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Seasonal anestrus of sheep flocks

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ABSTRACT

Objective: To determine seasonal anestrus in relation to the season of the year, feeding type, breed, and social environment variables of sheep production systems in Singuilucan, Hidalgo, Mexico.

Design/Methodology/Approach: Based on n=41 semi-structured surveys applied to the producers of the study area, a logistic regression analysis was carried out to determine the influence of the study variables on the seasonal anestrus of sheep production systems.

Results: Thirty-nine production units with seasonal anestrus periods were identified. Seasonal anestrus was influenced by the season of the year, feeding type, breed, and social environment variables ($P<0.05$). The anestrus periods were influenced ($P<0.05$) by spring (season of the year), range and shed system with concentrate feeding (feeding type), wool sheep (breeds), and the presence or absence of rams in the flock (social environment).

Study Limitations/Implications: Determining which variables influence seasonal anestrus will help to develop sheep reproductive programs.

Findings/Conclusions: Wool sheep have a seasonal anestrus in spring. The season of the year, feeding type, breed, and social environment variables influenced the seasonal anestrus of sheep production systems in Singuilucan, Hidalgo, Mexico.

Keywords: sheep reproduction, interviews, photoperiod.

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INTRODUCTION

Sheep production is the main livestock activity in Mexican rural communities; this activity allows the inhabitants to overcome poverty, complementing their income (Galaviz *et al.*, 2011; Herrera *et al.*, 2019). Mexico has 8,805,206 sheep. Out of that total, 1,105,275 sheep are located in Hidalgo, which is the second sheep producer in the country (SIAP, 2022). The sheep from this region are mainly crossed livestock (Suffolk or Hampshire × hair sheep) and are located in marginal areas, pastures, and areas with agricultural waste (Hernández *et al.*, 2017). It is of minor importance because, in some cases, it is a subsystem of agricultural or livestock production systems (Pérez *et al.*, 2011). Although they are a major source of livelihood for rural populations, there is a lack of information about sheep production systems (Vázquez *et al.*, 2018).

Seasonality of reproduction is one of the main limitations of sheep productivity (Ramírez-Ramírez *et al.*, 2021) and poses a main challenge for the development of sheep reproduction management strategies (Vera *et al.*, 2013). This phenomenon is the result of the incomplete knowledge about the mechanisms that rule seasonal reproduction (Zahoor *et al.*, 2018). In this type of reproduction, ewes have a reproductive cycle and an anestrus cycle during different times of the year (Ungerfeld, 2016). This behavior is one of the adaptation mechanisms developed by mammals as part of their survival strategies and is synchronized by external environmental signs that, in turn, drive the internal circuit of the seasonal breeding cycle (Wood and Loudon, 2018). The photoperiod is one of the major environmental factors that regulate the reproductive cycle of sheep (Leyva *et al.*, 2023; Ramírez-Ramírez *et al.*, 2021) and it is mainly based on the daily increase or reduction of sunlight. Melatonin secretion takes place at night; this hormone synchronizes the physiological processes with the environmental conditions (Ungerfeld, 2016). Meanwhile, nutrition is an important regulator of reproduction and it may stimulate the hypothalamic-pituitary-gonadal axis (Urviola and Fernández, 2017). In addition, other factors, such as breed and social environment, impact reproductive processes and determine the duration of the seasonal anestrus (Arroyo, 2011; Urviola and Fernández, 2017). However, there is not enough knowledge about all the variables involved in this process and the degree to which they influence the seasonal anestrus of sheep. Consequently, further research should be carried out to understand sheep reproduction (Arroyo, 2011; Abecia *et al.*, 2024). Therefore, the objective of this study was to determine the relation of seasonal anestrus with the season of the year, feeding type, breed, and social environmental variables of the sheep production systems in Singuilucan, Hidalgo, Mexico. The hypothesis was that seasonal anestrus depends on the evaluated variables.

MATERIALS AND METHODS

Study Area

The study was carried out in the municipality of Singuilucan, Hidalgo, Mexico, located between 19° 52' and 20° 08' N at 2,645.88 m.a.s.l. The area has a temperate subhumid climate with summer rains. The mean annual temperature ranges from 10 °C to 16 °C, while precipitation reaches 400-1,100 mm (INEGI, 2009).

Data Collection

Data were obtained from primary sources, through semi-structured interviews with producers, relatives, and employees. The interviews included some specific questions. Qualitative and quantitative research methods were used to analyze data. In addition, a simple random sampling method was used, considering each production unit as a sample (Bustamante, 2011).

