Reproductive and productive behavior of hair sheep under an intensive production system

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ABSTRACT
Objective: To evaluate the reproductive and productive behavior of four hair sheep breeds in an intensive production system.
Design/Methodology/Approach: Data recorded over 4 years (2016-2019) from a production unit that works with Blackbelly, Pelibuey, Dorper, and Katahdin breeds were analyzed. The following variables were evaluated: fertility, prolificacy, birth weight (BW), weaning weight (WW), weaned lamb yield (WLY), daily weight gain during lactation (DWGL), offspring born alive (OBA), male offspring (MO), and female offspring (FO). All information was analyzed using Chi-square tests and analysis of variance.
Results: The fertility, BW, WW, and WYL variables recorded different values between breeds ($P<0.05$). The greatest fertility and prolificacy were recorded by Blackbelly, while Dorper recorded the lowest values ($P<0.05$). BW and WW were highest in Dorper and lowest in Blackbelly ($P<0.05$). Finally, the sheep that recorded the highest WYL were the Blackbelly, while the Dorper registered the lowest values ($P<0.05$). BW and DWGL values reached maximum values ($P<0.05$) in Dorper rams, followed by Katahdin. The greatest number of OBA was observed in Blackbelly and Pelibuey ($P<0.05$).
Study Limitations/Implications: Further studies should be carried out to validate this research.
Findings/Conclusions: Blackbelly ewes produced more kilograms of weaned lambs per lambing ewe. The Dorper and Katahdin rams in the pre-weaning period recorded higher weight at weaning.

Keywords: reproductive efficiency, productivity, fertility, weight gain.

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INTRODUCTION

As a result of the high demand for sheep (*Ovis aries*) meat products in Mexico, special attention should be given to lamb production systems focused on supply, since the increase in demand for sheep products has forced Mexico to import live cattle for

slaughter (Bobadilla *et al.*, 2021). Since the annual production of sheep meat in Mexico amounts to 39,852 t and the *per capita* consumption per year is 0.6 kg, approximately 63,000 t year^{-1} must be imported, mainly from New Zealand, Australia, the United States of America, Chile, and Canada (SIAP, 2019). Consequently, sheep production should be redirected towards the production of lambs for supply (Calderón-Cabrera *et al.*, 2022).

Sheep farming in Mexico has incorporated hair breeds, as a result of their ability to adapt to hot, temperate, and dry climates (González-Garduño *et al.*, 2010). Additionally, Vicente *et al.* (2020) have reported that they do not have reproductive seasonality, a characteristic that allows the sheep industry to maintain a constant meat production throughout the year. Additionally, studies carried out in the arid and dry region of northwestern Mexico during the summer season have documented that high temperatures do not drastically reduce the productive capacity of the Pelibuey, Katahdin, and Dorper hair breed sheep, as well as their crosses (Macías *et al.*, 2013; Macías *et al.*, 2016). For their part, Chay *et al.* (2019) reported that the combination of prolificacy with the low mortality rate of lambs in the pre-weaning period is an essential factor that favors productivity in Pelibuey and Katahdin sheep breeds. Consequently, these animals have high productive and reproductive potential in any region of the country.

Two hair sheep breeds (Pelibuey and Blackbelly) are frequently used in production systems, due to their high reproductive efficiency and their level of biological adaptation to heat and high humidity conditions (Vicente *et al.*, 2020). Likewise, breed groups such as Katahdin and Dorper are used as parental breeds in some commercial herds (Oliva *et al.*, 2002; Nava *et al.*, 2006). However, Chay *et al.* (2019) mentioned that the birth weight and pre-weaning development of lambs of the Pelibuey breed are lower than in other breeds, such as Katahdin and Dorper (Macías *et al.*, 2012; Hinojosa *et al.*, 2015). Even though the Blackbelly and Pelibuey breeds have lower productive performance, it is necessary to evaluate their behavior in sheep production systems located in different regions of the country, both as a pure breed and in different crossbreeding systems with Dorper and Katahdin (Bores *et al.*, 2002). The birth weight and pre-weaning development of the lambs of hair breeds are low and inferior to wool or meat breeds —a situation that has led to the incorporation of rams from breeds specialized in meat production, such as Dorper and Katahdin (Macías *et al.*, 2010), into crossbreeding systems.

