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Effect of supplementation with avocado meal on lamb diets on growth and carcass performance

Efecto de suplementación con harina de aguacate en dietas de corderos sobre crecimiento y el rendimiento de la canal

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ABSTRACT

To evaluate the inclusion of avocado meal (AM) in diets for sheep (0, 2.5, 5 and 10%) with a forage:concentrate 40:60 ratio, on productive behavior and carcass characteristics. Ninety-six Pelibuey-Dorper male lambs with an average initial weight of 32.83 ±0.707 kg, 8 animals per treatment, in a 4x3 four diets and factorial arrangement with feeding periods of 28, 56 and 84 days were used. Final weight and slaughter weight increased ($p < 0.05$) with 10% inclusion compared to the control. In daily weight gain, feed intake, carcass weight and intramuscular fat, values were equal ($p > 0.05$) with the inclusion of 10% AM and 0% AM. Feed conversion, DM, CP, energy and carcass performance efficiencies did not improved with AM. The longer the intake time (56 and 84 days), the higher the daily weight gain, feed intake, feed efficiency of DM, CP and energy ($p < 0.05$), and the lower the feed conversion rate, with no differences for final weight and carcass performance ($p < 0.05$). Daily gain and carcass weight indicate a slight positive trend due to the inclusion of 10% AM at 84 days. Inclusion does not affect the productive behavior of growth in sheep.
Keywords: avocado meal, growth performance, carcass, sheep.

RESUMEN

Para evaluar la inclusión de harina de aguacate (AM) en dietas para ovinos (0, 2.5, 5 y 10%) con una relación forraje:concentrado 40:60, sobre el comportamiento productivo y características de la canal. Se emplearon 96 corderos machos Pelibuey-Dorper con peso inicial promedio de 32.83 ±0.707 kg, ocho animales por tratamiento, en arreglo factorial 4x3 con cuatro dietas y periodos de alimentación de 28, 56 y 84 días antes del sacrificio. Peso final y peso al sacrificio incrementaron ($p < 0.05$) con inclusión del 10% en comparación al control. En ganancia de peso diaria, consumo alimento, peso de la canal y grasa intramuscular, los valores fueron iguales ($p > 0.05$) con inclusión de 10% AM y la del 0%. La conversión alimenticia, eficiencias de MS, PC y de energía, y el rendimiento de la canal no se mejoran con AM. A mayor tiempo de consumo 56 y 84 días aumentan ($p < 0.05$) ganancia de peso por día, consumo alimento, eficiencias alimenticias de MS, PC y energía, y disminuye conversión alimenticia, sin diferencias para peso final y canal. Ganancia diaria y peso de la canal indican una ligera tendencia positiva por la inclusión de AM al 10 % por 84 días. La inclusión no afecta el comportamiento productivo del crecimiento en ovinos.
Palabras clave: harina de aguacate, comportamiento en crecimiento, canal, ovinos.

INTRODUCTION

Productive performance in animals can be improved by feed additives or feeding strategies. It is mentioned that the maximum animal growth rate is limited by its genetic potential, physiological and nutritional factors. In the nutritional sense, energy is an important requirement in ruminants. It contributes to heat generation, growth, activity and production. Energy is often the first and most important consideration when selecting an ingredient; in addition to the current high and fluctuating prices of ingredients, which have prompted the search for alternative feed sources. It is possible to take advantage of agro-industrial by-products and discarded agricultural resources for human consumption with high nutritional potential for animal feed (Romero-Huelva *et al*., 2017; De Evan *et al.,* 2020; Moghaddam *et al*., 2019; Ruiz-Hernández *et al*., 2019). Mexico is a leader in avocado production and contributes 30% of total production in the world (SIAP, 2017). This has led to the existence of a large amount of this fruit considered as waste, which results from the elimination of large quantities during this fruit packing process.

Avocado discarded for human consumption due to physical damage or size, it is considered an important source of energy for animals (Grageola *et al*., 2010; Van Ryssen *et al.,* 2013;), mainly due to its fat content (10-30%), in addition to maintaining lipid and cholesterol homeostasis (Solís, 2012; Hernández-Lopez *et al*., 2016). The addition of lipid sources to the diet has effects on performance and carcass characteristics, these include lower feed intake, increased palatability, growth rate, feed conversion and carcass (Azain, 2001). In a study in broilers, the inclusion of avocado oil extraction by-product reduced feed intake and growth (Van Ryssen *et al.,* 2013). Hernández-López *et al*. (2016), reported that including 30% of waste avocado on a wet basis reduced intramuscular fat content in fattening pigs.

