ISSN: 2594-0252

AGRO PRODUCTIVIDAD

Year-long evaluation of total soluble proteins in the trunk of two pine species from northeastern Mexico

pág. 49

Año 16 • Volumen 16 • Número 12 • diciembre, 2023 (suplemento)

Colegio de Postgraduados

Production and quality of meat from hair sheep grazing on Tanzania grass and supplemented with different protein levels

Hernández-Canul, Dominga[1]; Cruz-Hernández, Aldenamar[1]; Gómez-Vázquez, Armando[1*]; Govea-Luciano, Alejandra[1]; Ramírez-Bribiesca J. Efrén[2]; Plascencia-Jorquera, Alejandro[3]; Cordoba-Izquierdo, Alejandro[4]; Martínez-Martínez, Ricardo[5]

[1] Universidad Juárez Autónoma de Tabasco, División Académica de Ciencias Agropecuarias, Carretera Villahermosa-Teapa Km 25, R/A La Huasteca 2da. Sección, Villahermosa Centro Tabasco, México, C. P. 86280.

[2] Colegio de Postgraduados Campus Montecillo, Postgrado en Recursos Genéticos y Productividad-Ganadería, Carretera México-Texcoco km 36.5, Montecillo, Texcoco, Estado de México, México, C. P. 56264.

[3] Departamento de Ciencias Naturales y Exactas, Universidad Autónoma de Occidente, Guasave, 81048, México.

[4] Departamento de producción Agrícola y Animal, Universidad Autónoma Metropolitana Unidad Xochimilco, Ciudad de México, México.

[5] Universidad de Guadalajara, Centro Universitario de la Costa Sur Autlán de Navarro, Avenida Independencia Nacional 151, Centro, Jalisco, México, C. P. 48900.

* Correspondence: armando.gomez@ujat.mx

ABSTRACT

Objective: To evaluate the effect of a supplementary feeding (with different crude protein (CP) levels) in the yield and growth performance and meat characteristics of hair lambs grazed on Tanzania grass.

Design/Methodology/Approach: A 120-d^{-1} experiment was conducted; it included four treatments and seven replications in a completely randomized design. Twenty-eight hair lambs (22.6±1.6 kg LW) were allowed to graze on Tanzania grass (*Panicum maximum*) and were provided concentrate feeds (with 10, 12, 14, and 16% crude protein). The aim was to assess the effects of the latter food on growth, carcass characteristics, and meat quality.

Results: Compared with the lambs fed with 10, 12, and 14% CP, the heaviest carcasses ($P<0.05$) were obtained from lambs fed with 16% CP. The percentage of crude protein and fat of the biceps femoris linearly increased ($P<0.05$) as the CP percentage increased in the concentrate feed. Meat color, water retention capacity, and cutting force were not impacted by the CP percentage of the concentrate feeds. Compared with the lambs fed with 10, 12, and 14%, the lowest palmitic acid percentage and the highest oleic acid percentage were found in the meat of lambs fed with 16% CP.

Study Limitations/Implications: A high area was selected to avoid excessive rain.

Findings/Conclusions: Compared with the lambs fed with 10, 12, and 14% CP, the lambs grazed on Tanzania grass and supplemented with 16% CP grew more, recorded a higher carcass yield, and their meat had a better unsaturated fatty acids ratio.

Keywords: Growth, Carcass, Pelibuey, Crude Protein, *Panicum maximum*.

Citation: Hernández-Canul, D., Cruz-Hernández, A., Gómez-Vázquez, A., Govea-Luciano, A., Ramírez-Bribiesca J. E., Plascencia-Jorquera, A., Cordoba-Izquierdo, A., & Martínez-Martínez, R. (2023). Production and quality of meat from hair sheep grazing on Tanzania grass and supplemented with different protein levels. *Agro Productividad*. https://doi.org/10.32854/agrop.v16i12.2762

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: June 19, 2023.
Accepted: November 18, 2023.
Published on-line: January 31, 2024.

Agro Productividad, 16(12) suplemento. December. 2023. pp: 3-12.