For their part, Dorper breed sheep have demonstrated a great growth rate: when they are crossed with Pelibuey females, lambs can gain up to 25% more weight per day than Pelibuey breed lambs (Cloete *et al.*, 2000; Hinojosa *et al.*, 2013; Mayren-Mendoza *et al.*, 2018). There is scarce information about the development of offspring of hair sheep breeds from birth to weaning, which makes it difficult to characterize the pre-weaning performance of each of these breeds. Therefore, generating this information would increase the efficiency of the sheep production systems of the country. Consequently, the objective of this research was to evaluate the reproductive and productive behavior of four hair sheep breeds in an intensive production system.

MATERIALS AND METHODS

Location of the study area

The study was carried out at the Rancho Universitario of the Universidad Autónoma de Ciudad Juárez, located 63 km northwest of the city, at 1,100 m.a.s.l. and with an average annual rainfall of 244 mm. According to the Köppen classification, modified by García (2004), the climate of the region is hot (BWh) and cold (BWK) desert.

Database

A database was generated from the reproductive and productive records of lambing ewes, mated with rams of the same breed, and their offspring. This information was collected over a 4-year period (2016-2019) and was the result of the implementation of synchronized mating programs, in which male and female hair sheep (Blackbelly, Pelibuey, Katahdin, and Dorper) were used. The records of 400 females and eight males were used to generate information about both the breeders and the offspring born in the study period. Exogenous hormones were used with females with synchronized estrus, which were subjected to controlled natural mating with rams of the same breed. The fertility (%), prolificacy, and weaned lamb yield (WLY; kg female^{-1}) of the ewes were recorded. In the case of the lambs, the following variables were recorded: birth weight (BW; kg), daily weight gain during lactation (DWGL; g), weaning weight (WW; kg), offspring born alive (OBA; n), male offspring (MO; %), and female offspring (FO; %). The information obtained from the offspring was used to evaluate the reproductive and productive performance of both ewes and rams.

Animals and management

The females and males were kept in an intensive production system (stabling and one birth every eight months). They were housed in pens equipped with feeders, waterers, and shades, and fed *ad libitum* with a maintenance diet [9% crude protein (CP) and 3.2 Mcal of metabolizable energy (ME kg^{-1})], made up of commonly used ingredients in the study region: Sudan grass (*Sorghum drumondii*) hay and alfalfa (*Medicago sativa*).

Regarding reproductive management, the females were integrated into groups of 25 individuals and were programmed to give birth every eight months (three births in two years). Each group of females was subjected to a synchronized mating program, which consisted of the use of a progestin for 12 days (intravaginal sponge; 20 mg of Cronolone; Chronogest CR®, MSD, Animal Health) and the intramuscularly injection of 250 IU of eCG (equine chorionic gonadotropin; GonActive® eCG, Virbac), 24 hours before the sponges were removed. Once the females showed estrus, a controlled mating program was used with two matings per female: one at the beginning of estrus and the second, 12 h later. Finally, the number of mated, pregnant, and lambing females was recorded to determine fertility and prolificacy. Likewise, during the lambing, lactation, and weaning season, all information regarding the lambs was recorded.

Study variables

The variables evaluated were: fertility, prolificacy, BW, WW, WYL, DWGL, OBA, MO, and FO.

Statistical analysis

All information was analyzed under a completely randomized design, using breed as treatment (Blackbelly, Pelibuey, Katahdin, and Dorper). The prolificacy, BW, WW, DWGL, OBA, and WYL variables were analyzed with the PROC GLM procedure. Fertility, FO, and MO were analyzed using a Chi-square test with the PROC FREQ procedure. Mean comparisons were performed with the t-student test at $P<0.05$. All statistical procedures were developed with the SAS statistical package version 9.12 for Windows (SAS, 2004).

