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Effect of the addition of palmitic acid on fattening performance, carcass and meat quality of sheep

Yuridia Bautista-Martinez[1], Lorenzo Danilo Granados-Rivera[2*], Jorge Alonso Maldonado-Jáquez[3*], Pablo Arenas-Baéz[4]

[1]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Tamaulipas, Ciudad Victoria, Tamaulipas, México; [2]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental General Terán, General Terán, Nuevo León, México; [3]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental La Laguna, Matamoros, Coahuila, México; [4]Universidad Autónoma Chapingo, Unidad Regional Universitaria de Zonas Áridas, Bermejillo, Durango, México

***Corresponding Authors**: Lorenzo Danilo Granados Rivera, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental General Terán, General Terán, Nuevo León, México. Email: granados.danilo@inifap.gob.mx; Jorge Alonso Maldonado Jáquez, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental La Laguna, Matamoros, Coahuila, México. Email: maldonado.jorge@inifap.gob.mx

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Abstract

This study aimed to investigate the effect of palmitic acid, added in the diets of finishing male sheep, affecting productive variables, carcass quality and meat. A total of 21 male sheep, cross of the Dorper and Pelibuey breeds, were used and divided into three treatments: control (CON), comprising sheep fed with the base diet; PA3 treatment, in which the diet included 3% palmitic acid; and PA6 treatment, in which the diet included 6% palmitic acid. The addition of 3% palmitic acid in the diet improved productive variables, carcass quality, and modified the antioxidant capacity without affecting the physicochemical characteristics of the meat.

Keywords: daily weight gain; fatty acid profile; feed conversion; total antioxidant capacity

Introduction

Because of the search for strategies that allow satisfying the national demand for sheep meat, sheep farming in Mexico has opted for the use of intensive or mixed production systems instead of the extensive system chosen traditionally. In this sense, new feeding technologies have been implemented, such as the incorporation of different energy sources in the diets offered, in order for the sheep to express their genetic potential, and hence achieve an increase in growth, reduce finishing time, improve meat quality and carcass yield (Etherton, 2009). Since energy is one of the nutrients that has the greatest influence on productive variables, such as daily weight gain, feed conversion and feed efficiency, the use of fats as an energy source in sheep feed has been justified (Ramírez-Bribiesca *et al.*, 2021).

This has led to the development of research that proposes the use of different specific fatty acids as an energy option; this is the case of palmitic acid, which has been used in diets of dairy cows to improve production (Chamberlain and DePeters, 2017). However, to the best of our knowledge, there are no precedents on the use of pure palmitic acid in feeding sheep intended for meat production and its effect on their productive variables, carcass and meat quality in ruminants intended for meat production, compared to some studied oils high in palmitic acid content, such as palm oil (Castro *et al.*, 2005; Dutta *et al.*, 2008) but not as a protected fatty acid (FA) in rumen with 99% purity.

Therefore, since feeding is one of the most important factors influencing production, carcass and meat quality (Prache *et al.*, 2021), the objective of this study was to evaluate the effect of palmitic acid, added in the finishing diets of sheep, on productive variables, carcass and meat quality.

Materials and Methods

The procedures carried out with the sheep were approved by the Bioethics and Animal Welfare Committee of the School of Veterinary Medicine and Zootechnics, the Autonomous University of Tamaulipas, with certificate No. CBBA_10_2021. The study was carried out in the sheep area of the Zootechnical post of the School of Veterinary Medicine and Zootechnics. The place has a semi-arid warm climate, classified as BS1(h') hw (Vargas *et al.*, 2007).

Animal management and treatments

A total of 21 male sheep, crosses of the Dorper and Pelibuey breeds, weaned recently, aged 3 months, and having an average weight of 14 kg, were used. The sheep were placed in individual pens, equipped with individual feeders and drinkers. The animals were adapted to the basal finishing diet for 15 days before commencing the experiment. During the 90-day fattening period, three treatments were evaluated, each with seven lambs (Table 1). The control treatment (CON) comprised feeding the sheep with base diet only; in the PA3 treatment, the base diet included 3%

Table 1. Ingredients and chemical composition of experimental diets.

