Postpartum reproductive efficiency of hair breed sheep additioning bypass fat and a gluconeogenic ingredient

Eficiencia reproductiva postparto de ovejas de pelo adicionando grasa de sobrepaso y un ingrediente gluconeogénico

OSORIO-MARÍN, Yolanda†*, CONDE-HINOJOSA, Miguel Paul, GALLEGOS-SÁNCHEZ, Jaime and TORRES-HERNÁNDEZ, Glafiro

Universidad Politécnica de Francisco I. Madero, Unidad Académica Metztitlán, México
Universidad Autónoma Chapingo, Departamento de Zootecnia, México.
Colegio de Postgraduados, Campus Montecillo, México.

ID 1st Author: *Yolanda, Osorio-Marín* / **ORC ID:** 0000-0003-0281-094X

ID 1st Co-author: *Miguel Paul, Conde-Hinojosa* / **ORC ID:** 0000-0003-4689-1390

ID 2nd Co-author: *Jaime, Gallegos-Sánchez* / **ORC ID:** 0000-0001-6062-805X

ID 3rd Co-author: *Glafiro, Torres-Hernández* / **ORC ID:** 0000-0002-0479-1191

DOI: 10.35429/EJE.2023.19.10.9.17 Received July 15, 2023; Accepted December 30, 2023

Abstract

The aim of this study was to evaluate the effect of to addition the fat by pass and propionate calcium on resumption of the postpartum activity of hair-breed ewes suckling to theirs lambs. A total multiparous of 80 multiparous just lambing ewes with body weight 48±10 kg, were assigned to one of four treatments under randomized complete desing: 1) AC: Continuos suckling without the addition ingredient in your diet (n=22). 2) ACG: Continuos suckling+10 g fat by pass in the diet (n=20). 3) ACP: Continuos suckling+15 g propionate calcium in the diet (n=18) and 4) ACGP: Continuos suckling+10g fat by pass+ 15g propionate calcium in the diet (n=20). The results showed that the treatments presented similar (P>0.05) response to estrus, onset to estrus, return rate, gestation rate, lambing rate, prolificacy and fecundation. It is highlighted that ewes respond favorably to the syncronization protocol initiated at 25 days postpartum even if the ewes are continuosly suckling their lambs. The supplementation with by pass fat or calcium propionate did not affect the reproductive variables evaluated for the resumption of postpartum reproductive activity in hair sheep.

Fat protected, Prolificacy, Calcium propionate

Resumen

El objetivo de este estudio fue evaluar el efecto de la suplementación de grasa de sobrepaso y propionato de calcio sobre el reinicio de la actividad reproductiva postparto de ovejas de pelo que se encuentran amamantando a sus corderos. Se utilizaron un total de 80 ovejas multíparas recién paridas con un peso promedio de 48±10 kg, que fueron asignadas aleatoriamente bajo un diseño completamente al azar a uno de cuatro tratamientos: 1) Amamantamiento continuo (AC, n=22), ovejas lactando no recibieron algún ingrediente en su dieta. 2) Amamantamiento continuo + grasa (ACG, n=20), ovejas lactando recibieron 10 g de grasa/oveja en su dieta. 3) Amamantamiento continuo + propionato (ACP, n=18), ovejas lactando recibieron 15 g de grasa/oveja en su dieta y 4) Amamantamiento continuo + propionato + grasa (ACGP, n=20), ovejas lactando recibieron 10g de grasa + 15 g de propionato de calcio/oveja en su dieta. Los resultados demostraron que los tratamientos presentaron similar (P>0.05) respuesta al estro, inicio al estro, tasa de retorno, tasa de gestación, tasa de parto, prolificidad y fecundación. Se destaca que las ovejas responden favorablemente al protocolo de sincronización iniciado a los 25 días postparto incluso si las ovejas se encuentran en amamantamiento continuo. La suplementación con grasa de sobrepaso o propionato de calcio no afectaron las variables reproductivas evaluadas para el reinicio de la actividad reproductiva postparto de ovejas de pelo.