RESULTS AND DISCUSSION

The results of the reproductive and productive evaluation of the hair sheep breed are presented in Table 1. The Blackbelly breed sheep had higher fertility (94%; $P<0.05$) than all the other breeds. Prolificacy was higher ($P<0.05$) in sheep of the Blackbelly, Pelibuey, and Katahdin breeds than in the Dorper breed, which recorded a 1.3 prolificacy (Table 1). Birth weights (BW) were higher ($P<0.05$) in lambs of the Dorper and Katahdin breeds, a behavior that was reflected in the weight at weaning ($P<0.05$; Table 1). Blackbelly showed the highest performance of weaned lamb ($P<0.05$) and surpassed the other breeds in the study by 17% (30.6 *vs.* 26.1 kg female^{-1}; Table 1).

In this study, fertility ranges from 89.6% to 94.1% and the maximum value was obtained by the Blackbelly breed. In this regard, Macías *et al.* (2009) report similar results in Pelibuey sheep for this variable, with a range of 81 to 93%. On the contrary, Gómez *et al.* (2006) reported lower fertility (78%).

The Blackbelly and Pelibuey breeds stand out in the prolificacy variable with respect to the other two breeds evaluated; this increased prolificacy results in a greater number of lambs born and therefore greater productivity. Regarding the offspring born alive variable, the Blackbelly and Pelibuey breeds stand out. In this sense, Rastogi (2001) and Knights *et al.* (2012) reported that the Blackbelly breed shows high prolificacy (1.77 and 2.0, respectively). Regarding the Pelibuey breed, Martínez *et al.* (2011) and Magaña *et al.* (2013) report prolificacies of 1.41 and 1.53, respectively. Similarly, Hernández-Montiel *et al.* (2020) stated that the prolificacy value in Pelibuey is ~1.5 lambs per birth; this value may be associated with the genetic makeup of the breed, since 57 SNPs associated with litter size have been reported. Some of the genes associated with litter size in Pelibuey include: CLSTN2, MTMR2, CCDC174, NOM1, ANKRD11, DLG1, ALPK3, ROBO2, CGA,

Table 1. Reproductive and productive evaluation of four hair sheep breeders.

Breed ewe	Fertility (%)	Prolificacy* Mean±SEM	Birth weight (kg) Mean±SEM	Weaning weight (kg) Media±SEM	Weaned lamb yield (kg ewe^{-1}) Mean±SEM
Blackbelly	94.1a	1.9±0.20a	2.9±0.20b	16.1±1.12b	30.6±2.3a
Pelibuey Canelo	89.6b	1.6±0.10a	3.1±0.14b	16.4±1.50b	26.2±1.7b
Katahdin	91.9b	1.5±0.13a	3.6±0.08a	17.5±0.08a	26.3±2.6b
Dorper	90.8b	1.3±0.18b	4.3±0.17a	19.8±0.86a	25.7±1.7b

a,b Values with different literal within columns, are different ($p>0.05$). * Lambs per ewe calved. ±SEM=Standar Error Means.

and KDM4A. Additionally, four SNPs (s37914.1 (Chr 4: 117, 719, 020 bp), s02969.1 (Chr 5: 184, 537 bp), OAR15_13905772.1 (Chr 15: 13, 872, 637 bp), and s15631.1 (Chr 19: 57.489.437 pb)) confirm that different underlying genetic mechanisms are involved in the prolificacy of Pelibuey sheep, such as candidate genes related to reproduction, seasonality, milk production, and weight. In the case of the Dorper breed, Gavojdian *et al.* (2013) reported low prolificacy (1.2); this value is similar to the result obtained in this study (1.3), which causes a lower number of lambs at birth.

Regarding the birth weight (BW) variable, similar results were obtained in the Blackbelly (2.9 kg) and the Pelibuey (3.2 kg) breeds; these results match the findings of Macías *et al.* (2009) who indicated a BW of 3.3, 2.9, and 3.1 kg for the Pelibuey, Katahdin, and Dorper breeds, respectively. However, in the present study, the Katahdin and Dorper breeds obtained similar birth weights (3.6 and 4.3 kg, respectively), which were higher than the Blackbelly and Pelibuey breeds. These results are similar to those reported in other studies, in which of 4.0 kg (Gavojdian *et al.*, 2013) and 3.8 kg (Mellado *et al.*, 2016) were obtained for the Dorper breed: the BW detected for Katahdin lambs in this study matches the results of Burque (2005) and Castillo *et al.* (2021), who reported a BW of 3.5 and 4.0 kg, respectively.

