did not exhibit a significant difference for food conversion in these periods.

Table 4 shows the effect of the essential oil and bagasse of oregano on the slaughtering and the characteristics of rabbit carcasses. The hot carcass yield (HCY) exhibited an effect of the treatments (*P*<0.0004); T2 (48.19 %), T4 (50.66 %) and T5 (49.87 %) had the highest yield, and T1 had the lowest (44.27 %). The yield of the organs of the digestive tract was also influenced by the treatments (*P*<0.0020); T4 had the lowest yield (21.02 %), while T1 and T3 had the highest yields (29.67 and 28.36 % respectively). The head yield (*P*<0.0050) was highest in the rabbits of T1 (10.28 %) and lowest in those of T4 (8.70 %) and T6 (8.68 %). The yield of the thoracic viscera (*P*=0.4064), legs (*P*=0.6988), skin (*P*=0.0542) and blood (*P*=0.0530) was not influenced by effect of the treatments. The lower yield of abdominal viscera can be attributed to the fiber provided by OB, as this can stimulate peristaltic movements mechanically, which promote the circulation of the contents of the gastrointestinal tract(33); at the same time, it may regulate these processes through the compounds generated by the fermentation of the ingested food(30). On the other hand, the greater yields observed in treatments with oregano can be ascribed to the fact, pointed out by Hernández and Dalle Zotte(19), that the rabbits have the ability to improve the incorporation of the fatty acids and nutrients provided by the diet into the muscle. This suggests that the rabbits supplemented with oregano incorporated some of its compounds into the meat, and, therefore, the chemical characteristics of the meat were modified, increasing the yield.

Table 4: Effect of the essential oil and bagasse of oregano on the yield of the meat and non-meat components of the rabbits (%)

	Treatment						
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	***P*-value**
Hot carcass	44.27±1.12^{b}	48.19±1.00^{ab}	47.27±1.24^{ab}	50.66±1.18^{a}	49.87±1.00^{a}	47.20±0.97^{ab}	<0.004
Cold carcass	43.07±1.05^{b}	47.80±0.93^{a}	46.62±1.16^{ab}	49.63±1.10^{a}	48.54±0.93^{a}	46.87±0.91^{ab}	<0.001
Digestive tract	29.67±0.85^{a}	24.49±0.76^{b}	28.36±0.94^{a}	21.02±0.90^{c}	23.39±0.76^{cb}	23.44±0.74^{cb}	<0.002
Thoracic viscera[2]	1.22±0.43	1.19±0.38	1.14±0.47	1.10±0.45	1.18±0.38	1.19±0.37	Ns
Head	10.28±0.31^{ab}	9.085±0.27^{bc}	10.27±0.34^{a}	8.70±0.32^{c}	9.07±0.27^{bc}	8.68±0.27^{c}	<0.005
Feet and hands	3.91±1.03	5.37±0.91	3.89±1.14	3.51±1.09	3.61±0.91	4.63±0.89	Ns
Skin	8.01±0.53	8.02±0.47	9.03±0.59	10.03±0.56	9.25±0.47	9.28±0.46	Ns
Blood	3.14±0.54	4.62±0.48	2.65±0.60	4.45±0.57	3.26±0.48	4.19±0.47	Ns
			Yield of technological cuts (%)				
Leg	37.72 ± 1.11	36.83 ± 0.97	37.63 ± 1.26	37.72 ± 1.15	39.22 ± 0.97	37.58 ± 0.92	Ns
Arms	14.56 ± 0.44	13.37 ± 0.38	14.46 ± 0.50	14.21 ± 0.46	14.57 ± 0.38	14.30 ± 0.37	Ns
Loin	20.94 ± 0.74^{b}	24.65 ± 0.64^{a}	23.46 ± 0.84^{ab}	25.27 ± 0.76^{a}	26.06 ± 0.64^{a}	24.89 ± 0.61^{a}	<0.0001
Rib cage	20.24 ± 0.59	20.98 ± 0.51	21.90 ± 0.67	22.49 ± 0.61	21.94 ± 0.51	21.90 ± 0.49	Ns

T1= control (n=18), T2= 0.25 g/kg of EOO (n=14), T3= 0.40 g/kg of EOO (n=16), T4= 20% of OB (n=16), T5= 0.25 g/kg of EOO + 20% of OB (n=18), T6= 0.40 g/kg of EOO + 20% of OB (n=18).