INTRODUCTION

Sheep farming in Mexico mainly takes place in the central, northern-central, and southern regions of the country. Southern Mexico is characterized by a tropical, warm, and humid weather, with quantitative and qualitative seasonal fluctuations regarding food supply (Gómez-Vázquez *et al.*, 2011). Therefore, the main limitations of this sheep breeding system include low nutrient forages that do not meet the food requitements of the animals (Gómez-Vázquez *et al.*, 2011; Amendola-Massiotti *et al.*, 2018). However, grazing Pelibuey production is expanding in the tropical region of Mexico. Consequently, the main products are <8 month-young lambs with a live weight of 20 kg. These lambs are purchased by commercial breeders, who finalize them with diets rich in grains, until the lambs reach a 30-40 kg live weight (Gómez-Vázquez *et al.*, 2011). This yield-growth rate is more difficult to obtain with Pelibuey sheep than with other breeds used for meat production (*e.g.*, Dorper and Katahdin). These breeds have been crossed with Pelibuey to improve the growth rate of lambs (Gómez-Vázquez *et al.*, 2011; Herrera-Corredor *et al.*, 2021). In the tropics, grazing Pelibuey and its hair sheep crosses have recorded <75 g^{-1} d^{-1} weight gains; however, when they are completely confined or when their diet is supplied with concentrates, they reach a 191-218 g^{-1} d^{-1} average weight gain (Galina *et al.*, 2007; Piñeiro-Vázquez *et al.*, 2009). Consequently, if animal yield is to reach its maximum value, supplementation is essential for a successful grazing sheep production (Ramírez *et al.*, 1995; Gómez-Vázquez *et al.*, 2011). In addition, supplementing with proteins increased weight gain (WG) in pure breed sheep under a tropical grazing system (Habib *et al.*, 2001; Becholie *et al.*, 2005; Mayren-Mendoza *et al.*, 2018). The best tropical green forage supply is 300 g^{-1} d^{-1}, rather than 150 and 600 g^{-1} d^{-1} (Archiméde *et al.*, 2008). Nevertheless, the proteins in supplements, growth yield, and meat quality of hair sheep crosses that graze on tropical grasses have been the evaluated in a limited number of researches. Therefore, the objective of this study was to evaluate the effect of including supplementary feeding and different crude protein (CP) levels on growth yield and meat characteristics of hair sheep grazed on Tanzania grass.

MATERIALS AND METHODS

The growth behavioral test was developed in a commercial sheep farm in Jalapa, State of Tabasco, Mexico. The area has a 26 °C average temperature and a mean relative humidity of 80%. The experiment consisted of four treatments and 7 replications. The experimental units (EU) were 28 hair lambs (22.6±1.6 kg body weight; 9-month-old), grazing in Tanzania grass (*Panicum maximum*). The EU were assigned in a completely randomized experimental design (CDR). The treatments consisted of four concentrate feeds (Table 1) with different CP levels: 10,12, 14, and 16%, in a dry basis. Therefore, a quantitative factor with equally spaced levels was studied. One and a half hectares were divided into four pastures. A single group of lambs grazed in each area from 06:00 am to 06:00 pm, under a 30-day rotation arrangement. Subsequently, the lambs were housed in 2.5×1 m individual pens, inside a stable, where each lamb was fed 300 g of concentrate feed. Lambs had free access to fresh water.

The period of adaptation to the pens and to the supplementary feedings lasted 15 d-1. The growth performance test lasted 120 d-1. Twice a month, before the supplementation, samples of the supplementary feedings were taken directly from the feeders; the composite sample lasted 120 d-1. Five-hundred grams of the composite samples were dried in a

Table 1. Ingredients and proximal analysis of the supplementary feedings.

	Tanzania grass	**Concentrate feed (CP % DM)**			
		10	**12**	**14**	**16**
Ingredient, % MS					
Grain of corn		25.0	25.0	25.0	25.0
Soy Flour 48% PC		0.0	2.5	7.1	11.7
Wheat flour		15.0	15.0	15.0	15.0
Rice polishing		15.0	15.0	15.0	15.0
MG5 Grass Hay		27.2	24.5	19.9	15.3
Coconut flour		5.0	5.0	5.0	5.0
Sugar cane molasses		10.0	10.0	10.0	10.0
Mineral Premix		2.0	2.0	2.0	2.0
Salt		0.5	0.5	0.5	0.5
Calcium carbonate		0.3	0.3	0.3	0.3
Urea		0.0	0.2	0.2	0.2
Composition					
Dry matter, %	78.0	88.1	88.3	88.2	88.6
Crude protein, % DM	11	10.3	12.1	14.2	16.1
Neutral detergent fiber, % DM	70	35.41	30.99	30.01	28.22
Acid detergent fiber, % DM	38	20.16	17.17	16.81	15.30
Ashes, %	12	28.51	26.51	23.12	19.73
EM	1.17	2.54	2.57	2.65	2.72

CP: crude protein; DM: dry matter; High bioavailability mineral compound: phosphorus 5%, calcium: 13%, sodium: 16%, chlorine: 24%, magnesium: 0.60%, sulphur: 0.18%, inorganic zinc: 3,000 ppm, organic zinc: 250 ppm, manganese: 1,100 ppm, cobalt: 125 ppm, iodine: 40 ppm, selenium: 5 ppm, vitamin A: 275,000 UI/kg, vitamin D3: 12,500 UI/kg, vitamin E: 500 UI/kg. MG5 grass hay: Tanzania grass (*Panicum maximum* cv. Tanzania) in a dry basis.

convection oven, at 90 °C for 48 h, in order to determine dry matter (DM), crude protein (CP), and ashes (AOAC, 2005), as well as neutral and acid detergent fiber (Van Soest *et al.*, 1991). Body weights were recorded at the beginning of the experiment and, subsequently, every 14 d^{-1}.