In the weaning weight (WW) variable, Macías *et al.* (2009) reported weights of 18.5 kg for Dorper and 14.5 kg for Pelibuey —values lower than those found in the present study (19.8 kg for Dorper). In a study carried out in the Mexican humid tropics, Chay *et al.* (2019) found weaning weights of 15.3 kg for Pelibuey and 16.0 kg for Katahdin —lower than the values obtained in this study.

There is a relationship between the number of lambs born and weaned per ewe, reflect in the efficiency with which Blackbelly sheep wean a greater number of kilograms per ewe, followed by Pelibuey and Katahdin. This has a favorable effect on the weaning productivity of hair ewes: ewes with two lambs (mainly Blackbelly and Pelibuey) record better results. The ability of an ewe to wean a greater number of lamb kilograms is conditioned by the size of the litter at birth, growth rate, and pre-weaning mortality (Macías-Cruz *et al.*, 2009, Macías-Cruz *et al.*, 2012). Ewes with two lambs were more productive at weaning, indicating that the combination of prolificacy with low lamb mortality rate in the pre-weaning period is an essential factor for the improvement of the productivity of hair ewes (Chay *et al.*, 2019). A better economic remuneration for sheep farmers would be achieved by combining the reproductive efficiency of Blackbelly with the productive efficiency of Dorper; therefore, greater WYL would be achieved with the direct crossing of the two aforementioned breeds.

Table 2 shows the results for the productive parameters of hair breed rams on their offspring. Birth weights (BW) are higher ($P<0.05$) in Dorper, followed by Katahdin, with a similar behavior ($P<0.05$) in the daily weight gain for the lactation (DWGL) variable. For the offspring born alive variable, a greater number of offspring was observed in the Blackbelly and Pelibuey breeds ($P<0.05$). Finally, for the female offspring and male offspring variables, no significant effect was observed between ram breeds and their offspring ($P>0.05$).

Table 2. Productivity of the offspring of the rams of four hair breeds.

Breed ram	Birth weight (kg) Mean±SEM	DWG during lactation (g) Mean±SEM	Live born pups (n) Mean±SEM	% Female offspring	% Male offspring
Blackbelly	2.5±0.20a	142±0.20a	54±1.7a	60	40
Pelibuey Canelo	3.1±0.14a	125±0.10a	48±1.1a	45	55
Katahdin	3.7±0.08b	209±0.13b	45±2.0a	54	46
Dorper	4.2±0.17b	259±0.18b	39±1.3b	50	50

a,b Values with different literal within columns, are different (α=0.05). ± SEM=Standar Error Means.
DWG: daily weight gain.

The birth weight (BW) values for Dorper breed lambs in this work were similar to those reported in other studies: 3.8 kg (Czismar *et al*., 2013) and 4.4 kg (Castillo *et al*., 2021). The BW obtained in Katahdin lambs matches the figures reported by Ehrhardt *et al*. (2018) and Vicente-Pérez *et al*. (2021): 3.7 and 3.9 kg, respectively. Although the BW values reported in this study were obtained using pure breeds, these results match the findings of López *et al*. (2021), who found a similar BW (3.8 kg), when Dorper or Katahdin parental breeds are used. Likewise, Macías *et al*. (2010) have reported that crosses of these paternal breeds with the maternal Pelibuey breed have the advantage of producing offspring for supply with acceptable growth rates.

The pre-weaning behavior of hair sheep breeds must be studied to determine their productive and economic efficiency, before deciding whether or not they should be incorporated into commercial farms. In this regard, Hinojosa *et al*. (2009) highlighted the pre-weaning productive efficiency of Dorper and Katahdin. These authors evaluated lambs on daily pre-weaning weight gain and established a better performance by these two breeds. These results match the findings of this work, where the same two breeds were superior to Blackbelly and Katahdin. This has a favorable impact on weaning weights, which is important in production systems where more kilograms of lamb can be weaned. Furthermore, crossing Blackbelly and Pelibuey breeds (as maternal base) and Dorper and Katahdin (as paternal base) would have a greater impact on the weight of the lambs at weaning and on the kilograms of lamb weaned per female.