Ingredient (% of DM)	CON	PA3	PA6
Sorghum grain	17.1	17.1	17.1
Maize grain	17.1	17.1	17.1
Wheat bran	9.0	9.0	9.0
Soymeal	9.0	9.0	9.0
Urea	1.2	1.2	1.2
Molasses	4.8	4.8	4.8
Mineral premix*	1.8	1.8	1.8
Maize stubble	8	8	8
Alfalfa hay	32	29	26
Palmitic acid	–	3	6
Chemical composition (% DM)			
Dry matter	90.21	90.32	90.51
Crude protein	11.40	11.42	11.39
NDF	35.40	34.9	34.79
ADF	20.50	20.48	20.51
Ether extract	1.99	5.01	7.03
Ash	6.03	6.21	6.12
ME (Mcal/kg DM)	2.65	2.92	3.16
Fatty acids			
<C16:0	2.55	2.52	2.40
C16:0	24.54	26.89	29.48
C16:1	1.50	1.48	1.42
C18:0	2.94	2.91	2.89
C18:1 n-9	16.68	16.55	16.35
C18:2 n-6	18.74	18.54	18.72
C18:3 n-3	32.28	30.54	28.23
C20:0	0.77	0.57	0.51

*Premix minerals for fattening of lambs (Ovitec 302 F® Tenusa Throuw Nutrition, Monterrey, NL, México) contained: calcium, 22%; sodium, 8%; manganese, 1,000.00 ppm, zinc, 1,000.00 ppm, vit. A, 150,000.00 IU/kg; vit. E, 150,000.00 IU/kg.
NDF: neutral detergent fiber; ADF: acid detergent fiber; CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid.

palmitic acid; and the PA6 treatment base diet included 6% rumen-protected palmitic acid with 99% purity (Jefo Dairy Fat).

Daily weight gain (DWG)

Lambs were weighed individually in the morning (before offering food) using an industrial portable digital LCD hanging scale with a capacity of 0.62–500 kg (crane scale), with a measurement error of 0.01 kg at the beginning of the experimental phase; the animals were also weighed at every 8 days until the end of fattening. The DWG was obtained by the difference in final live weight minus the initial live weight between the number of days elapsed between the two weighing (expressed in kilograms).

Feed Conversion (FC)

It was obtained by dividing the total feed consumption by the total weight gain (expressed in kilograms) of each animal per treatment. Feed consumption was weighed on an Ohaus 20 kg × 1 g mechanical scale OHAUS Europe GmbH (model OHAUS01300).

Feed Efficiency (FE)

It was obtained by dividing the total weight gain between the total food consumption of each animal per treatment.

Carcass and meat quality characteristics

At the end of the 90-day fattening period, the sheep were weighed and subsequently slaughtered. After slaughter, the carcasses were cooled to 4°C for 24 h and the cold carcasses were weighed to calculate carcass yield. Carcass length, thorax width, thorax depth, leg length, and leg girth were measured according to the Fisher and Boer (1994) methodology.

The thickness of back fat of the rib consisted of measuring with a caliper the depth of the fatty tissue at the level of the intercostal space between the 12th and 13th rib. The left half carcass at the back was cut and dissected to measure the following variables: back weight, meat percentage, bone percentage, total subcutaneous and intermuscular fat percentage, and waste percentage; meat–bone and meat–fat ratios were calculated according to the Bianchi *et al.* (2006) methodology.

The pH was measured 24-h postmortem from a section of the *Longissimus dorsi* muscle by inserting electrode of a portable potentiometer (H198161, Hanna Instruments, Woonsocket, RI, USA). Luminosity (L*), red index (a*), and yellow index (b*) values were measured with a colorimeter (Mod CR-400/410; Minolta, Tokyo, Japan). The drip loss was measured with the methodology mandated by Morón-Fuenmayor and García (2004) by using 30 g of meat. The yield per cooking was determined by the Guerrero *et al.* (2002) methodology by placing 50-g meat samples in Bain-Marie at 75°C for 15 min. Later, the samples were withdrawn and allowed to cool to be weighed again. The values were expressed as the percentage of the sample with respect to its initial weight.