On the other hand, Fránquez *et al*. (2017), offering 21% fresh avocado paste to fattening pigs improved feed conversion, but decreased weight gain by reducing voluntary feed intake. Regarding the use of avocado meal and paste in ruminants, there is little information that focuses on compositional aspects, digestibility and *in situ* rumen degradability (Eliyahu *et al*., 2015). In a recent study in dairy goats when including a fresh mixture of avocado pulp and peel in the diet, they concluded that it is a by-product with high moisture content, but its dry matter is rich in unsaturated fat which influenced milk fat content and quality (De Evan *et al.,* 2020). However, there is no evidence of the use of whole avocado meal in sheep on aspects of productive performance.

The aim of this study was to evaluate the effect of different levels of avocado meal during different feeding times on growth performance and carcass characteristics in sheep.

MATERIAL AND METHODS

Location

The experiment was conducted at the Laboratory of Nutritional Physiology and Experimental Surgery of the Academic Unit of Agriculture from Autonomous University of Nayarit, located at 9 km of the Tepic-Puerto Vallarta highway in Nayarit, Mexico.

Preparation of avocado meal (AM) with whole fruit

In diet preparation for lambs, Hass avocado fruits were used; discarded from those destined for human consumption, due to their small size. Fruits were harvested in packing plants located in Xalisco Nayarit, Mexico. They were stored at room temperature until they reached consumption maturity, when the avocado skin changed from green to black following the methodology written by Lemus-Flores *et al*. (2020) and Lemus *et al*. (2017), which describe the proximate chemical characteristics and fatty acid profile. To obtain a homogeneous mixture of ripe and whole avocados (pulp, seed and peel), the fruit was ground in a mobile hammer mill without sieve, powered by a 5 HP gasoline engine. When fresh, the pulp was stored at room temperature, without additives, in plastic containers. The paste was then left at room temperature for four days until a dry paste was obtained, which was again passed through the mill to obtain whole fruit avocado meal for incorporation into lambs' diets.

Animals and diets

A total of 96 male Pelibuey-Dorper crossbred lambs with an average weight of 32.833 (±0.707) kg were used, which were distributed distributing 8 animals in each of the 12 treatments, under a 4x3 factorial arrangement; four diets and three feeding time periods were considered. Four diets for each time period were with different levels of AM in dry basis. Diets with 0, 2.5, 5 and 10 % AM were used with a forage: concentrate 40:60 ratio (Table 1), according to previous results published by Lemus-Flores *et al*. (2020). Feeding times with avocado (FD) in fattening were 28, 56 and 84 days before slaughter, in order to evaluate the effect of avocado meal on sheep development. The animals were handled according to national guidelines for the use and care of animals (NOM-062-ZOO-1999, 2001). During the experimental period animals were housed in pens of 2 x 2 m, with cement floors and separated from each other. Each pen was equipped with a steel sheet feeder and an automatic waterer. Prior to the experiment, the sheep were subjected to a three-day period of adaptation to the pen and feeding management. Diets were provided daily, according to the sheep weight, with a consumption of 3.5 % of live weight (DM/animal/day), plus 10 % of rejection; each day before serving the new feed, the leftover was collected to evaluate the consumption.

Table 1. Diets with different concentrations of avocado meal

Ingredients, %	0	2.5	5	10
Avocado meal	0.00	2.50	5.00	10.00
Alfalfa meal	40.00	37.50	35.00	30.00
Sorghum grain	46.91	47.00	46.30	44.47
Soy meal	4.59	2.00	3.00	3.56
Canola meal	0.10	2.30	2.00	3.27
Sugar Cane molasses	7.00	7.00	7.00	7.00
Minerals with monensin (0.3%)	1.00	1.00	1.00	1.00
Urea	0.10	0.40	0.40	0.40
Magnesium Oxide (0.3 %)	0.30	0.30	0.30	0.30
Nutritional value calculated on dry basis				
Digestible energy Mcal/kg	2.58	2.67	2.77	2.97
Crude Protein	14.00	14.00	14.00	14.00
Grasa Cruda	2.39	3.56	4.67	6.92
Crude Fat	13.29	13.13	12.86	12.43
Calcium	0.85	0.84	0.8	0.75
Phosphorus	0.28	0.30	0.29	0.30
Cost/kg (MXN$)	4.48	4.35	4.37	4.36

MXN$: Mexican Pesos.