Grasa protegida, Prolificidad, Propionato de calcio

Citation: OSORIO-MARÍN, Yolanda, CONDE-HINOJOSA, Miguel Paul, GALLEGOS-SÁNCHEZ, Jaime and TORRES-HERNÁNDEZ, Glafiro. Postpartum reproductive efficiency of hair breed sheep additioning bypass fat and a gluconeogenic ingredient. ECORFAN Journal-Ecuador. 2023. 10-19:9-17.

* Correspondence to Autor (E-mail: osorio.marin.yolanda@hotmail.com)
† Researcher contributing as first author.

Introduction

The population of hair sheep has been increasing in the last years in the American continent with a wide distribution, not being reduced only to tropical regions as previously thought; nowadays hair sheep are distributed from tropical regions as well as in temperate and arid regions (McManus et al., 2010). In Mexico, Pelibuey sheep or their crosses with Dorper and Kathadin are the main hair sheep genotypes distributed in the national territory (Chay-Canul et al., 2016). This is due to their ability to adapt to different climates and the low reproductive seasonality of these sheep. Thanks to this, it is possible to develop reproductive programmes throughout the year (Arroyo, 2011) and these breeds are considered an alternative to cover the country's demand for sheep meat (Herrera-Corredor et al., 2010). However, it is necessary to improve their reproductive parameters to achieve this objective; one of the strategies to achieve this is proper postpartum management; a tool that has been used to minimise the time of the restart of postpartum ovarian activity, increase flock productivity and the economic condition of producers (Morales-Terán et al., 2004). However, newly lambed ewes suffer severe metabolic stresses when transitioning from a non-lactating to a lactating state of gestation; therefore nutritional management is of paramount importance at this point (Babaei et al., 2019). Nutrition has been shown to be an important factor that can modify reproductive behaviour (Ashworth et al., 2009). In this regard, energy supplementation by including various energy ingredients, such as protected oils and fats, has been chosen at different physiological stages for different purposes

(Holst et al., 2005; Radunz et al., 2009; Raju et al., 2015; Bhatt and Sahoo, 2017; Lerma-Reyes et al., 2018; Haro et al., 2020) the purpose is to increase energy in the diet without increasing the proportion of grains avoiding ruminal acidosis (Silva et al., 2011). On the other hand, the inclusion of glucose precursors has increased in ruminants, such as calcium propionate and glycerol as they have been shown to optimise nutrient utilisation and improve production (Avila et al., 2011; Lee-Rangel et al., 2012; Avila-Stagno et al., 2013; Mendoza-Martínez et al., 2016; Miranda et al., 2017; Cifuentes-López et al., 2018).

However, the use of both has not been studied in the postpartum period of hair ewes, for the restart of postpartum ovarian activity. Therefore, the aim of this study was to evaluate the inclusion of top fat and calcium propionate in the postpartum ovarian restart of hair ewes while they were suckling their lambs.

Methodology

Location

The present work was carried out at the Montecillo Campus of the Colegio de Postgraduados, in the facilities of LaROCa (Sheep and Goat Reproduction Laboratory), located in Texcoco de Mora, State of Mexico. Geographically located between the coordinates 19º 27'51.90" N latitude and 98º 54'34.30" W longitude at an altitude of 2250 m. With 644.8 mm of annual rainfall and an average temperature of 15º C (García, 2004).

Animals, management and treatments

A total of 80 recently lambed hair ewes at the end of July 2019, were used; with an average weight of 48±10 kg at lambing. Ewes with their offspring were randomly allocated to one of 4 treatments using a completely randomised design.

The ewes remained in continuous suckling with their lambs throughout the experiment, i.e. the lambs remained with their mothers 24 hours a day. The treatments consisted of the addition or not of some energy ingredient in the diet of the lactating ewes during the synchronization protocol; which was carried out 25 days after lambing, for the resumption of postpartum ovarian activity. 1) Continuous suckling (AC, n=22), lactating ewes did not receive any ingredient in their diet. 2) Continuous suckling + fat (ACG, n=20), lactating ewes received 10 g of surplus fat / ewe in their diet. 3) Continuous suckling + propionate (ACP, n=18), lactating ewes received 15 g calcium propionate / ewe in their diet and 4) Continuous suckling + propionate + fat (ACGP, n=20), lactating ewes received 10 g fat + 15 g calcium propionate / ewe in their diet.