The samples used to measure cooking yield were cut into rectangular strips of 4-cm length, 1-cm width, and 1-cm height, parallel to muscle fibers. The cut force was measured on a texture analyzer (Model: TAXT2i; Scarsdale, NY, USA) equipped with a Warner–Bratzler single blade.

Fatty acid profile

To determine the FA profile of the sheep meat, fat purification was carried out through methylation of fatty acids using the methodology assigned by Granados-Rivera *et al.* (2017).

The identification of FA was done by comparing the retention period of each peak obtained in the chromatogram with a standard of 37 components of FA methyl esters (Nu-Check Company; Elysian, USA). For this, we used a chromatograph (Hewlett Packard 6890 USA), FID detector, G2613A automatic injector, and silica capillary column (100-m × 0.25-mm × 0.20-μm thick; SPTM-2560; Supelco).

Total antioxidant capacity

The antioxidant capacity was determined by 2,2-diphenyl-1-picrylhydrazyl (DPPH) on 0, 1, 3, 5, 7 and 9 days of refrigeration by spectrophotometry (Visible Spectrophotometer Varian Cary 1E UV, USA) at 517 nm (Godínez-Juárez *et al.*, 2022).

Statistical analysis

Productive variables, carcass and meat quality were analyzed using a completely randomized design. For productive variables, the initial weight of the animals was considered as a covariate using the GLM procedure of statistical package SAS 9.4. Mean values were obtained and compared using the adjusted Tukey's test.

The total antioxidant capacity of the meat was analyzed using the MIXED procedure of SAS 9.4 for a completely random design with repeated mean values. The model included the main effects of treatments, periods, and the interaction of treatment by period. The appropriate covariance structure for the analysis was determined by testing different structures, and the covariance structure with negative or near-zero values was chosen according to the Akaike and Schwartz criteria (Herrera and Garcia, 2010).

Results

The sheep that were fed with the PA3 treatment had a higher daily weight gain and the final weight, compared to the CON and PA6 treatments ($p \leq 0.05$), which favorably influenced the conversion and feed efficiency of PA3 treatment (Table 2).

The addition of palmitic acid in the sheep diet influenced the characteristics that define quality of the carcass (Table 3). The carcass weight, yield, its length, thorax width, back weight, percentage of muscles, bone, intramuscular fat, and meat–fat ratio were higher in the sheep of PA3 treatment, showing significant differences with respect to CON and PA6 treatment.

The physicochemical characteristics, which define meat quality, were not modified by the addition of palmitic acid in the sheep diet (Table 4).

Table 2. Productive variables of sheep fed in stables adding palmitic acid to the diet.

Variable	CON	PA3	PA6	SEM	*p*
FW (kg)	32.33[b]	38.74[a]	32.29[b]	0.556	0.0001
FI (kg)	1.30[a]	0.94[c]	1.14[b]	0.100	0.0001
DWG (kg)	0.20[b]	0.27[a]	0.20[b]	0.028	0.0004
FC	6.33[a]	3.53[b]	5.65[a]	0.585	0.0001
FE	0.15[b]	0.29[a]	0.17[b]	0.034	0.0001

CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid; FW: final weight; FI: feed intake; DWG: daily weight gain; FC: feed conversion; FE: feed efficiency.
[a,b,c]Different letters in the same row present statistical differences ($p < 0.05$).

Table 3. Characteristics of the sheep carcasses with added palmitic acid to the finishing diet.