Evaluation of production and carcass performance in lambs

At each time and for each diet, initial and final live weight measurements were taken, final weight gain (kg) and average weight gain per day (kg) were calculated. Dry matter (DM) intakes were obtained, feed conversion (FC), feed efficiency for DM use, crude protein (CP) and energy were calculated. Daily DM intake was determined from the difference between the weight of feed offered and rejected at the end of each experimental day. At slaughter, the following were obtained: weight at slaughter in sheep that were fed for 24 hours, carcass weight, carcass performance (%) considering the weight at slaughter minus the weight of viscera, head, skin and inedible parts; the weight of the left leg was also measured. The protocols established by the Mexican Official Standard, for the "Humane slaughter of domestic and wild animals" (NOM-033-ZOO-1995, 2014N) were followed. Immediately after slaughter, a sample of 100 g of meat from the *Longissimus dorsi* muscle was taken from each sheep, which were preserved at -18 ºC until the intramuscular fat was obtained, which was expressed as a percentage, using solvents (Chloroform-methanol), according to the method described by Folch *et al*. (1957).

Experimental design and statistical analysis

The data obtained for growth performance and carcass characteristics were analyzed using a factorial design, with a fixed and random effects model. Diets (AM included at 0, 2.5, 5 and 10 %), feeding time (FD at 28, 56 and 84 days before slaughter) and the

interaction diet by time (AM*FD) were considered as fixed effects; animals were considered as random effects. Statistical analysis was done with the Linear Mixed Model procedure and comparison of means by Bonferroni test ($p<0.05$), with SPSS v20 software (2008). Response surface regressions were calculated using Minitab v15 (2007), according to a multivariate model that included AM, FD and their interaction (AM*FD), to obtain the maximum response optimization of AM and FD in each variable.

RESULTS

In the productive performance in sheep growth and carcass characteristics after the experimental days, significant differences were observed ($p<0.05$) (Table 2), it was observed that the final weight and slaughter weight increased with the 10% AM inclusion level, compared to the 0% control diet. In the weight gain per day, daily feed intake, carcass weight and intramuscular fat variables, the highest values were presented with statistical equality in the inclusion of 10% and 0% AM. Although the treatment with a 10% AM inclusion presented high values in carcass weight, the carcass performance (%) was low; similar to the diets with AM inclusion, which could be due to a greater accumulation of visceral fat that was not quantified in this work. No statistical differences were observed in FC, nor in DM and CP efficiencies. It was observed that the greater AM inclusion, the lower the efficiency in the use of dietary energy, as well as the carcass performance compared to the 0% control diet.

According to the feeding time (FD) in the use of diets with AM, seven variables were different ($p <0.05$). The longer the feeding time (56 and 84 days), weight gain per day, daily feed intake, DM, CP and energy feed efficiencies increased and FC decreased. For the final weight and carcass weight variables, no modifications were observed with feeding time.

In the interaction of AM inclusion and FD feeding time, it was observed that the longer the feeding and inclusion time, the better the final weight; something similar occurs with the daily weight gain, contrary to the DM feed conversion, which is higher in the first days of feeding influenced; perhaps due to the change in feeding due to the greater contribution of avocado meal in the ration. For feed and protein efficiency, the same effect was observed, with an improvement as the time of flour inclusion increased. In energy efficiency, it was observed that the lower amount of meal in the ration (control and 2.5%) and the longer feeding times showed the best interaction, perhaps influenced by the lower amount of fat in the rations compared to diets with 5% and 10% of AM. For slaughter weight, an interaction was observed in the avocado meal inclusion in the three percentages of AM inclusion, improving at 56 days. This was contrary to what occurred in carcass performance (%) where without the inclusion of AM (0 %) there was a positive effect over a longer period of time.