Feeding

Ewes were fed a balanced diet according to their requirements (2.3 Mcal/kg DM of ME and 15% CP), as recommended (NRC, 2007).

For the treatments with propionate or fat surplus, this ingredient was added directly to the diet (Table 1).

The experimental diets were offered when the oestrus synchronization protocol had already started; from day 5 to day 9, i.e. they were offered for 5 days.

Water was available ad libitum throughout the study.

Ingredient (Kg)*.	Treatments			
	AC	ACG	ACP	ACGP
Wheat straw	40	36	40	36
Alfalfa	29	25	29	25
Concentrate	20	20	20	20
Corn	5	5	5	5
Fat	0	0.50	0	0.50
Calcium propionate	0	0.75	0	0.75
Minerals	1	1	1	1
Molasses	5	5	5	5
*Portions offered on an as offered basis per kg of dry matter.				

Table 1 Ingredients in experimental diets offered to hair ewes

Oestrus synchronization protocol

The synchronization protocol consisted of insertion of an intravaginal device (CIDR, Controlled Internal Drug Release; with 0.3 g progesterone, Pfizer) into the ewe for 9 days from day 25 post parturition. 48 h before withdrawal, 1 mL ewe-1 of prostaglandin (PGF2, Dinoprost; Lutalyse, Pharmacia & Upjhon, Michigan, USA) was applied intramuscularly. After 48 h, the CIDR was removed and oestrus was detected every 4 h for 72 h with the help of male guards wearing aprons to avoid copulation with the female.

Artificial insemination (AI)

Prior to artificial insemination, semen was collected and evaluated from healthy and reproductively fit rams. Artificial insemination (AI) was carried out 12 to 18 hours after the ewes had shown oestrus.

The ewes were shaved and disinfected in the abdominal region. Subsequently, insemination was carried out using the abdominal laparoscopy technique, in which a 0.25 mL straw of semen was introduced, depositing half of the straw in each uterine horn.

Diagnosis of pregnancy

Gestation diagnosis was made at 35 days post-service with a portable ultrasound (Aloka SSD 500, 7 Mhz transducer).

Reproductive variables

The following reproductive variables were used to assess the resumption of postpartum ovarian activity in ewes.

Oestrus response

Number of ewes showing signs of oestrus after removal of the device relative to the total number of ewes in each treatment.

$$\%Estro = \frac{No.de\ ovejas\ que\ presentaron\ estro}{No.total\ de\ ovejas\ por\ tratamiento} \times 100 \quad (1)$$

Onset of oestrus

Interval between removal of CIDR and onset of oestrus. The distribution was determined by the number of ewes that went into oestrus up to 72 hours after removal of the CIDR.

Return to oestrus

Number of ewes showing return to oestrus at 17 or 34 days post-insemination.

$$\%Retorno = \frac{No.de\ ovejas\ que\ presentaron\ retorno\ a\ estro}{No.total\ de\ ovejas\ por\ tratamiento} \times 100 \quad (2)$$

Gestation rate

Number of ewes diagnosed pregnant in relation to total number of ewes per treatment.

$$\%Gestación = \frac{No.\ de\ ovejas\ gestantes}{No.\ total\ de\ ovejas\ por\ tratamiento} \times 100 \quad (3)$$

Lambing rate

Number of ewes lambed to total number of ewes per treatment.

$$\%Parto = \frac{No.\ de\ ovejas\ paridas}{No.\ total\ de\ ovejas\ por\ tratamiento} \times 100 \quad (4)$$

ISSN-On line: 1390-9959

Fertility

Total number of lambs born to the total number of ewes per treatment.

$$\%Fecundidad = \frac{No.de\ corderos\ nacidos}{No.total\ de\ ovejas\ por\ tratamiento} \times 100 \quad (5)$$

Prolificacy

Number of lambs born to number of ewes lambed per treatment.

$$Prolificidad = \frac{No.\,de\ corderos\ nacidos}{No.\,total\ de\ ovejas\ por\ tratamiento} \times 100$$

Statistical analysis

The statistical package (SAS, 2012) was used for statistical analysis of the data. Significant differences were considered at P<0.05. Logistic regression using PROC LOGISTIC was used for the variables oestrus response, return to oestrus, gestation rate and lambing rate. The prolificacy and fecundity variables were analysed using a POISSON distribution using PROC GENMOD. The Shapiro and Wilk test (Shapiro and Wilk, 1965) was used for the variable onset of oestrus to observe univariate normality and then the analysis was carried out with the Kaplan Meier survival curve method using the Log-Rank test, with the LIFETEST procedure.