Grass samples (0.5 m^2) were taken from the prairies, at the beginning and at the end of each grazing period; the soil was cut 8 cm above ground level. Every day, for five days (115-120), each lamb was given 3-g capsules of chromium oxide. Stool samples (20-30 g) were taken from each animal during five days (115-120 days) and, afterwards, the samples were compared per animal. Grass consumption was estimated according to the method described by Geerken *et al.* (1987). Feed conversion was calculated as the ratio between daily intake (grass+300 g of concentrate, in a dry matter basis) and daily weight gain, from day 115 to day 120.

The lambs were slaughtered when the 120 d^{-1} test period was completed. The weight of the carcass was recorded right after the slaughter (warm carcass) and once the carcass was refrigerated (frozen carcass), at −20 °C, for 24 h in an authorized slaughterhouse.

One day after the slaughter, 200 g of bicep femoris were taken from the left hind leg; the sample was wrapped in kitchen foil and frozen at −20 °C for its subsequent analysis. The color of the meat (*a**: red intensity; *b**: yellow intensity; and *L**: luminosity) was measured using a Minolta CM-2002 chroma meter (Minolta Co., LTD, Japan). Afterwards, the Chroma value $\left(Chroma = a*2 + b*2\right)$ and the Hue value $\left(Hue = \left[\tan{-1}\left(b*/a*\right)\right]\right)$ were also determined. The pH of the meat was calculated using a HI 99163 digital pH meter (Hanna Instruments, Inc., USA). The tenderness of the meat was measured using the Warner Bratzler method, with a TAX-T2 texture analyzer (Texture Technologies Corp, Scarsdale, NY, USA). Water retention capacity was determined using the gravimetric method proposed by Honikel (1998). A water bath was used to find out water cooking loss: 4 g of meat were placed in hermetic bags and cooked at 75 °C for 35 minutes. The total percentage of evaporative and drip losses was calculated according to Obuz *et al.* (2003), using the following formula:

$$\left[\left(raw\ material - weight\ after\ cooking\right) / raw\ weight\right] \times 100$$

The moisture, fat, crude protein (CP), and ash content of the meat were determined following the procedures of the AOAC (2005). Fifty grams of the meat samples were homogenized and lyophilized (Lyph-Lock 6, Labconco Co., MO, USA.) and one gram was extracted using 2:1 (v/v) chloroform-methanol, following the indications of Folch *et al.* (1957). Stratified samples were analyzed using a HP 6890 gas chromatograph (Hewlett-Packard Co., DE, USA.), in order to establish fatty acid content.

To determine the importance of the quantitative factor (CP %), each one of the evaluated variables was subjected to an analysis of variance, using the CDR method. For some of the variables, it included the repeated measurements factor (measurement days). The initial live weight (LW) was used as a covariable; however, it was excluded from the model ($P>0.05$). The lamb was considered as a random element in the model and the repeated measurement was analyzed inside the animal. Feed conversion and meat characteristics were analyzed without the repeated measurement. In order to evaluate the effect of the supplement (CP %), a Tukey's multiple comparison test was carried out. Additionally, once the quantitative factor reached a significative level, lineal, quadratic, and cubic octagonal polynomials were used to determine the polynomial degree that accurately describes the average response of the variable in question. The data were processed using the pro mixed procedure and the SAS v 9.4 statistical software (2017).

RESULTS AND DISCUSSION

The final weight, total weight, and daily weight gain, as well as the weight of the carcass composition, were quadratically impacted ($P<0.05$) by the increase of the CP percentage in the concentrate feed. However, the feed conversion index was not impacted by the different protein levels of the concentrate feed (Table 2). Consequently, the heaviest lambs and carcasses ($P<0.05$) were those fed with concentrate + 16% CP, while those fed with concentrate feed + 10, 12, and 14% CP obtained lower results (Table 2).

Table 2. Growth behavior of hair lambs grazing on Tanzania grass (*Panicum maximum* cv. Tanzania) and supplemented with a concentrate feed with different CP percentages.