Table 2. Productive and carcass performance of lambs fed different levels of avocado meal at different times before slaughter

	AM				FD				p <
	0	2.5	5	10	28	56	84	Sem	AxF
Final weight (kg)	46.20^{b}	46.37^{b}	46.85^{b}	49.02^{a}	46.99	47.6	46.73	0.57	*
Weight gain per day (kg)	0.26^{a}	0.24^{b}	0.23^{b}	0.26^{a}	0.23^{b}	0.25^{a}	0.26^{a}	0.006	*
Daily feed consumption (kg DM)	1.16^{a}	1.10^{b}	1.13^{ab}	1.17^{a}	1.11^{b}	1.17^{a}	1.15^{a}	0.013	ns
Feed conversion (kg DM/kg body weight)	4.52	4.75	4.92	4.81	5.08^{a}	4.68^{b}	4.49^{b}	0.15	*
Feed efficiency (kg wt/kg DM)	0.22	0.22	0.21	0.22	0.20^{b}	0.22^{a}	0.23^{a}	0.005	*
Protein efficiency (kg wt/kg CP)	1.59	1.55	1.47	1.56	1.46^{b}	1.55^{a}	1.62^{a}	0.04	*
Energy efficiency (kg wt/Mcal)	0.09^{a}	0.09^{a}	0.07^{b}	0.07^{b}	0.07^{b}	0.08^{a}	0.08^{a}	0.002	*
Slaughter weight (kg)	45.39^{b}	46.04^{ab}	46.29^{ab}	48.00^{a}	46.24	47.3	45.75	0.58	*
Carcass weight (kg)	24.39^{a}	23.12^{b}	23.59^{ab}	24.40^{a}	23.37	24.29	23.96	0.34	ns
Carcass performance (%)	53.76^{a}	50.23^{b}	51.02^{b}	50.98^{b}	50.44^{b}	51.61^{ab}	52.44^{a}	0.49	*
Average leg weight (kg)	3.45	3.22	3.47	3.41	3.33	3.45	3.39	0.08	ns
Intramuscular fat (%)	3.86^{a}	2.99^{b}	2.91^{b}	3.35^{ab}	3.18	3.29	3.37	0.21	ns

AM: effect of avocado meal supplementation level, %; FD: effect of feeding time, days; sEm: standard error of the mean; AxF: interaction between avocado meal supplementation level and feeding time with p value; *p <0.05; ns: not significant; DM: dry matter; CP: crude protein; a, b: different letters in the same row indicate statistical differences (p < 0.05) for AM and FD.

Table 3. Response surface regressions and maximum response optimization with the inclusion of avocado meal at different feeding times

Variables	AM	FD	RESP	R^2	Best prediction equations
Final weight (kg)	10	84	49.83	0.59	Y=47.84-0.12(AM)-0.03(FD)+0.007(AxF)
Weight gain per day (kg)	10	84	0.29	0.66	Y=0.25-0.01(AM)-1.41(FD)+0.001(AxF)
Daily feed consumption (kg DM)	10	84	1.18	0.56	Y=1.11-0.001(AM)+0.0003(FD)+0.0006(AxF)
Feed conversion (kg DM/kg body weight)	10	28	5.78	0.41	Y=4.44+0.22(AM)+0.004(FD)-0.003(AxF)
Feed efficiency (kg wt/kg DM)	10	84	0.25	0.64	Y=0.23-0.008(AM)-1.81(FD)+0.0001(AxF)
Protein efficiency (kg wt/kg CP)	10	84	1.77	0.63	Y=1.62-0.06(AM)-0.001(FD)+0.001(AxF)
Energy efficiency (kg wt/Mcal)	0	28	0.09	0.66	Y=0.09-0.005(AM)-0.0001(FD)+0.0006(AxF)
Slaughter weight (kg)	10	84	47.98	0.47	Y=46.28+0.14(AM)-0.02(FD)+0.002(AxF)
Carcass weight (kg)	10	84	24.82	0.68	Y=23.76-0.11(AM)-0.001(FD)+0.003(AxF)
Carcass performance (%)	0	84	52.81	0.72	Y=51.20-0.38(AM)+0.02(FD)+0.0034(AxF)
Average leg weight (kg)	10	84	3.49	0.45	Y=3.39-0.01(AM)-0.0005(FD)+0.0003(AxF)
Intramuscular fat (%)	0	84	3.56	0.32	Y=3.09+0.006(AM)+0.006(FD)-0.0006(AxF)

RESP: maximum optimal response according to the variable; R^2: squared correlations of the model; DM: dry matter; CP: crude protein; AM: effect of avocado meal supplementation level, %; FD: effect of feeding time, days; AxF: interaction between avocado meal supplementation level and feeding time.