Results and discussion

The results obtained in this experiment on the resumption of ovarian activity in hair ewes during postpartum due to the effect of supplementation are shown in table 2.

Trat	n	Oestrus (%)	Return (%)	Gestation rate (%)	Lambing rate (%)	Prolificacy	Fertility
AC	22	45.5 [a] (10/22)	0 [a] (0/22)	45.5 [a] (10/22)	45.5 [a] (10/22)	1.1 [a]	0.5 [a] (11/22)
ACG	20	40 [a] (8/20)	0 [a] (0/20)	40 [a] (8/20)	40 [a] (8/20)	1.1 [a]	0.5 [a] (9/20)
ACP	18	55.6 [a] (10/18)	16.7 [a] (3/18)	50 [a] (9/18)	50 [a] (9/18)	1.4 [a]	0.7 [a] (13/18)
ACGP	20	45 [a] (9/20)	15 [a] (3/20)	45 [a] (9/20)	45 [ab] (9/20)	1.0 [a]	0.5 [a] (9/20)

AC: Continuous suckling, ACG: Continuous suckling + Fat, ACP: Continuous suckling + Propionate, ACGP: Continuous suckling + Fat + Propionate.
a,b Different letters indicate differences between treatments at P<0.05.

Table 2 Reproductive variables evaluated in the postpartum period of hair ewes

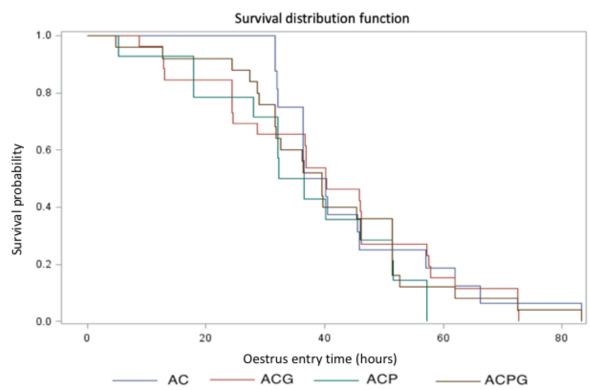
Supplementation with fat or calcium propionate during the synchronization protocol did not affect (P>0.05) the percentage of ewes in oestrus. Although some ewes did respond to the synchronization protocol whi lambing rate started at 25 days postpartum, a low oestrus incidence rate of less than or equal to 55% was observed in the 4 treatments.

Similarly, for the variables return rate, gestation rate and lambing rate, the treatments had no significant differences (P>0.05).

Graphic 1 shows the survival curves of the distribution of the hours of onset of oestrus for each treatment.

It can be seen that the variable onset of oestrus was not affected by the addition of top fat or calcium propionate.

However, it can be seen that the treatment with the addition of calcium propionate was the treatment that went into oestrus at an average of 60.68 hours.



Graphic 1 Oestrus onset survival curves formed by Kaplan-Meyer survival estimators at different times per treatment (P<0.05)
AC: Continuous suckling, ACG: Continuous suckling + Fat, ACP: Continuous suckling + Propionate, ACGP: Continuous suckling + Fat + Propionate.
Source: SAS, 2012

Although no significant differences were found in the prolificacy and fecundity variables (P>0.05), propionate promises to be a window of opportunity for the resumption of postpartum ovarian activity.

ISSN-On line: 1390-9959

The results of the present work are not similar to those found in another study from the same research in which, in contrast to these results, all ewes responded favourably to the synchronization protocol showing signs of oestrous behaviour.

This could be related to the presence of negative energy balance (NEB) in the ewes, as NEB is associated with suppression of reproductive function and ovarian cyclicity (Crown et al., 2007; Hill et al., 2008; Crowe et al., 2014).

Energy deficiency especially during critical physiological stages has been shown to negatively affect growth, milk production and subsequent reproduction (Horton et al., 1992).