	Concentrate feed (CP % DM)					P-Value	
	10	12	14	16	SEM	L	Q
Initial live weight, kg	22.7	22.5	22.7	22.8	1.59	0.12	0.13
Final live weight, kg	30.3	30.5	32.2	35.7	1.93	0.01	0.49
Total weight gain, kg	7.6	8.0	9.5	12.9	1.31	0.01	0.19
DWG, g	65.0	65.0	79.1	107.5	5.93	0.01	0.04
Total DMC, kg/d	0.69[a]	0.68[a]	0.77[b]	0.99[c]	0.11	0.01	0.04
Grass consumption, kg/d	0.38	0.39	0.47	0.70	0.19	0.01	0.32
Feed conversion	10.72	10.4	9.7	9.23	0.84	0.01	0.43
Warm carcass yield, kg	13.7	13.9	14.6	17.0	1.57	0.01	0.45
Frozen carcass yield, kg	12.9	13.0	13.6	16.0	1.71	0.01	0.25
WCY, %	45.21[a]	45.57[a]	45.34[a]	47.62[b]	3.11	0.32	0.01
FCY, %	42.57[a]	42.62[a]	42.24[a]	44.82[b]	2.09	0.21	0.01

CP: crude protein; DM: dry matter; SEM: standard error of the mean; DWG: daily weight gain; DMC: dry matter consumption; WCY: warm carcass yield; FCY: frozen carcass yield.
[a, b, c] Superscripts in the same line are different ($P<0.05$).
Tanzania grass: *Panicum maximum* cv. Tanzania.

Kashani and Bahari (2017) have proved that males reach a greater weight gain, with a lower amount of fat, than females; they are also better fed and have a better food conversion and daily weight gain. Gomes *et al.* (2012) have reported that animals with low intake of residual feed have a lower support metabolizable energy requirement. Therefore, they have more energy available for production —*i.e.*, the animals with high residual gain use less energy in their physiological support processes— and, consequently, they have more energy available for the deposition of tissues (Gomes *et al.*, 2012). In addition, Montelli *et al.* (2021) and Nascimento *et al.* (2020) reported that lambs with high residual weight gain use food more efficiently. This phenomenon could be associated with lower rumination rates. Consequently, the difference between the various parameters could be the result of the different protein balance, rather than of the different energy balance.

Meanwhile, the total dry matter consumption (DMC) recorded differences between the concentrate feeds with 14 and 16% CP and the concentrate feeds with 10 and 12% CP; however, the highest difference percentage was obtained by the concentrate feed with 16%. Meanwhile, a lineal growth was observed in grazing as the CP percentage increased in the concentrate feed. The highest value was obtained once again by the concentrate feed + 16% CP (Table 2). There were significative differences ($P<0.05$) between the yield of the warm and frozen carcasses. Compared with the concentrate feed with 10, 12, and 14% CP, the highest yield was obtained by the concentrate feed with 16% CP.

Cooking did not cause a loss of moisture content, ash percentage, color measurements, cutting force, water retention capacity, and water loss in the treatments of this experiment. However, the CP percentage and the biceps femoris recorded a linear increase ($P<0.05$) as the CP percentage increased in the supplementary feeding. The concentrate feed +

14 and 16% CP obtained better results than the supplementary feedings + 10 and 12% CP (Table 3).

The ash content of the chemical composition of the biceps femoris did not differ between the protein levels of the supplementary feeding. This phenomenon can be the result of the mineral proportion on the muscle tissue, which remains constant between hair sheep (Fidelis *et al.*, 2017). Meanwhile, Giraldez *et al.* (2021), in their study about Assaf sheep, and Fidelis *et al.* (2017), in their study about Nellore bulls, did not find differences in the ash content of the longissimus muscle and they also found similarities in the meat moisture content of the animals. Both results match the finding of this experiment.

There were no differences in the pH of the biceps femoris between the different CP levels of the concentrate feeds in this study. Other studies (Giráldez *et al.*, 2021; Montelli *et al.*, 2021) reported a similar pH behavior in sheep meat. These results also match the findings of Gomes *et al.* (2012) and Fidelis *et al.* (2017), who reported a similar pH in Nellore livestock, 24 h after they were slaughtered. Almeida *et al.* (2017) mentioned that the pH recommended for a good quality meat in small ruminants must fluctuate between 5.5 and 5.8; a similar value was recorded in this study for the feed with 10 and 16% CP for the 5.5 and 5.8 pH, respectively.