CONCLUSIONS

The Katahdin and Dorper breeds are an alternative for the improvement of the weaning weight compared to the Blackbelly and Pelibuey breeds. However, the Blackbelly breed favors higher weaned lamb performance than the Pelibuey, Katahdin and Dorper breeds. The Blackbelly breed should be included in intensive production systems, as pure breeds or crossbred with other breeds, to increase the number of lambs born.

REFERENCES

Bobadilla, S. E. E., Ochoa, A. F. y Perea, P. M. 2021. Dinámica de la producción y consume de carne ovina en México 1970 a 2019. *Agronomía Mesoamericana*. *32*(3):963-982. doi: https://doi.org/10.15517/am.v32i3.44473

Bores, Q. R. F., Velázquez, M. P. A. y Heredia y Aguilar, M. 2002. Evaluación de razas terminales en esquemas de cruza comercial con ovejas de pelo F1. *Téc. Pecu. Méx. 40*(1):71-79. Disponible en: https://www.redalyc.org/pdf/613/61340104

Calderón-Cabrera, J., Santoyo-Cortés, V.H., Martínez-González, E. G., Palacio-Muñoz, V.H. 2022. Modelos de negocio para la producción de ovinos en el nororiente y centro del Estado de México. *Revista Mexicana de Ciencias Pecuarias, 13*(1):145-162. doi: https://doi.org/10.22319/rmcp.v13i1.5816

Castillo, H. G., Oliver, G. M. R., Castillo, H. R., Salvador, F. O. y Maldonado, J. J. A. 2021. Desempeño pre-destete de corderos comerciales cruzados con Dorper, Katahdin y Romanov. III Congreso Internacional en Ciencias Agronómicas y Veterinarias. CICAV-2021.

Chay, C. A. J., García, H. R. A., Magaña, M. J. G., Macías, C. U. y Luna, P. C. 2019. Productividad de ovejas Pelibuey y Katahdin en el trópico húmedo. *Ecosist. Recur. Agropec. 6*(16):159-165. doi: 10.1080/1828051X.2019.1599305

Cloete, S. W. P., Snyman, M. A. and Herselman, M. J. 2000. Productive performance of Dorper sheep. *Small Ruminant Res.* 36:119-135. doi: 10.1016/S0921-4488(99)00156-X

Csizmar, N., Györi, Z., Budai, C., Olah, J., Kovacs, A., and Javor, A. 2013. Influence of Birth type and Sex on the Growth performance of Dorper lambs. *Scientific Papers: Animal Science and Biotechnologies. 46*(2):347-350.

Ehrhardt, R. A., Moody, J., Makela, B. and Veiga-Almudena, L. 2018. The effect of late lactation and pre-breeding nutrition on reproductive outcomes in an accelerated lambing system. *J. Anim. Sci.* 97:173. doi: 10.1093/jas/skz258.356.

García, E. 2004. Modificaciones al Sistema de Clasificación Climática de Köppen, Serie Libros, núm. 6, Instituto de Geografía. UNAM, México.

Gavojdian, D., Cziszter, L. T., Pacala, N. and Sauer, M. 2013. Productive and reproductive performance of Dorper and its crossbreds under a Romanian semi-intensive management system. *S. Afr. J. Anim. Sci. 43*(2):219-228. doi: 10.4314/sajas.v43i2.12

Gomez, J. D., Balasch, S., Gomez, L. D., Martino, A. and Fernandez, N. 2006. A comparison between intravaginal progestagen and melatonin implant treatments on the reproductive efficiency of ewes. *Small Rumin. Res.* 66:156-163. doi: 10.1016/j.smallrumres.2005.08.020

González-Garduño, R., Torres-Hernández, G. and Arece-García, J. 2010. Comportamiento productivo y reproductivo de ovinos Pelibuey en un sistema de pariciones aceleradas con tres épocas de empadre al año. *Zootecnia Tropical. 28*(1):51-56. [citado 2022-05-23], pp.51-56. Disponible en: <http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-72692010000100007&lng=es&nrm=iso>

Hernández-Montiel, W., Martínez-Núñez, M. A., Ramón-Ugalde, J. P., Román-Ponce, S. I., Calderón-Chagoya, R. y Zamora-Bustillos, R. 2020. Genome-wide association study reveals candidate genes for litter size traits in pelibuey sheep. *Animals. 10*(3).434. doi:10.3390/ani10030434

Hinojosa, C. J. A., Oliva, H. J., Torres, H. G. y Segura, C. J. C. 2013. Comportamiento productivo de corderos F1 Pelibuey × Blackbelly y cruces con Dorper y Katahdin en un sistema de producción del trópico húmedo de Tabasco, México. *Archivos de Medicina Veterinaria* 45:135-143. doi: 10.4067/S0301-732X2013000200004.