Therefore, the idea of using supplementation was to increase efficiency and nutrient uptake to improve postpartum reproduction of ewes; as (Haro et al., 2020) did to improve animal production. Supplementation with various gluconeogenic ingredients or protected fats has been shown to have good results (Mahouachi et al., 2004; Abdalla, 2013; Silva et al., 2011; Pérez-Hernández et al., 2009a; Mejía Vázquez et al., 2017). The use of protected fats in the diet of ewes has had variable results; in this research work the ewe received 10 g of fat supplementation per day, which is a lower amount than what (Kumar et al., 2006) incorporated palm oil calcium soaps (10%) in the diet of growing lambs and it had no adverse effects on growth and carcass characteristics of the lambs.

Some studies report that the inclusion of fatty acids has been unable to alter the size or number of follicles by dietary effect (Molina-Mendoza et al., 2013), consequently if follicles do not grow, they will not be able to secrete oestradiol, necessary for females to show oestrus behaviour, possibly this occurred with the ewes in this experiment.

On the other hand, negative effects on fibre intake and digestibility have been reported with the addition of fat, so only 3-5% is allowed in the diet, as this is the maximum level that rumen micro-organisms can tolerate (Bayourthe et al., 1993).

In the case of calcium propionate, (Cifuentes-López et al., 2018) added (40 g/kg DM) to finishing lambs on alfalfa-based diets did not affect feed intake or live weight, but improved performance and desirable carcass attributes in finishing lambs. However, based on the above information, we cannot compare the results, because the animals in which the studies were carried out, including this one, were at different physiological stages and were even carried out on sheep of different sexes. But in general, it can be observed that the supplementation of fat and calcium propionate have had good results in the inclusion of sheep diets.

Nutrition is considered a possible environmental factor capable of affecting not only oocytes and embryos in their immediate environment, but also changes in the environment in which the female lives, during the breeding season and in early gestation. Such changes can generate effects that will result in offspring, including reproductive behaviour in subsequent generations (Ashworth et al., 2009). Possibly, in this study, supplementation for 5 days with either top-up fat or calcium propionate was not able to fully counteract the negative energy balance, which is known to be one of several factors that can significantly affect the resumption of postpartum ovarian activity (Pérez-Hernández et al., 2009b).

In a study by (Babaei et al., 2019) they suggest gradually increasing energy levels, in this case grain, specifically maize in diets to improve feed intake of ewes during peripartum to reduce the severity of the negative energy balance during this period. It follows from the above that research is still being carried out with traditional ingredients that provide energy, but this does not mean that grains are cheap and affordable for producers.

That is why ingredients that can partially replace grains in critical stages are sought in the cheapest possible way, with excellent results. However, it must be considered that although the ewes did not show the expected results to the supplementation of energy supplements, this could be a consequence of the management of the ewes, because although they did not respond to the supplementation, they did come into heat, in addition to reaching lambing, that is, good management is probably key to the success in a good reproductive efficiency of the flock.

On the other hand, it is known that the restart of ovarian activity takes place thanks to the participation of some hormones, neurotransmitters and proteins (Lozano et al., 1998; Dobek et al., 2013; Crowe et al., 2014). Endogenous opioid peptides (EOPs) are neurotransmitters that are synthesised during lactation and their activity is to regulate the secretion and release of GnRH (Russell, 2008; Arroyo et al., 2009), the absence of this hormone causes the inhibition of ovarian activity by delaying the growth of follicles that fail to mature (Arroyo et al., 2009).

It should be noted that during the present study the ewes were in continuous suckling and the secretion of opioids could have an effect on the ewes that did not respond to the synchronization protocol, regardless of the fact that the dates on which this study was carried out were during the reproductive season.