Thoracic viscera: Lungs, trachea, esophagus, and heart.

[abc] Different letters in the same row indicate significant difference (*P*<0.05).

With respect to the yield of the technological cuts of the carcass, supplementation with EOO and OB did not influence the yield of the legs (*P*=0.6256), the arms (*P*=0.1585) or the ribs (*P*=0.1810); however, it did increase the yield of the loin (*P*<0.0001) in T2 (24.65 %), T4 (25.27 %), T5 (26.06 %), and T6 (24.89 %). According to Dalle Zotte and Szendrö[3], of the pieces that make up the carcass (legs, arms, ribs and spine), the spine exhibits a low fat content; however, the rabbit has the ability to incorporate the fatty acids provided by the diet into the lipid tissue and the inter- and intramuscular fat; this may account for the higher yield of the spine of the animals fed with oregano. As for the legs, arms and ribs, no significant difference was found (*P*>0.05) between the treatments, since they normally have a higher fat content.

On the other hand, Garcia *et al*[34] found that caecal fermentation generates varying amounts of volatile fatty acids from the fiber provided by the diet, which, when partially absorbed, cover 10 to 30 % of the energy requirements of maintenance energy[35,36,37], representing additional energy to what was expected at the time of balancing the food ration.

As for pH, it was found that the pH of the meat of the rabbits in T1 and T4 increased (*P*=0.0190) with time (5.18 - 5.90 and 5.75 - 5.90, at 24 h and 10 d *post-mortem*, respectively), while the meat of T2 and T3 remained equal (*P*>0.5524) over time (Table 5).

Table 5: Effect of the essential oil and bagasse of oregano on the pH, water retention capacity and color of the rabbit meat

	Treatments						***P*-value**
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	
24 h *post mortem*							
pH	5.18±0.03[b]	5.80±0.03[ab]	5.82±0.03[a]	5.75±0.03[b]	5.76±0.03[b]	5.73±0.02[b]	0.0002
WRC (%)	55.99±1.45[ab]	59.40±1.62[a]	53.07±1.77[b]	60.30±1.45[a]	57.52±1.45[ab]	60.59±1.45[a]	0.0500
L*	62.26±0.82	56.60±0.73	59.78±1.01	56.66±0.91	57.06±0.76	57.19±0.66	0.3373
a*	5.63±0.68	4.09±0.62	4.84±0.82	3.73±0.74	4.51±0.64	4.08±0.56	0.3111
b*	7.51±0.44[a]	4.44±0.40[c]	6.34±0.52[a]	4.68±0.47[bc]	5.33±0.41[bc]	5.18±0.37[bc]	0.0430
10 days *post mortem*							
pH	5.90±0.03	5.87±0.03	6.00±0.04	5.90±0.03	5.89±0.03	5.92±0.03	0.5464
L*	55.90±0.82	57.92±0.73	57.47±0.95	58.73±0.91	56.50±0.70	58.59±0.71	0.3373
a*	9.23±0.68	6.95±0.62	7.71±0.78	6.89±0.74	7.63±0.60	6.25±0.60	0.3111
b*	7.11±0.44[a]	4.94±0.40[b]	6.82±0.49[a]	5.81±0.47[ab]	5.57±0.39[ab]	5.76±0.39[ab]	0.0430

L* = luminance; a* = tendency to red; b* = tendency to yellow; pH= potential for hydrogen; WRC= water retention capacity.