Variable	CON	PA3	PA6	SEM	*p*
Carcass weight	14.42[b]	20.10[a]	15.22[b]	0.981	<0.0001
Carcass yield (%)	44.67[b]	51.92[a]	47.30[b]	2.148	0.0019
Carcass length (cm)	66.80[b]	72.40[a]	64.40[b]	1.852	<0.0001
Thorax width (cm)	20.60[b]	24.60[a]	21.40[b]	0.516	0.0031
Thorax depth (cm)	24.00	24.60	23.00	0.125	0.1170
Leg length (cm)	30.20	32.60	32.20	1.494	0.0560
Leg girth (cm)	30.00	31.60	31.40	2.456	0.5494
Back fat thickness (mm)	2.66	2.74	2.34	0.616	0.5696
Tissue makeup of the back					
Back weight (kg)	1.80[b]	2.08[a]	1.52[c]	0.0832	<0.0001
Muscle (%)	42.11[b]	46.45[a]	43.11[b]	0.224	0.0001
Bone (%)	15.62[b]	17.78[a]	14.35[b]	0.1464	0.0008
Total fat (%)	21.90[c]	25.37[b]	29.30[a]	0.732	0.0098
Waste (%)	20.37[a]	10.4[b]	13.24[b]	0.125	0.0359
Intramuscular fat (%)	8.32[c]	14.95[a]	11.72[b]	0.727	0.0194
Subcutaneous fat (%)	13.58[b]	10.42[b]	17.58[a]	0.295	0.0469
Meat/fat	1.90[a]	1.83[a]	1.47[b]	0.045	0.0025
Meat/bone	2.69[b]	2.61[b]	3.00[a]	0.067	0.0356

CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid; SEM: standard error of the mean.
[a,b,c]Different letters in the same row present statistical differences ($p < 0.05$).

Table 4. Physicochemical characteristics of sheep meat with added palmitic acid to the finishing diet.

Variable	CON	PA3	PA6	SEM	*p*
ph	5.70	5.76	5.64	0.104	0.2439
L*	41.652	42.67	42.46	1.411	0.5044
a*	16.44	16.64	16.55	0.568	0.868
b*	6.59	6.94	6.58	1.965	0.9458
Drip loss (%)	3.06	3.36	3.60	0.351	0.0872
Cooking yield (%)	77.45	78.42	77.40	1.122	0.304
Shear force (kg/cm2)	4.17	3.92	3.96	0.219	0.1849

CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid; SEM: standard error of the mean; L*: luminosity index; a*: red index; b*: yellow index.

Table 5. Effect of the addition of palmitic acid in the cross of the Dorper- and Pelibuey-breed sheep diet on the fatty acid profile (g/100 g of fat) of meat.

Fatty acid	Common name	CON	PA3	PA6	SEM	*p*
C14:0	Myristic	6.09[a]	4.80[b]	5.05[b]	0.46	0.0021
C14:1	Myristoleic	0.09	0.10	0.08	0.01	0.1499
C15:0	Pentadecanoic	0.73	0.78	0.79	0.09	0.5732
C16:0	Palmitic	22.10[b]	24.42[a]	24.60[a]	0.38	<0.0001
C16:1 *cis-9*	Palmitoleic	2.80[b]	2.97[a,b]	3.21[a]	0.23	0.0427
C17:0	Heptadecanoic	2.01	1.94	2.01	0.10	0.404
C18:0	Stearic	21.00[b]	24.84[a]	24.82[a]	0.48	<0.0001
C18:1 *cis-9*	Elaidic	1.52	1.32	1.58	0.29	0.333
C18:1, n-9	Oleic	31.49[a]	28.05[b]	27.66[b]	0.51	<0.0001
C18:2, n-6	Linoleic	8.33[a]	7.05[b]	6.57[b]	0.37	<0.0001
C20:0	Arachidic	1.05	1.08	1.07	0.08	0.8574
C20:1 *cis-11*	Cis-11-eicosenoic	0.63[a]	0.50[b]	0.47[b]	0.05	0.0018
C18:3, n-3	Linolenic	0.37	0.37	0.38	0.01	0.2035
C20:4. n-6	Arachidonic	1.79	1.78	1.71	0.09	0.0787
SFA		52.98[b]	57.86[a]	58.34[a]	0.47	<0.0001
MUFA		36.53[a]	32.94[b]	33.03[b]	0.52	<0.0001
PUFA		10.49[a]	9.2[b]	8.66[c]	0.35	<0.0001

CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid; SEM: standard error of the mean; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.
[a,b,c]Different letters in the same row present statistical differences ($p \leq 0.05$).

Following fatty acids were found in the highest quantity in sheep meat: oleic acid (C18:1, n-9), stearic acid (C18:0), palmitic acid (C16:0), linoleic acid (C18:2, n-6), and myristic acid (C14:0). In total, these represented an average of 89.01% of the fatty acids that make up the meat of the CON treatment, 89.16% of the PA3 treatment, and 88.70 of the PA6 treatment (Table 5). In addition, differences were found in the sum of saturated fatty acids, monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) between treatments.