References

Abdalla, E. B. 2013. Effects of parity and nutrition plane during late pregnancy on metabolic responses, colostrum production and lamb output of rahmani ewes. Egyptian Journal of Animal Production, 50(3), 132-142. https://doi.org/10.21608/ejap.2013.93673

Arroyo, J. 2011. Estacionalidad reproductiva de la oveja en México. Tropical and Subtropical Agroecosystems, 14, 829-845. https://www.scielo.org.mx/pdf/tsa/v14n3/v14n3a1.pdf

Arroyo, J., Magaña-Sevilla, H., y Camacho-Escobar, M. A. 2009. Regulación neuroendocrina del anestro posparto en la oveja. Tropical and Subtropical Agroecosystems, 10, 301-312. https://www.redalyc.org/pdf/939/93912996001.pdf

Ashworth, C. J., Toma, L. M., y Hunter, M. G. 2009. Nutritional effects on oocyte and embryo development in mammals: Implications for reproductive efficiency and environmental sustainability. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1534), 3351-3361. https://doi.org/10.1098/rstb.2009.0184

Avila, J. S., Chaves, A. V., Hernandez-Calva, M., Beauchemin, K. A., McGinn, S. M., Wang, Y., Harstad, O. M., y McAllister, T. A. 2011. Effects of replacing barley grain in feedlot diets with increasing levels of glycerol on in vitro fermentation and methane production. Animal Feed Science and Technology, 166-167, 265-268. https://doi.org/10.1016/j.anifeedsci.2011.04.016

Avila-Stagno, J., Chaves, A. V., He, M. L., Harstad, O. M., Beauchemin, K. A., McGinn, S. M., y McAllister, T. A. 2013. Effects of increasing concentrations of glycerol in concentrate diets on nutrient digestibility, methane emissions, growth, fatty acid profiles, and carcass traits of lambs1. Journal of Animal Science, 91(2), 829-837. https://doi.org/10.2527/jas.2012-5215

Babaei, M. K., Mirzaei-Alamouti, H., y Nikkhah, A. 2019. Cereals level and source effects on rumen fermentation, colostrum and milk properties, and blood metabolites in periparturient ewes. Animal, 13(6), 1165-1172. https://doi.org/10.1017/S1751731118002720

Bayourthe, C., Moncoulon, R., y Vernay, M. 1993. Effect of protein-protected fat on ruminal and total nutrient digestibility of sheep diets. Journal of Animal Science, 71(4), 1026-1031. https://doi.org/10.2527/1993.7141026x

Bhatt, R. S., y Sahoo, A. 2017. Effect of feeding complete feed block containing rumen protected protein, non-protein nitrogen and rumen protected fat on improving body condition and carcass traits of cull ewes. Journal of Animal Physiology and Animal Nutrition, 101(6), 1147-1158. https://doi.org/10.1111/jpn.12628

Chay-Canul, A. J., Magaña-Monforte, J. G., Chizzotti M.L., Piñeiro-Vázquez A.T., Canul-Solís J.R. y Ayala-Burgos A.J. 2016. Energy requeriments of hair sheep in the tropcal regions of Latin America. Review. Revista Mexicana de Ciencias Pecuarias, 7(1), 105-125. https://doi.org/10.1007/s11250-011-9785-5

Cifuentes-López, R. O., Lee-Rangel, H. A., García-Lopez, J. C., Vicente, J. C., Flores-Primo, A., y Pinos-Rodríguez, J. M. 2018. Efecto del propionato del calcio en el peso vivo, consumo y canal de corderos alimentados con heno de alfalfa (Medicago sativa). Agrociencia, 52, 81-88. https://dialnet.unirioja.es/servlet/articulo?codigo=6745312

Crowe, M. A., Diskin, M. G., y Williams, E. J. 2014. Parturition to resumption of ovarian cyclicity: Comparative aspects of beef and dairy cows. Animal, 8, 40-53. https://doi.org/10.1017/S1751731114000251

Crown, A., Clifton, D. K., y Steiner, R. A. 2007. Neuropeptide Signaling in the Integration of Metabolism and Reproduction. Neuroendocrinology, 86(3), 175-182. https://doi.org/10.1159/000109095

Dobek, E., Górski, K., Romanowicz, K., y Misztal, T. 2013. Different types of opioid receptors involved in the suppression of LH secretion in lactating sheep. Animal Reproduction Science, 141(1-2), 62-67. https://doi.org/10.1016/j.anireprosci.2013.07.006

García, E. 2004. Modificaciones al sistema de clasifiación Climática de Köppen (Quinta edición). Instituto de Geografía-UNAM.
Haro, A. N., Carro, M. D., De Evan, T., y González, J. 2020. Influence of feeding sunflower seed and meal protected against ruminal fermentation on ruminal fermentation, bacterial composition and in situ degradability in sheep. Archives of Animal Nutrition, 74(5), 380-396. https://doi.org/10.1080/1745039X.2020.1756679