Response results of the surface regression, by the AM inclusion at different levels and FD, can be seen in Table 3, where it is observed that the highest calculated responses were found in the maximum values of inclusion of 10% AM and 84 FD, with the exception

of energy efficiency, carcass performance and intramuscular fat, which are higher at 0% AM. However, very low R^2 values were observed for the feed conversion, slaughter weight, average leg weight and intramuscular fat variables. The rest of variables present intermediate R^2 values, which indicate moderate prediction.

DISCUSSION

Sheep production is a common activity in tropical areas of Mexico, where hair breeds are used for their hardiness, fertility and adaptation to the climate; in this sense, the Pelibuey and Dorper breeds are the most widely distributed in this country; however, in these breeds the birth weight and pre-weaning development of lambs is low compared to other breeds. Consequently, the sheep feeding system could be a factor limiting the expression of genetic potential to produce sheep (Chay-Canul *et al*., 2019). Various efforts to employ agricultural and livestock by-products have been used in feeding, in this sense Mejía-Haro *et al*. (2011), report values of 71 g/day/ sheep when they used a silage containing 25 % nopal for the preparation of multinutritional blocks; however, no significant statistical differences were appreciated in the final weight of sheep. Rivas-Jacobo *et al*. (2017) achieved average gains of 138 g/day/sheep when using 500 g/day/sheep of brewery bagasse, which was supplied after grazing. Authors such as Ortiz *et al*. (2007) evaluated the inclusion of three levels of poultry manure made with coffee husks; they reported that with the inclusion of 20% of poultry manure in a fattening with young sheep, they achieved maximum values of 118 g/day/animal; these same authors report the highest final weight with the inclusion of coffee husk manure, achieving a linear effect on production. Gómez-Gurrola *et al*. (2017) evaluated the inclusion of 12 % of *Guazuma ulmifolia* and *Tithonia diversifolia* at different levels, in a ration with *Pennisetum* grass, where they achieved the highest daily weight gain at the highest level (40 %), with an average of 159 g/day/animal, where the highest level of inclusion achieved the highest final weight. The aforementioned values are considered low in comparison to those obtained in this study, where with the inclusion of 10 % AM reached the maximum averages of 260 g/day/bovine.

In this experiment it was observed that the AM inclusion at the highest level of 10% did not affect daily intake, but according to Lemus-Flores *et al*. (2020) higher levels affect intake and digestibility. The AM inclusion did not significantly affect feed conversion, similar to what Partida-Hernández *et al*. (2019) reported, when including alfalfa at 55 % and *Guazuma ulmifolia* at 8 % in lamb diets. It has been documented that the tannin content in feeds does not influence feed intake (Méndez-Ortiz *et al*., 2018); however, authors such as Zamora-Beltrán *et al*. (2018) indicate that an intake higher than 40 % of *Ricinus comunis* leaf meal affects dry matter intake and feed efficiency. In this experiment, neither FC nor DM and CP use efficiencies are affected, but energy use efficiency decreases when including values of 5 and 10 % AM. On the other hand, Rodríguez-Ruiz *et al*. (2018) evaluated the selection and consumption of *Enterolobium cyclocarpum* and

Caesalpinia coriaria fruit meals in sheep, where they achieved maximum intakes of 100 and 80 g/day/sheep respectively, perhaps influenced by the content of anti-nutritional factors in *Caesalpinia*; contrary to what occurred in this evaluation where maximum intakes of 117 g/day/sheep were achieved at AM inclusion10 %, with no negative effects on daily weight gain and carcass weight. When considering the results of Ly *et al*. 2021, who indicate that the digestibility of the whole avocado fruit is high, so that at levels up to 10% inclusion, they did not affect the daily intake nor the FC and feed efficiencies of DM and CP, which makes its use feasible in sheep fattening for a longer time of consumption. In this sense (De Evan *et al.,* 2020) evaluated the inclusion of avocado pulp and peel in goats, they reported an increase in the percentage of fat in the milk of goats fed avocado and a reduction in live weight.
In the present experiment, carcass performance was affected, since the three treatments where AM was included yielded an average of 3.7% less and at the time of slaughter of the sheep there was a greater accumulation of visceral fat, which must have influenced the aforementioned reduction.