Regarding the mean of total antioxidant capacity, differences were found in the interaction of treatment by time (Table 6). It is observed that on day 0, differences in the total antioxidant capacity were observed in all three treatments ($p < 0.05$). From day 1 to day 7, the highest values of total antioxidant capacity were demonstrated by the CON and PA3 treatment, with no differences between treatments ($p > 0.05$). On day 9, the total antioxidant capacity decreased in three treatments without showing differences between treatments.

Discussion

The daily weight gain obtained in this study was higher than 145–196 g per day reported by Dutta *et al.* (2008), who added 2.5–10% of palm oil in the diet of the sheep.

Table 6. Total antioxidant capacity (mmol/kg of dry matter of sheep meat) by adding different doses of palmitic acid to the diet.

Treatment	Days						SEM	*p*
	0	1	3	5	7	9		
CON	20.17[x,f]	20.72[x,e]	23.39[x,d]	25.63[x,a]	25.39[x,b]	24.90[x,c]	0.088	<0.0001
PA3	20.01[y,f]	20.74[x,e]	23.30[x,d]	25.79[x,a]	25.41[x,b]	24.92[x,c]	0.088	<0.0001
PA6	19.43[z,e]	20.54[y,d]	23.05[y,c]	25.47[y,a]	24.93[y,b]	24.88[x,b]	0.088	<0.0001
SEM	0.068	0.068	0.068	0.068	0.068	0.068		
p	<0.0001	0.0250	<0.0001	<0.0001	<0.0001	0.8812		

CON: control treatment; PA3: basal diet with 3% palmitic acid; PA6: basal diet with 6% palmitic acid; SEM: standard error of mean.
[a,b,c,d,e,f,g] In a row, means with different literals are different ($p < 0.01$).
[x,y,z d] In a column, means with different literals are different ($p < 0.01$).

This could be because palm oil in its olein or stearin form contains 37.9–73.8% palmitic acid, 40.7% oleic acid and 10.4% linoleic acid (Mohammadreza *et al.*, 2015), while in this study, 99% palmitic acid was used, and since it is protected in the rumen, palmitic acid can be used by the animal up to the small intestine and the energy can be used by the animal for its growth and weight gain.

An opposite effect occurred in case of PA6 treatment, that is increasing the amount of palmitic acid in the diet. The weight gain was lower than the PA3 treatment, without showing differences with the CON treatment; the same effect was reported by Dutta *et al.* (2008), who obtained maximum weight gain by adding 5% palm oil (196 g), but when palm oil was increased to 7.5% and 10%, the weight gain decreased to 163 g and 145 g, respectively.

Addition of 100-g palmitic acid in the diet improved feed conversion, compared to the average of 4.06 kg of dry matter consumed per kilogram of weight gained, as reported by Mendes *et al.* (2011), who used a protected fat based on soybean oil and calcium.

Regarding feed efficiency, the lambs of PA3 treatment had the best feed efficiency, compared to the lambs of CON and PA6 treatments; for each kilogram of feed they consumed, they gained an average of 296 g, while those that did not consume additional feed had 158-g weight gain. This was interpreted into 138-g less weight gain per kilogram of food consumed. Therefore, the use of fats in lamb diets improved feed efficiency because a greater amount of energy was absorbed, and the animal's metabolism allocated it for an increase in weight (Hernández-Bautista *et al.*, 2017).

In this study, adding 3% of palmitic acid increased carcass yield by 7.25%, compared to the CON treatment. On the other hand, Ferreira *et al.* (2010) reported that the use of protected fat in the form of calcium soaps in the sheep diet increased carcass yield by 5.04%. Then in the lambs of the PA6 treatment, the yield was similar with respect to those of the CON treatment. Therefore, using high amounts of protected fats in sheep feed did not have a favorable effect on carcass yield.