Hinojosa, C. J. A., Oliva, H. J., Torres, H. G., Segura, C. J. C. y González, G. R. 2015. Productividad de ovejas F1 Pelibuey × Blackbelly y sus cruces con Dorper y Katahdin en un sistema de producción del trópico húmedo de Tabasco, México. *Archivos de Medicina Veterinaria* 47:167-174. doi: 10.4067/S0301-732X2015000200007

Hinojosa, C. J. A., Regalado, A. F. M. y Oliva, H. J. 2009. Crecimiento prenatal y predestete en corderos Pelibuey, Dorper, Katahdin y sus cruces en el sureste de México. *Rev. Cient. 19*(5):522-532. [fecha de Consulta 23 de Mayo de 2022]. Disponible en: https://www.redalyc.org/articulo.oa?id=95911615013

Knights, M., Siew, N., Ramgattie, R., Singh, K. D. and Bourne, G. 2012. Effect of time of weaning on the reproductive performance of Barbados Blackbelly ewes and lamb growth reared in the tropics. *Small Rum. Res.* 103:205-210. doi: 10.1016/j.smallrumres.2011.09.042

López-Carlos, M., Fernández-Mier, R., Aréchiga-Flores, C., Hernández-Briano, P., Medina-Flores, C. y Ramírez-Chéquer, J. 2021. Crecimiento de corderos de pelo en el altiplano semiárido de Zacatecas durante el invierno. *Abanico Veterinario*. 11:1-14. doi:10.21929/abavet2021.4

Macías, C. U., Álvarez, V. F. D., Olguín, A. H. A., Molina, R. L. y Avendaño, R. L. 2012. Ovejas Pelibuey sincronizadas con progestágenos y apareadas con machos de razas Dorper y Katahdin bajo condiciones estabuladas: producción de la oveja y crecimiento de los corderos durante el periodo predestete. *Arch. Med. Vet*. 44: 29-37.

Macías, C. U., Álvarez, V. F. D., Correa, C. A., Díaz, M. R., Mellado, M., Meza, H. C. A. and Avendaño, R. L. 2013. Thermoregulation of nutrient-restricted hair ewes subjected to heat stress during late pregnancy. *J. Therm. Biol. 38*(1):1-9. doi: 10.1016/j.jtherbio.2012.09.002

Macías, C. U., Álvarez, V. F. D., Correa, C. A., Molina, R. L., González, R. A. y Soto, N. S. 2012. Ovejas Pelibuey sincronizadas con progestágenos y apareadas con machos de raza Dorper y Katahdin bajo condiciones estabuladas: producción de la oveja y crecimiento de corderos durante el periodo de destetes. *Archivos de Medicina Veterinaria*. 44: 29-37. doi: 10.4067/S0301-732X2012000100005.

Macías, C. U., Álvarez, V. F. D., Correa, C. A., Molina, R. L., González, R. A., Soto, N. S. and Avendaño, R. L. 2009. Pelibuey ewe productivity and subsequent pre-weaning lamb performance using hair-sheep breeds under a confinement system. *J. Appl. Anim. Res. 36*(2):255-260. doi: 10.1080/09712119.2009.9707071

Macías, C. U., Álvarez, V. F. D., Rodríguez, G. J., Correa, C. A., Torrentera, O. N. G., Molina, R. L, Avendaño, R. L. 2010. Crecimiento y características de canal en corderos Pelibuey puros y cruzados F1 con razas Dorper y Katahdin en confinamiento. *Arch. Med. Vet*. 42:147-154. doi: 10.4067/S0301-732X2010000300005