Regarding the color of the meat of the lambs, there were no differences in the *L**, *a**, and *b** parameters, between the different protein levels of the concentrate feed; these results match the findings of Arce-Recinos *et al.* (2022). The main factors that influence meat color include: pH, quantity and chemical state of myoglobin in the muscle, and intramuscular fat (Corazzin *et al.*, 2019). The color of the meat could be potentially explained by the lack of pH differences between the different protein levels of the concentrate feed. Montelli *et al.* (2021) reported lower *L** values (33.13) than the results obtained in this study. To be considered acceptable for consumption, the values of fresh lamb meat must be higher than *L** 34 and *a** 9.5 (Khliji *et al.*, 2010). In this regard, the average color values (*L** 38.6, *a** 19.7, and *b** 6.5) are close to the acceptable parameters for meat.

The level of fat in the meat plays an important role in its tenderness. Therefore, high fat level meat requires less cutting force than low fat level meat (Sañudo *et al.*, 2000). In this study, there were no difference in the cutting force required to cut cooked meat between the different protein levels of the concentrate feed. This phenomenon could be the result of the lack of differences, 24 h after the slaughter, in the intramuscular ether extract content and the pH, among the different protein levels of the supplementary feeding. Meanwhile, Montelli *et al.* (2021) recorded similar results with lambs. They observed that feed efficiency did not have an impact on the tenderness of the meat. However, efficient lambs can produce meat that requires a stronger cutting force, 3 d^{-1} after they are slaughtered (Giráldez *et al.*, 2021). Nevertheless, other authors have reported a similar cutting force (Gomes *et al.*, 2012; Fidelis *et al.*, 2017). Cooking loss is another meat parameter measured 24 h *post mortem*.

Meat has a high water content (approximately 75%). Most of this water is found inside the myofibrils, between the myofibrils and the cell membrane (sarcolemma), between the muscle cells, and between the muscle fascias. A small proportion of the water in the muscle is also attached to the proteins (Huff-Lonergan and Lonergan, 2005). Water loss is related

Table 3. Chemical composition and characteristics of the biceps femoris of hair lambs that grazed on Tanzania grass and were supplemented with concentrate feed, with different levels of crude protein.

	Concentrate feed (CP % DM)					**P-Value**	
	10	**12**	**14**	**16**	**SEM**	**L**	**Q**
Humidity, %	73.1	72.8	71.9	72.8	0.28	0.11	0.12
Crude protein, %	17.1[a]	19.5[b]	21.2[c]	21.5[c]	0.32	0.01	0.08
Fat, %	14.2[a]	16.5[b]	18.6[c]	18.9[c]	0.31	0.01	0.06
Ashes, %	1.1	1.0	1.0	1.0	0.01	0.20	0.32
Final pH	5.6	5.7	5.7	5.8	0.04	0.21	0.49
Color[1]							
L* (luminosity)	40.0	38.7	37.5	38.5	1.70	0.27	0.49
a* (reddening)	20.7	19.4	18.4	20.6	1.00	0.25	0.45
b* (yellowing)	7.0	6.2	6.0	6.8	0.80	0.43	0.19
Croma, $a^{*2}+b^{*2}$	27.4	25.6	25.3	27.4	1.30	0.32	0.43
Hue angle, $\tan^{-1}$(b*/a*)	32.6	31.7	31.1	31.7	3.30	0.12	0.25
Cutting force, kg/cm^2	2.7	3.1	3.0	2.8	0.22	0.42	0.21
WRC, mL	19.7	19. 8	19.5	19.7	0.20	0.46	0.48
WCL, mL	30.8	31.1	31.2	30.5	0.45	0.42	0.49

CP: crude protein; DM: dry matter; SEM: standard error of the mean; Lineal effect of the protein percentage in the concentrate feed (P<0.05).
*L** values are a luminosity measure (a higher value indicates a lighter color): *a** values are a reddening measure (a higher value indicates a redder color); and *b** values are a yellowing measure (a higher value indicates a yellower color).
WRC: water retention capacity, WCL: water cooking loss.
[a, b, c] Superscripts in the same line are different (P<0.05).

to the temperature used during cooking; this process can induce the denaturalization and contraction of myofibrils and collagen proteins between 40 and 60 °C. Consequently, the loss of water impacts the quality of meat, which becomes more resistant and firmer (Suleman *et al.*, 2020). These results match the findings of Giráldez *et al.* (2021), who reported a higher cooking loss during the first measurement (0 d) with efficient lambs (26.0%) than with inefficient lambs (22.6%). Nevertheless, their results differ from those reported by Montelli *et al.* (2021) with Dorper × Santa Inés male lambs, whose low, medium, and high classes had similar cooking loss percentages.