Herrera-Corredor, A., Salazar-Ortiz, J., Morales-Terán, G., Pro-Martínez, A., y Gallegos-Sánchez, J. 2010. Efecto del aceite de soya en la dieta y la condición corporal sobre la población folicular y tasa ovulatoria de ovejas pelibuey en dos épocas reproductivas. Universidad y Ciencia, 26, 205-210. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0186-29792010000200008

Hill, J. W., Elmquist, J. K., y Elias, C. F. 2008. Hypothalamic pathways linking energy balance and reproduction. American Journal of Physiology-Endocrinology and Metabolism, 294(5), E827-E832. https://doi.org/10.1152/ajpendo.00670.2007

Holst, P. J., Hall, D. G., y Lee, G. J. 2005. Colostrum production and hormone responses of parturient ewes fed varying amounts and types of supplement. Australian Journal of Experimental Agriculture, 45(10), 1231. https://doi.org/10.1071/EA03124

Horton, G. M. J., Wohlt, J. E., Palatini, D. D., Y Baldwin, J. A. 1992. Rumen-protected lipid for lactating ewes and their nursing lambs. Small Ruminant Research, 9(1), 27-36. https://doi.org/10.1016/0921-4488(92)90053-7

Kumar, R., Sivaiah, K., Reddy, Y. R., Ekambram, B., Reddy, T. J., y Reddy, G. V. N. 2006. Effect of supplementation of dietary protected lipids on intake and nutrient utilization in Deccani lambs. Tropical Animal Health and Production, 38(2), 151-158. https://doi.org/10.1007/s11250-006-4248-0

Lee-Rangel, H. A., Mendoza, G. D., y González, S. S. 2012. Effect of calcium propionate and sorghum level on lamb performance. Animal Feed Science and Technology, 177(3-4), 237-241. https://doi.org/10.1016/j.anifeedsci.2012.08.012

Lerma-Reyes, I., Mendoza-Martínez, G. D., Rojo-Rubio, R., Mejia, M., Garcia-Lopez, J. C., y Lee-Rangel, H. A. 2018. Influence of supplemental canola or soybean oil on milk yield, fatty acid profile and postpartum weight changes in grazing dairy goats. Asian-Australasian Journal of Animal Sciences, 31(2), 225-229. https://doi.org/10.5713/ajas.17.0058

Lozano, J. M., Forcada, F., y Abecia, J. A. 1998. Opioidergic and nutritional involvement in the control of luteinizing hormone secretion of postpartum Rasa Aragonesa ewes lambing in the mid-breeding season. Animal Reproduction Science, 52(4), 267-277. https://doi.org/10.1016/S0378-4320(98)00137-7

Mahouachi, M., Rekik, M., Lassoued, N., y Atti, N. 2004. The effect of constant dietary energy supply during late gestation and early lactation on performances of prolific D'man ewes. Animal Research, 53(6), 515-525. https://doi.org/10.1051/animres:2004033

McManus, C., Paiva, S. R., y Araújo, R. O. de. 2010. Genetics and breeding of sheep in Brazil. Revista Brasileira de Zootecnia, 39(suppl spe), 236-246. https://doi.org/10.1590/S1516-35982010001300026

Mejía Vázquez, Á., Vicente Pérez, R., Osorio, Y., Avendaño Reyes, L., Correa Calderón, A., D. Álvarez, F., y Macías Cruz, U. 2017. Síntesis de calostro y desarrollo de las crías por efecto de la inclusión de aceite de soya en la dieta preparto de ovejas de pelo. Revista Mexicana de Ciencias Pecuarias, 8(1), 01. https://doi.org/10.22319/rmcp.v8i1.4307

Mendoza-Martínez, G. D., Pinos-Rodríguez, J. M., Lee-Rangel, H. A., Hernández-García, P. A., Rojo-Rubio, R., y Relling, A. 2016. Effects of dietary calcium propionate on growth performance and carcass characteristics of finishing lambs. Animal Production Science, 56(7), 1194. https://doi.org/10.1071/AN14824