Macías, C. U., Gastélum, M. A., Álvarez, F. D., Correa, A., Díaz, R., Meza, H. C. A, Mellado, M. and Avendaño, R. L. 2016. Effects of summer heat stress on physiological variables, ovulation and progesterone secretion in Pelibuey ewes under natural outdoor conditions in an arid region. *Anim. Sci. J. 87*(3):354-360. doi: 10.1111/asj.12430

Magaña, M. J. G., Huchin, C. M., Aké, L. R. J. and Segura, C. J. C. 2013. A field study of reproductive performance and productivity pf Pelibuey ewes in Southeastern Mexico. *Trop. Anim. Health Prod*. 45:1771-1776. doi: 10.1007/s11250-013-0431-2

Martínez, R. R. D., Reyna, S. L., Torres, H. G. Mastache, L. A. A. y Michel, A. A. C. 2011. Evaluación de la fertilidad y proñificidad en cicloes reproductivos de ocho meses durante tres estaciones en ovejas Pelibuey en el trópico seco mexicano. *Revista Científica, FCV-LUZ. XXI*(5):383-387. [fecha de Consulta 23 de Mayo de 2022]. Disponible en: https://www.redalyc.org/articulo.oa?id=95919362001

Mayren-Mendoza, F. J., Rojas-García, A. R., Maldonado-Peralta, M. A., Ramírez-Reynoso, O., Herrera-Pérez, J., Torres-Salado, N., Sánchez-Santillán, P., Bottini-Luzardo, M. B. y Hernández-Garay, A. 2018. Comportamiento productivo de ovinos Pelibuey en pastoreo suplementados con follaje de *Guazuma ulmifolia* Lam. *Agro Productividad. 11*(5):29-33. Recuperado a partir de https://revista-agroproductividad.org/index.php/agroproductividad/article/view/367

Mellado, J., Marín, V., Reyes-Carrillo, J. L., Mellado, M., Gaytán, L. and De Santiago, Ma. De los A. 2016. Effects of non-genetic factors on pre-weaning growth traits in Dorper sheep managed intensively in Central Mexico. *Ecosistemas y Recursos Agropecuarios. 3*(8): 229-235. Recuperado en 24 de junio de 2022, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2007-90282016000200229&lng=es&tlng=en.

Nava, L. V. M., Oliva, H. J. e Hinojosa, C. J. A. 2006. Mortalidad de los ovinos de pelo en tres épocas climáticas en un rebaño comercial en la Chontalpa, Tabasco, México. *Univers. y Cien. 22*(2):119-129. doi: 10.19136/era.a22n2.315

Oliva, H. J., Mora, M. H., Sánchez, M. J. M. e Hinojosa, C. J. A. 2002. Producción de ovinos de pelo en Tabasco. Condiciones climáticas y apareamiento. Kuxulkab'. 8(15):12-15.

Rastogi, R. K. 2001. Production performance of Barbados blackbelly sheep in Tobago, West Indies. *Small Rum. Res. 41*(2):171-175. doi: 10.1016/s0921-4488(01)00199-7

SAS, 2004. SAS/STAT, users guide software released 9.12. SAS Institute Inc., Cary, NC.

SIAP. (2019). Food and Agricultural Overview 2019 (First edit). México, D. F. Retrieved from https://nube.siap.gob.mx/gobmx_publicaciones_siap/pag/2019/Agricultural-Atlas-2019

Vicente, P. R., Macías, C. U., Avendaño, R. L., Correa, C. A., López, B. M. A. y Lara, R. A. L. 2020. Impacto del estrés por calor en la producción de ovinos de pelo. Revisión. *Rev. Mex. Cienc. Pecu. 11*(1):205-222. doi: 10.22319/rmcp.v11i1.4923

Vicente-Pérez, R., Macías-Cruz, U., Avendaño-Reyes, L., García-Flores, E. O., Martínez-Martínez, R., Montañez-Valdez, O. D., Reyes-Gutiérrez, J. A., Chay-Canul, A. J. y Crosby-Galván, M. M. 2021. Suplementación de ácidos grasos poliinsaturados en el empadre de ovejas nulíparas Katahdin: eficiencia reproductiva y crecimiento pre-destete de las crías. *Revista Mexicana de Ciencias Pecuarias. 12*(2):586-597. doi:10.22319/rmcp.v12i2.5540