Most of the fatty acids were not impacted by the treatments; however, as the CP % increase in the concentrate feed, the highest molar ratio (P<0.05) of palmitic (C16:0) and oleic (C18:1, cis-9) acids in the biceps femoris had a quadratic impact (P<0.05) (Table 4). Compared with the meat of the lambs fed with a concentrate feed with 10, 12, and 14% CP, the lowest percentages of palmitic acid and the highest percentages of oleic acid were found in the meat of the lambs fed with a concentrate feed with 16% CP. Likewise, the highest percentage of unsaturated fatty acids (P>0.05) and the lowest percentage of saturated fatty acids (P<0.05) were found in the meat of lambs fed with a concentrate feed + 16% CP.

Table 4. Fatty acids ratio in the bicep femoris of lambs supplemented with concentrate feeds.

	Concentrate feed (CP % DM)					**P-Value**	
	10	**12**	**14**	**16**	**SEM**	**L**	**Q**
Lauric C12:0	0.3	0.3	0.4	0.3	0.09	0.42	0.46
Myristic C14:0	3.3	3.3	3.8	3.1	0.9	0.21	0.42
Pentadecanoic C15:0	0.6	0.4	0.5	0.4	0.8	0.12	0.11
Palmitic C16:0	24.9	25.4	24.7	23.5	3.1	0.19	0.21
Heptadecanoic C17:0	1.2	1.0	1.1	1.0	0.3	0.37	0.29
Stearic C18:0	19.7	19.3	18.5	18.0	3.9	0.45	0.65
Palmitoleic C16:1	1.8	2.3	2.4	2.0	0.5	0.13	0.37
Oleic C18:1 cis-9	41.1[b]	41.1[b]	41.3[b]	44.5[a]	4.3	0.01	0.04
Elaidic C18:1 trans-9	1.8	1.7	2.0	1.7	0.3	0.17	0.36
Linolenic C18:3n-3	0.3	0.2	0.3	0.2	0.1	0.19	0.54
Linoleic C18:2n-6	4.5	4.6	4.5	4.8	1.8	0.44	0.44
CLA cis-9, trans-11	0.5	0.4	0.5	0.5	0.07	0.13	0.47
Saturated	50	49.7	49	46.3	7.9	0.19	0.32
Unsaturated	50	50.3	51	53.7	7.1	0.42	0.46

CP: crude protein; DM: dry matter; SEM: standard error of the mean.
[a, b] Superscripts in the same line are different ($P<0.05$).

Oleic acid (18:1n-9) is beneficial to human health. According to Calder (2015), monounsaturated oleic acid (part of the Omega 9 family) reduces cholesterol and blood pressure and can improve glucose control and insulin sensitivity. Meanwhile, Schwingshacki and Hoffmann (2014) conducted a systematic review and a meta-analysis, proving that a higher oleic acid consumption is connected to a lower risk of coronary heart disease, cardiovascular events, and cardiovascular mortality. Therefore, the fatty acid (FA) composition has a significant influence on the attributes of meat and its nutritional value (Wood and Enser, 2017). The data about the FA composition of lamb meat are diverse. On the one hand, Camacho *et al.* (2017) reported that hair female lambs had more monounsaturated FA (mainly oleic acids) than male lambs. On the other hand, Erasmus *et al.* (2017) observed a similar behavior, reporting that female lambs had a higher α-linolenic acid (C18:3n-3) and polyunsaturated FA content in the subcutaneous fat than male lambs. In this study, the meat of male lambs recorded a higher fatty acid content (oleic C18:1 cis-9), while the rest of the meat did not report FA differences. Currently, there is a growing interest in manipulating the carcass quality and the FA composition of livestock meat, since consumers would find a higher polyunsaturated FA content more appealing (Vahmani *et al.*, 2020).

CONCLUSIONS

The meat of hair lambs that grazed on Tanzania grass and were supplemented with a concentrate feed + 16% CP recorded higher growth performance and carcass yields, as well as a better unsaturated fatty acid ratio, than the meat of lambs supplemented with a concentrate feed + 10, 12, and 14% CP.

ACKNOWLEDGEMENTS

The authors would like to thank: (1) the Consejo Nacional de Ciencia y Tecnología (CONAYT) for the MSc scholarship granted to Dominga Hernández Canul; (2) the Laboratorio de Nutrición Animal, Colegio de Posgraduados, Mexico; and (3) Mr. José Manuel Piña Gutiérrez (ScD) who granted access to the facilities of the "El Rodeo" ranch.

REFERENCES

Almeida RFC, Françozo MC, Ludovico A. (2017). Fatty acid profile and lambs meat quality fed with different levels of crude glycerin replacing corn. *Semina Ciencias Agrarias 38*(4): 2051–2064. DOI: 10.5433/1679-0359.2017v38n4p2051.