In an evaluation on the quality and carcass performance of grazing lambs supplemented with fermented sugar cane, Frías *et al*. (2011) reported values of 42 % in the carcass; in carcass performance, values were not favored by the AM inclusion, which reached values higher than 50 %. In this evaluation, the control treatment presented the highest performance with 53.76 %. In the reports presented in this section, feeding times range from 45 to 90 days, which are necessary to reach a slaughter weight above 40 kg. Providing AM for longer (56 and 84 days), improves results in most of variables evaluated for performance and carcass characteristics.

The interaction of the AM inclusion with feeding time showed that it does improve daily weight gain and slaughter weight of sheep, as well as feed efficiency of DM and CP; however, carcass performance did not show a positive effect, similar to what was reported with the use of vegetable oils in sheep diets by Martínez-Marín *et al*. (2012), who concluded that it is possible to include moderate amounts of vegetable oils rich in unsaturated fatty acids in the diet of small ruminants, without causing negative effects on nutrient digestibility, which could happen in this experiment with the use of avocado meal, which is rich in unsaturated fatty acids, in agreement with the reports of authors such as De Evan *et al.* (2020) and Lemus *et al*. (2017).

CONCLUSIONS

The use of avocado meal up to maximum levels of 10% does not have a negative effect on the productive behavior in the growth of sheep. Consumption and daily weight gain are not affected; even final weight and slaughter weight are improved; however, it will be necessary to evaluate the quality of meat from sheep fed avocado meal.

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CITED LITERATURE

AZAIN JM. 2001. Fat in swine nutrition, in: Lewis AJ, Southern LL. Eds., *Swine Nutrition*. CRC Press, New York. ISBN 9780849306969. https://doi.org/10.1201/9781420041842

CHAY-CANUL AJ, García-Herrera RA, Magaña-Monforte JG, Macias-Cruz U, Luna-Palomera C. 2019. Productividad de ovejas Pelibuey y Katahdin en el trópico húmedo. *Ecosistemas y Recursos Agropecuarios*. 6(16):159-165. https://doi.org/10.19136/era.a6n16.1872

DE EVAN T, Dolores CM, Fernández YJE, Haro A, Arbesú L, Romero-Huelva M, Molina-Alcaide E. 2020. Effects of feeding multinutrient blocks including avocado pulp and peels to dairy goats on feed intake and milk yield and composition. *Animals*. 10(194):1-12. https://doi.org/10.3390/ani10020194

ELIYAHU ED, Yosef E, Weinberg ZG, Hen Y, Nikbachat M, Solomon R, Mabjeesh SJ, Miron J. 2015. Composition preservation and digestibility by sheep of wet by-products from the food industry. *Animal Feed Science and Technology*. 207:1-9. ISSN: 0377-8401. https://doi.org/10.1016/j.anifeedsci.2015.05.005

FOLCH J, Lees M, Stanley GHS. 1957. A simple method for the isolation and purification of total lipides from animal tissues. *Journal of Biological Chemistry*. 226 (1): 497- 509. ISSN en línea 1083-351X. https://asset-pdf.scinapse.io/prod/2168526937/2168526937.pdf

FRÁNQUEZ P, Rodríguez G, Lemus C, Grageola F, Ly J. 2017. Performance traits and indexes of the intake pattern of fattened pigs with fresh paste of whole avocado. *Cuban Journal of Agricultural Science*. 51(3):329-336. ISSN: 2079-3480. https://www.redalyc.org/pdf/1930/193057229006.pdf

FRÍAS JC, Aranda EM, Ramos JA, Vázquez C, Díaz P. 2011. Calidad y rendimiento en canal de corderos en pastoreo suplementados con caña de azúcar fermentada. *Avances en Investigación Agropecuaria*. 15(3):33-44. http://www.redalyc.org/articulo.oa?id=83720034004