Miranda, L. A., Lee-Rangel, H. A., Mendoza-Martínez, G. D., Crosby-Galván, M. M., Relling, A. E., Pinos-Rodríguez, J. M., Rubio-Rojo, R., y González-Hernandez, M. 2017. Efecto del propionato de calcio en la fermentación in vitro de dietas a base de sorgo. Revista de la Facultad de Ciencias Agrarias Universidad Nacional de Cuyo Mendoza Argentina, 47, 231-243. http://www.scielo.org.ar/pdf/refca/v49n1/v49n1a16.pdf

Molina-Mendoza, P., Acosta-Dibarrat, J., Peralta-Ortíz, J. G., y Ávila-Castillo, V. R. 2013. Role of fat addition in sheep reproduction. En A.-F. Z. M. Salem (Ed.), Nutritional strategies of animal feed additives. Nova Science Publishers, Inc.

Morales-Terán, G., Pro-Martínez, A., Figueroa-Sandoval, B., Sánchez-del-Real, C., y Gallegos-Sánchez, J. 2004. Amamantamiento continuo o restringido y su relación con la duración del anestro postparto en ovejas Pelibuey. Agrociencia, 38, 165-171. https://www.redalyc.org/pdf/302/30238204.pdf

NRC. 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids (p. 11654). National Academies Press. https://doi.org/10.17226/11654

Pérez-Hernández, P., Hernández-Valdez, V. M., Figueroa-Sandoval, B., Torres-Hernández, G., Díaz-Rivera, P., y Gallegos-Sánchez, J. 2009a. Efecto del tipo de amamantamiento en la actividad ovárica postparto de ovejas pelibuey y tasas de crecimiento de corderos en los primeros 90 días de edad. Revista Científica de la Facultad de Ciencias Veterinarias, XIX(4), 343-349. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-22592009000400005

Pérez-Hernández, P., Hernández-Valdez, V. M., Figueroa-Sandoval, B., Torres-Hernández, G., Díaz-Rivera, P., y Gallegos-Sánchez, J. 2009b. Efecto del tipo de amamantamiento en la actividad ovárica postparto de ovejas pelibuey y tasas de crecimiento de corderos en los primeros 90 días de edad. Revista Científica de la Facultad de Ciencias Veterinarias, 19, 343-349. https://www.redalyc.org/pdf/959/95911613005.pdf

Radunz, A. E., Wickersham, L. A., Loerch, S. C., Fluharty, F. L., Reynolds, C. K., y Zerby, H. N. 2009. Effects of dietary polyunsaturated fatty acid supplementation on fatty acid composition in muscle and subcutaneous adipose tissue of lambs1. Journal of Animal Science, 87(12), 4082-4091. https://doi.org/10.2527/jas.2009-2059

Raju, S., Reddy, Y. R., Nagalakshmi, D., y Raghunandhan, T. 2015. Effect of Supplementation of Dietary Protected Lipids at Varying Levels of Feed Restriction on Growth Performance and Carcass Characteristics in Deccani Ram Lambs. Animal Nutrition and Feed Technology, 15(3), 439. https://doi.org/10.5958/0974-181X.2015.00044.X

Russell, J. A. 2008. Opioids. En ENCYCLOPEDIA OF STRESS (Experimental Neurology, Vol. 212). Elsevier. https://linkinghub.elsevier.com/retrieve/pii/S0014488608002422

SAS. 2012. SAS/STAT: User´s guide statistics released 9.1. (2nd ed.). Cary, N.C., USA.

Shapiro, S. S., y Wilk, M. B. 1965. An Analysis of Variance Test for Normality (Complete Samples). Biometrika, 52(3/4), 591. https://doi.org/10.2307/2333709

Silva, T. M., Oliveira, R. L., Barbosa, L. P., Neto, A. F. G., Bagaldo, A. R., Lanna, D. P. D., Silva, M. C. A. da, y Jesús, I. B. de. 2011. Preliminary Study on Meat Quality of Goats Fed Levels of Licury Oil in the Diet. Asian-Australasian Journal of Animal Sciences, 24(8), 1112-1119.
https://doi.org/10.5713/ajas.2011.11053.

ISSN-On line: 1390-9959