Regarding carcass length and thorax width of the sheep, the lambs of the PA3 treatment had a greater conformity than those of the CON and PA6 treatments. However, Ferreira *et al.* (2010) reported an opposite effect in sheep of the Santa Inés breed, which on consuming a protected fat in the diet did not show significant differences in carcass length and thorax width, with values of 51.00–52.56 cm and 26.55–27.47 cm, respectively. This effect could be due to size differences between the breeds, since in the present study, crosses of the Dorper and Pelibuey breed animals were used, which are larger than the Santa Inés breed.

The percentage of muscle was significantly higher in sheep that were fed with the PA3 treatment. However, the proportions obtained were lower than those reported by Bianchi *et al.* (2006) in Corriedale breed, crosses of the Hampshire Down and Corriedale breeds and that of the Southdown and Corriedale breeds, and Churra breed sheep with a muscle proportion of 49.4–61.28%. The authors attributed these variations to the breed of the animal, because breed influences the composition and quality of carcasses.

The proportion of total fat and subcutaneous fat was higher in the sheep of the PA6 treatment; however, the highest proportion of intermuscular fat was obtained in the lambs of the PA3 treatment. In this case, the total fat and its different fractions were not influenced by the weight of the animal, as reported by Field *et al.* (1990). The effect could be attributed to the addition of palmitic acid in the diet of the sheep; the lambs of the PA6 treatment, by consuming more fat in the diet, accumulated a greater amount of total fat and peripheral fat, the latter is regularly found in greater proportion than intramuscular fat in animals (Horcada-Ibáñez *et al.*, 2009). Furthermore, feeding has a direct relationship with the amount of fat present in the diet, and if the energy levels exceed the requirements of the animal (positive energy balance), the fat deposit would increase depending on the excess energy, compared to the total requirement of the animal for bones and muscles (González *et al.*, 2006).

The percentage of bone was higher in the animals of the PA3 treatment. This could be related to the weight and size of the shoulders, which were larger than those of the animals of the CON and PA6 treatments.

The pH values in meat did not change with the addition of palmitic acid in the diet, and the pH results were found in the range of 5.59–5.89, similar to those reported in Charollaias, Awassi and Romanov sheep (De Lima Júnior *et al.*, 2016). Therefore, the feeding of the animals does not influence the final pH of the meat.

The L^*, a^* and b^* indexes were not modified by the differences in the feeding of the sheep. Pérez-Chávez *et al.* (2019) reported L^* index for the crosses of the Katahdín- and Pelibuey-breed lambs from 35.66 to 37.72, lower than those found in the present study. However, in sheep meat, lightness varies from 33.1 (Hopkins *et al.*, 2005) to 54.0 (Corazzin *et al.*, 2019). Regarding a^* index, values from 5.31 (De Lima Júnior *et al.*, 2016) to 19.47 (Pérez-Chávez *et al.*, 2019) are reported, while for b^* index, values from 3.54 (Pérez- Chávez *et al.*, 2019) to 18.2 (Corazzin *et al.*, 2019) were observed. These values would depend on the muscle type and breed of the animals.

Drip loss and cooking yield were also not modified by the inclusion of palmitic acid in the diet, and the values found were similar to 3.86% drip loss and 79.26% cooking yield as reported by De Lima Júnior *et al.* (2016).

The addition of palmitic acid in the diet had no effect on meat texture; however, the cutting force was lower than that reported by Silva *et al.* (2005), with values from 8.40 kg to 10.21 kg in meat of the crosses of Romney, East Friesian, and Finn and Dorset breed sheep, and similar to the cutting force values of 4.1–4.7 kg reported for pure Corriedale breed and the cross of Hampshire Down and Corriedale breeds and that of Southdown and Corriedale breeds. This demonstrates, the factor that determines texture of the meat is the breed of the animals (Juárez *et al.*, 2012).

The highest concentration of oleic fatty acid (C18:1, n-9) was determined in the sheep meat of three treatments. Similar results were reported by Cruz-González *et al.*, (2014), with concentrations of 34.29 g/100 g of fat in lambs of the Pelibuey, Blackbelly, Dorper and Katahadin breeds from semi-intensive systems.