GÓMEZ-GURROLA A, Del Sol-García G, Sanginés-García L, Loya-Olguín L, Benítez-Meza A, Hernández-Ballesteros A. 2017. Rendimiento en canal de corderos de pelo, alimentados con diferentes proporciones de *Tithonia diversifolia* y *Pennisetum* spp. *Abanico Veterinario*. 7(2):34-42. ISSN 2448-6132. http://dx.doi.org/10.21929/abavet2017.72.3

GRAGEOLA F, Sanginés L, Díaz C, Gómez A, Cervantes M, Lemus C, Ly J. 2010. The effect of breed and dietary level of avocado fat on the N and energy balance in young pigs. *Journal of Animal and Feed Science*. 19: 37-49. https://doi.org/10.22358/jafs/66268/2010

HERNÁNDEZ-LÓPEZ SH, Rodríguez-Carpena JG, Lemus-Flores C, Grageola-Nuñez F, Estévez M. 2016. Avocado waste for finishing pigs: Impact on muscle composition andoxidative stability during chilled storage. *Meat Science*. 116:186–192. https://doi.org/10.1016/j.meatsci.2016.02.018

LEMUS C, Bugarín J, Grageola F, Rodríguez JG, Mejía K, Valdivia R. 2017. Características químicas de la pasta de aguacate Hass fruto completo (*Persea americana* Mill.*)* Mexicano de Nayarit destinado a la alimentación animal. *Revista Computadorizada de Producción Porcina*. 24(2):112-118. ISSN 1026-9053. http://www.iip.co.cu/RCPP/242/06%20CLemus.pdf

LEMUS-FLORES C, Bugarin Prado JO, Grageola Nuñez F, Valdivia Bernal R, Ruiz Dimas I, Bonilla Cardenas JA, Segura Correa JC. 2020. The effect of avocado flour, sunflower oil and different forage: concentrate ratios in the final diet on feed intake, digestibility and productive performance of male sheep. *Veterinarski Arhiv*. 90 (4):353-364. ISSN 0372-5480. https://doi.org/10.24099/vet.arhiv.0802

LY J, Fránquez P, Rodríguez G, Lemus C, Dominguez IA, Grageola F. 2021. Note on in vitro digestion of avocado products for pigs. *South African Journal of Animal Science*. 51 (1):138-141. ISSN 0375-1589 (print), ISSN 2221-4062 (online). http://dx.doi.org/10.4314/sajas.v51i1

MARTÍNEZ-MARÍN AL, Pérez-Hernández M, Pérez-Alba LM, Carrión-Pardo D, Gómez-Castro AG. 2012. Adición de aceites vegetales a la dieta de cabras lecheras: efecto sobre la digestibilidad y los resultados productivos. *Archivos de Medicina Veterinaria.* 44(1):21-28. https://dx.doi.org/10.4067/S0301-732X2012000100004

MEJÍA-HARO J, Delgado-Hernández JL, Mejía-Haro I, Guajardo-Hernández I, Valencia-Posadas M. 2011. Efectos de la suplementación con bloques multinutricionales a base de nopal fermentado sobre la ganancia de peso de ovinos en crecimiento. *Acta Universitaria.* 21(1):11-16. ISSN: 0188-6266.
http://www.redalyc.org/articulo.oa?id=41618395003

MÉNDEZ-ORTIZ FA, Sandoval-Castro CA, Ventura-Cordero J, Sarmiento-Franco LA, de Jesús Torres-Acosta, Juan Felipe. 2018. Efecto de la ingesta de taninos sobre el consumo y ganancia de peso de ovinos. *Avances en Investigación Agropecuaria*. 22(1):73-74. http://www.redalyc.org/articulo.oa?id=83757427033

MINITAB v15 (2007), Minitab® Statistical Software, LLC. All Rights Reserved, 2021. https://www.minitab.com/es-mx/about-us/

MOGHADDAM VK, Elahi MY, Nasri MHF, Elghandour MMMY, Monroy JC, Salem AZM, Karami M, Mlambo V. 2019. Growth performance and carcass characteristics of finishing male lambs fed barberry pomace-containing diets. *Anim Biotechnol*. 15:1-7. https://doi.org/10.1080/10495398.2019.1674861