Amendola-Massiotti RD, Rojas-López O, Tórtora-Pérez JL, Burgueño-Ferreira JA, Huerta-Bravo M, Hernández-Garay A. (2018). Estacionalidad de la alimentación bajo pastoreo en la cría ovina: Estudio de una unidad de producción. *Agroproductividad 11*(5): 113-117. https://revista-agroproductividad.org/index.php/agroproductividad/article/view/384

AOAC (Association of Official Analytical Chemists). 2005. Official methods of análisis, 18th Edition Arlington, VA, USA. 2024 p.

Arce-Recinos C, Ramos-Juárez JA, Hernández-Cázares AS, Crosby-Galván MM, Alarcón-Zuñiga B, Miranda-Romero LA, Zaldivar-Cruz JM, Vargas-Villamil L, Aranda Ibañez EM, Vargas-Vello-Pérez E, Chay-Canul AJ. (2022). Interplay between feed efficiency indices, performance, rumen fermentation parameters, carcass characteristics and meat quality pelibuey lambs. *Meat Science* 183, 108670. https://doi.org/10.1016/j.meatsci.2021.108670

Archiméde H, Pellonde P, Despois P, Etienne T, Alexandre G. (2008). Growth performances and carcass traits of Ovin Martinik lambs fed various ratios of tropical forage to concéntrate under intensive conditions. *Small Ruminant Research* 75: 162-170. https://doi.org/10.1016/j.smallrumres.2007.10.001

Becholie D, Tamir B, Terrill TH, Singh BP, Kassa H. (2005). Suitability of tagasaste (*Chamaecytisus palmensis* L.) as a source of protein supplement to a tropical grass hay fed to lambs. *Small Ruminant Research* 56: 55-64. https://doi.org/10.1016/j.smallrumres.2004.02.012

Camacho A, Torres A, Capote J, Mata J, Viera J, Bermejo LA, Argüello A. (2017). Meat quality of lambs (hair and wool) slaughtered at different live weights. *Journal of Applied Animal Research, 45*(1): 400–408. https://doi.org/10.1080/09712119.2016.1205498

Erasmus SW, Muller M, Hoffman LC. (2017). Authentic sheep meat in the European Union: Factors influencing and validating its unique meat quality. *Journal of the Science of Food and Agriculture 97*(7): 1979–1996. https://doi.org/10.1002/jsfa.8180

Fidelis HA, Bonilha SFM, Tedeschi LO, Branco RH, Cyrillo JNSG, Mercadante MEZ. (2017). Residual feed intake, carcass traits and meat quality in Nellore cattle. *Meat Science* 128: 34–39.

Folch J, Lees M, Stanley SGH. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry*. 226:497–509. https://doi.org/10.1016/S0021-9258(18)64849-5

Galina MA, Guerrero M, Puga CD. (2007). Fattening Pelibuey lambs with sugar cane tops and corn complemented with or without slow intake urea supplement. *Small Ruminant Research* 70: 101-109. https://doi.org/10.1016/j.smallrumres.2006.01.014

Geerken CM, Calzadilla D, González R. (1987). Aplicación de la técnica de dos marcadores para medir el consumo de pasto y la digestibilidad de la ración de vacas en pastoreo suplementadas con concentrado. *Pastos y Forrajes 10*(3): 266-273.

Giráldez FJ, Mateo J, Carballo DE, Caro I, Andrés S. (2021). Divergent values in feed efficiency promote changes on meat quality of fattening lambs. *Small Ruminant Research* 198, 106353. https://doi.org/10.1016/j.smallrumres.2021.106353

Gomes RC, Sainz RD, Silva SL, César MC, Bonin MN, Leme PR. (2012). Feedlot performance, feed efficiency reranking, carcass traits, body composition, energy requirements, meat quality and calpain system activity in Nellore steers with low and high residual feed intake. *Livestock Science* 150: 265–273. https://doi.org/10.1016/j.livsci.2012.09.012

Gomez-Vazquez A, De la Cruz-Lazaro E, Pinos-Rodriguez JM, Guerrero-Legarreta I, Plascencia-Jorquera A, Joaquin-Torres BM. (2011): Growth performance and meat characteristics of hair lambs grazing stargrass pasture without supplementation or supplemented with concentrate containing different levels of crude protein, *Acta Agriculturae Scandinavica, Section A - Animal Science, 61*(3): 115-120. http://dx.doi.org/10.1080/09064702.2011.623714

Habib G, Siddiqui MM, Mian FH, Jabba J, Khan F. (2001). Effect of protein supplements of varying degradability on growth rate, wool yield and wool quality in grazing lambs. *Small Ruminant Research 41*(3): 247-256. https://doi.org/10.1016/S0921-4488(01)00219-X