Smeti *et al.* (2018) reported 17.70–19.92 g/100 g of stearic fatty acid (C18:0), the values similar to those found in the present study; the researchers added rosemary essential oils to the diet. Stearic fatty acid is one of those found in large quantity in sheep meat, and although it is a saturated fatty acid, its intake in human diet has no effect on total cholesterol (Basulto *et al.*, 2009).

Unsaturated fatty acids, such as linoleic acid (C18:2, n-6) and Cis-11-eicosenoic acid (C20:1 cis-11), are found in lower amounts in the meat of sheep and are supplemented with palmitic acid in the diet.

The meat obtained from the treatments that included palmitic acid had a higher amount of total saturated fatty acids. This could be because the palmitic acid incorporated in the diet is a saturated fat. Juárez *et al.* (2010) explained that the composition of fatty acids directly depended on the diet. This is supported by the results of the present study, because the meat of the treatment that did not added palmitic acid in the diet had a higher concentration of both MUFA and PUFA.

Further, it was found that sheep meat of the PA6 treatment had a lower total antioxidant capacity, compared to the sheep meat of the CON and PA3 treatments. This could be due to the fact that the chemical composition of the ingredients that make up the diet of the animals had an effect on the chemical composition of the meat and the quality of the product (Rivas-Cañedo *et al.*, 2013).

Ramírez-Bribiesca *et al.* (2021) found that diets with a higher concentration of saturated fatty acids produced animal meat with a higher amount of saturated fatty acids and a lower proportion of MUFA and PUFA. The latter having one or more free hydrogen would be oxidized by capturing some free radicals, product of the meat oxidation process (Kumar *et al.*, 2015).

Palmitic acid, being a saturated fatty acid, if supplemented through the diet, results in a higher amount of saturated fatty acids in meat, which causes a lower total antioxidant capacity. The values obtained for the total antioxidant capacity in sheep meat were lower than 33 mmol Trolox Eq/kg and 30 mmol Trolox Eq/kg found in pork and beef, respectively, which indicates that sheep meat is more susceptible to oxidation processes (Serpen *et al.*, 2012).

The total antioxidant capacity of sheep meat during the days of storage (expressed as mmol/kg dry base of the sheep meat) increased until day 5 in the three treatments. This means that during the storage period, the antioxidant compounds of the meat inhibited oxidation process, donating hydrogen atoms to counteract free radicals; however, after day 5, the total antioxidant capacity decreased because the antioxidant compounds present in meat were depleted and there was no way to prevent or slow down the oxidation process. The results demonstrated that the amount of oxidative compounds in meat would be inhibited during the first days of storage, and therefore the total antioxidant capacity of the meat would increase, up to an average period of 5–6 days in sheep meat (Libién-Jiménez *et al.*, 2015). However, although the formation of oxidative substances would continue after this timeframe, the total antioxidant capacity would decrease. The results indicated that adding 100 g of palmitic acid to the diet of finishing sheep would not have any negative effect on the total antioxidant capacity of the meat, that is oxidizing compounds would not be increased by adding this amount of palmitic acid in the diet. However, using 200 g of palmitic acid in the diet would decrease the total antioxidant capacity of the meat, thus resulting in more rapid deterioration of the meat and modifying color, smell, and flavor.

Conclusions

The addition of 3% palmitic acid in the diet improves daily weight gain, feed conversion, feed efficiency, carcass yield, and the proportion of muscle and intramuscular fat, while the physicochemical characteristics of the meat and total antioxidant capacity are not affected.

The addition of 3% and 6% palmitic acid in the diet of the lambs increased the content of stearic acid, which does not represent a problem in human nutrition, because it has a neutral effect on lipoproteins or plasmatic lipids. Addition of palmitic acid in meat increases a fatty acid that is attributed to being a source of energy for humans, for its ability to bind certain proteins necessary for functions of the nervous system, and for the formation of pulmonary surfactant and to guarantee cell junction. Likewise, the amount of saturated fatty acids is also increased in meat. However, the addition of 3% and 6% palmitic acid in the diet of lambs decreased the amount of linoleic acid in the meat, a fatty acid considered essential in the human diet.

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Author Contributions

All authors worked at all the stages of this research project.

Conflict of Interest

There was no conflict of interest to declare.

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