T1= control (n=18), T2= 0.25 g/kg of EOO (n=14), T3= 0.40 g/kg of EOO (n=16), T4= 20% of OB (n=16), T5= 0.25 g/kg of EOO + 20% of OB (n=18), T6= 0.40 g/kg of EOO + 20% of OB (n=18).

[ab] Different letters between rows indicate difference between treatments in the *post mortem* time (*P*<0.05).

The WRC was influenced by effect of the treatments (*P*=0.0500); the meat of T2, T4 and T6 showed higher WRC (48.89, 60.30 60.59 %, respectively), and T3 (53.07 %) exhibited the lowest WRC. The antioxidant activity of the oregano on muscle fibers(38) may have influenced the WRC, since in species such as the chicken, the addition of antioxidants in the diet has been found to preserve the functionality of the membranes and increase their activity as a semi-permeable barrier(39). Conversely, Meineri *et al*(40) did not find the same effect when adding *Salvia hispanica* to the diet of rabbits. On the other hand, the pH is directly related to the WRC, and this can vary according to the hydrolysis of proteins with the release of ammonia and the hydrolysis of lipids with the release of fatty acids(41). It has been said(42) that essential oils can coagulate the cytoplasm by damaging the lipids and proteins; damage to the cell membrane can cause the release of macromolecules and lysis(43,44) by modifying the pH(5), which would affect the stability of the proteins directly impacting the WRC(45). On the other hand, Dalle Zotte and Szendrö(3) mentioned that rabbit meat is characterized by being rich in unsaturated fatty acids; this entails a problem for the meat, because it renders it more sensitive to oxidation(29); as a result, the functionality of the cell membranes is partially or totally reduced(40). Various studies(2,3,46) reported antioxidant activity by the compounds of oregano; however, Cox *et al*(42) found that certain components of aromatic plants such as oregano can have a negative effect on lipids and proteins because they do not have specific cellular receptors(5); this may be attributed to the difference in pH found at 24 h and 10 d *post mortem* in the meat of T4.

With regard to the color, the luminance (L*) was not influenced by the treatments (*P*=0.3373) at 24 h and 10 d *post mortem*, with the exception of the T1 at 24 h to 10 d, since the meat of T1 had more luminance at 24 h. The tendency to red (a*) was not influenced by the treatment (*P*=0.3111) but it was by the time (*P*<0.0004), as at 10 d *post mortem* the value of a* increased in all the treatments. The tendency to yellow (b*) was influenced by the effect of the treatments (*P*<0.0430); T1 and T3 showed the highest value, while T2 had the lowest.

The results of this study differ from those reported by some authors who found no effects when adding oregano leaves(14) to the diet, and EOO to the water supplied to growing rabbits(23); this may be due to the fact that the dose of EOO administered was lower than the one evaluated in this research for the essential oil and bagasse of Mexican oregano, which may have influenced the color of the meat, and to the content of certain phenolic compounds(47). In other species such as birds, high doses of essential oil (500 mg kg^{-1}) in the diet have been observed to cause a significant antioxidant effect(48). In addition, the presence of oxygen on the muscle fiber oxidizes the meat, taking up a darker color(45); this would explain the high value of a* found at 10 d *post mortem* in all treatments, and the lower L* in the control treatment (T1), which is indicative of the effect of the antioxidant activity of the compounds of the oregano(49). This could suggest changes in the nutritional and physical characteristics of the meat that may be of interest to researchers.

Conclusions and implications

The results confirm that OB can be an integral part of the diet of rabbits for fattening. Including 20 % of bagasse of oregano into the diet positively influences the daily weight gain, the food conversion, and the carcass and loin yield, and increases the water retention capacity; likewise, the combination 0.25 g kg^{-1} of EOO + 20% of OB has a similar effect. Finally, the minimum concentration of essential oil of oregano (0.25 g kg^{-1} of EOO) is sufficient to influence the productive characteristics and quality of the rabbits. In conclusion, incorporating essential oil and bagasse of oregano (alone or in combination) into the diet of rabbits for fattening improves the productive characteristics and the quality of the carcass and the meat.

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