Herrera-Corredor CA, Salazar-Murillo EA, SánchezHernández MA, Rosales-Nieto CA, Zaragoza-Bastida A, Rivas-Jacobo MA. (2021). Evaluación productiva de ovejas y corderos bajo pastoreo con y sin suplementación estratégica. *Ecosistemas y Recursos Agropecuarios* Núm. Esp. II: e2972. DOI: 10.19136/era.a8nII.2972

Honikel KO. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Science*. 49: 447-457. https://doi.org/10.1016/S0309-1740(98)00034-5

Huff-Lonergan E, Lonergan SM. (2005). Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Science, 71*(1): 194–204. https://doi.org/10.1016/j.meatsci.2005.04.022

Kashani SMM, Bahari M. (2017). The effect of sex and weaning age on growth performance of first generation lambs derived from crossing romanov and zel. *Journal of Animal Research and Nutrition 2*(1:4): 1–6. DOI: 10.21767/2572-5459.100024

Mayren-Mendoza FJ, Rojas-García AR, Maldonado-Peralta MA, Ramírez-Reynoso O, Herrera-Pérez J, Torres-Salado N, Sánchez-Santillán P, Bottini-Luzardo MB, Hernández-Garay A. (2018). Comportamiento productivo de ovinos pelibuey en pastoreo suplementados con follaje de *Guazuma ulmifolia* Lam. *Agroproductividad 11*(5): 29-33.

Montelli NLLL, Alvarenga TIRC, Almeida AK, Alvarenga FAP, FurushoGarcia IF, Greenwood PL, Pereira IG. (2021). Associations of feed efficiency with circulating IGF-1 and leptin, carcass traits and meat quality of lambs. *Meat Science* 173, 108379. https://doi.org/10.1016/j.meatsci.2020.108379

Nascimento EM, Maggioni H, Bach CIS, Do Nascimento WG, Fernandes SR, Neto AFG. (2020). Residual intake and body weight gain on the performance, ingestive behavior, and characteristics of longissimus muscle of Dorper×Santa Inés lambs. *Small Ruminant Research* 192, 106248. https://doi.org/10.1016/j.smallrumres.2020.106248

Obuz E, Dikeman ME, Loughin TM. (2003). Effects of cooking method, reheating, holding time, and holding temperature on beef longissimus luborum and biceps femoris tenderness. *Meat Science* 65: 841-851. doi.org/10.1016/S0309-1740(02)00289-9

Piñeiro–Vázquez AT, Oliva HJ, Hinojosa–Cuéllar JA. (2009). Use of mineral supplementation with monensin sodium in Pelibuey female lambs during the postweaning growth. *Archivos de Medicina Veterinaria* 41: 35-41. https://www.researchgate.net/publication/289078785

Ramírez RG, Huerta J, Kawas JR, Alonso DS, Mireles E, Gómez MV. (1995). Performance of lambs grazing in a buffelgrass (*Cenchrus ciliaris*) pasture and estimation of their maintenance and energy requirements for growth. *Small Ruminant Research 17*(2): 117-121. https://doi.org/10.1016/0921-4488(95)00666-9

Sañudo C, Alfonso M, Sánchez A., Delfa R, Teixeira A. (2000). Carcass and meat quality in light lambs from different fat classes in the EU carcass classification system. *Meat Science, 56*(1): 89–94. https://doi.org/10.1016/S0309-1740(00)00026-7

SAS Institute, Inc. (2017). SAS/STAT® 14.3 User's Guide: High-Performance Procedures. SAS Institute, Inc. Cary, NC, USA.

Suleman R, Wang Z, Aadil RM, Hui T, Hopkins DL, Zhang D. (2020). Effect of cooking on the nutritive quality, sensory properties and safety of lamb meat: Current challenges and future prospects. *Meat Science* 167, 108172. https://doi.org/10.1016/j.meatsci.2020.108172

Vahmani P, Ponnampalam EN, Kraft J, Mapiye C, Bermingham EN, Watkins J, Proctor SD, Dugan MER. (2020). Bioactivity and health effects of ruminant meat lipids. Invited Review. *Meat Science* 165, 108114 https://doi.org/10.1016/j.meatsci.2020.108114

Van Soest PJ, Robertson JB, Lewis BA. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science 74*(10): 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Wood J, Enser M. (2017). Manipulating the fatty acid composition of meat to improve nutritional value and meat quality. In P. P. Purslow (Ed.), New Aspects of Meat Quality (pp. 501–535). Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100593-4.00023-0