NOM-033-ZOO-1995. 2014. Sacrificio humanitario de los animales domésticos y silvestres. Publicada en el Diario Oficial de la Federación. México. https://www.dof.gob.mx/nota_detalle.php?codigo=5376424&fecha=18/12/2014

NOM-062-ZOO-1999. 2001. Especificaciones técnicas para la producción, cuidado y uso de los animales de laboratorio. Publicada en el Diario Oficial de la Federación. México. http://www.dof.gob.mx/nota_detalle.php?codigo=762506&fecha=22/08/2001

ORTIZ A, Elías A, Valdivié M. 2007. Evaluación de la pollinaza de cascarilla de café como *complemento* alimenticio en la ceba de ovinos en pastoreo. *Pastos y Forrajes.* 30(2):279-286. http://www.redalyc.org/articulo.oa?id=269119703008

PARTIDA-HERNÁNDEZ M, Loya-Olguin JL, Gómez-Gurrola A, Ramírez-Ramírez JC, Hernández-Ballesteros JA, Amezcua-Jaeger T, Escalera-Valente F, Sanginés-García L. 2019. Reemplazo de grano de sorgo con fruto de *Guazuma ulmifolia* en dietas de corderos con diferente forraje. *Ecosistemas y Recursos Agropecuarios*. 6(17):253-262. https://doi.org.10.19136/era.a6n17.1613

RIVAS-JACOBO M, Herrera-Medina R, Santos-Díaz R, Herrera-Corredor A, Escalera-Valente F, Martínez-González S. 2017. Bagazo húmedo de cervecería como sustituto de cereales en la suplementación de ovinos. A*banico Veterinario*. 7(3):21-29. http://dx.doi.org/10.21929/abavet2017.73.2

RODRÍGUEZ-RUIZ ML, Palma-García JM. 2018. Selección y consumo de harinas de frutos de árboles nativos tropicales por ovinos. *Avances en Investigación Agropecuaria*. 22(1):59-60. ISSN: 0188-7890. https://www.redalyc.org/jatsRepo/837/83757427026/index.html

ROMERO-HUELVA M, Ramírez-Fenosa MA, Planelles-González R, García-Casado P, Molina-Alcaide E. 2017. Can by products replace conventional ingredients in concentrate of dairy goat diet. *Journal Dairy Science*. 100(6):4500-4512. https://doi.org/10.3168/jds.2016-11766

RUIZ-HERNÁNDEZ O, Ibarra-Hinojosa M, Hernández-Meléndez J, Lucero-Magaña F, Cienfuegos-Rivas E, Martínez-González J. 2019. Comportamiento de corderos de ovejas alimentadas con cáscara fresca de naranja y niveles de suplementación. *Abanico Veterinario.* 9:1-10. http://dx.doi.org/10.21929/abavet2019.98

SIAP (Servicio de Información Agroalimentaria y Pesquera). 2017. *Atlas Agroalimentario:* Primera edición, Ciudad de México, México. https://www.gob.mx/senasica/articulos/mexico-primer-productor-mundial-de-aguacate?idiom=es

SOLÍS AK. 2012. Aproximación a una tipología del consumidor de aceite de aguacate. *Observatorio de la Economía Latinoamericana*. 175:1-4. ISSN 1696-8352. http://www.eumed.net/cursecon/ecolat/mx/2012/consumidor-aceite-aguacate-mexico.html

SPSS. (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

VAN RYSSEN JBJ, Skenjana A, Van Niekerk WA. 2013. Can avocado meal replace maize meal in broiler diets?. *Appied Animal Husbandry and Rural Development*. 6: 22-27. https://www.sasas.co.za/AAH&RD/can-avocado-meal-replace-maize-meal-in-broiler-diets/

ZAMORA-BELTRÁN J, del Viento-Camacho Alejandra, Palma-García JM. 2018. Inclusión de harina de lámina de hoja de *Ricinus communis* L. en la alimentación de ovinos. *Avances en Investigación Agropecuaria. 22 suppl*. 1:67-68. ISSN: 0188-7890 http://www.redalyc.org/articulo.oa?id=83757427030