Determining sample size and pilot test

Sample size was determined using the sample size determination method for a finite population, with a 95% confidence level, a 1.96 coefficient ($Z\alpha$), and 6% accuracy (Bustamante, 2011).

For this study, a pilot study (García, 2013) was carried out to determine a real (p) value (5%), which resulted in a sample size (n) of 40 sheep production units that should be surveyed out of a population of 191 registered production units (N) (INEGI, 2007). However, 41 surveys were conducted.

Evaluated variables

The seasonal anestrus dependent variable was obtained classifying the reproduction inactivity period according to natural anestrus types, starting on the months when producers reported births and estrus periods for their flocks. These classifications consider a 5-month gestation period and a 3-month anestrus period due to lactation.

There were four independent variables: season of the year, feeding type, breed, and social environment. The first variable recorded the variations of the hours of light per day during the different seasons of the year (spring, summer, autumn, and winter). This factor influences the reproductive behavior of sheep (Bittman and Karsch, 1984). The second variable included three feeding types: extensive system (range sheep grazing in pastures and fed on stubble from cereal crops); a shed system with concentrate feeding and forage systems (based on agricultural by-products); and mixed range, combined with grain and agricultural by-products (Partida *et al.*, 2013). Two groups were established for the third variable: 1) Hampshire and Suffolk crossed breed wool sheep; and 2) Dorper-Kathadin crossed breed hair sheep. The fourth variable depends on the presence or absence of a ram in the flock. Pregnant, lactating, or seasonal anestrus ewes are separated from rams.

Statistical Analysis

A bivariate and multivariate logistic regression was carried out. The percentage of significance was obtained with the R-square, based on the ratio between each independent variable and the dependent variables ($P<0.05$). The IBM SPSS Statistics software was used for this purpose (Rivadeneira *et al.*, 2020).

RESULTS AND DISCUSSION

Season of the year

Out of the 41 production units surveyed, two did not record seasonal anestrus, while the seasonal anestrus in the other 39 (95.1%) was dependent on the season of the year. Thirty-seven production units included in the latter group reported seasonal anestrus in spring ($P<0.05$) and two in summer (Table 1).

Feeding type

Thirty-nine production units with seasonal anestrus were identified for this variable. Thirty-three production units have a range feeding system. One of the two production units that used a shed-based feeding system had wool sheep, while the other had hair sheep; the former recorded seasonal anestrus, while the latter did not report this situation ($P<0.05$). Additionally, five out of the six production units that had a mixed feeding system recorded seasonal anestrus.

Table 1. Sheep production units that recorded seasonal anestrus in Singuilucan, Hidalgo, Mexico.

Variables	Production units with seasonal anestrus	p-value***
Seasons of the year*	39/41	0.05
Spring (April-June)**	37/37	0.05
Summer (July-September)**	2/2	0.743
Types of feed*	39/41	0.05
Free grazing**	33/33	0.05
Stabled**	1/2	0.05
Mixed**	5/6	0.147
Breed type**	39/41	0.05
Wool sheep	39/39	0.05
Hair sheep	0/2	0.05
Social environment**	39/41	0.05
Presence of males	31/31	0.05
Absence of males	8/10	0.05

* Polytomous independent variables: season of the year, feeding type.
** Dichotomous independent variables: breed, social environment.
*** *p* value of the production units that recorded seasonal anestrus, in relation with their production units per variable.

Breed

Out of the 41 evaluated production units, 39 reported seasonal anestrus. These productions units have wool sheep, while the two production units without seasonal anestrus have hair sheep ($P<0.05$).

Social environment

Out of the 39 production units that reported seasonal anestrus, 31 have a ram, while 8 did not have a ram in the flock ($P<0.05$).

Regarding the season of the year variable, the reports indicate that anestrus takes place during spring. Several factors regulate the seasonality of reproduction of wild and domestic ungulates, including the photoperiod, which changes depending on the season of the year. Photoperiod is the primary environmental factor that regulates annual reproduction cycles, followed by the environmental factors that influence food availability (Urviola and Fernández, 2017). Sheep secrete melatonin —a key hormone indicator of the changes in the length of a given day. This indicator changes depending on the season of the year (Li *et al.*, 2021). Melatonin is secreted at night, with a circannual rhythm stimulated mainly by the photoperiod. In its turn, it stimulates the pulsatile activity of the gonadotropin-releasing hormone neurons (Chemineau *et al.*, 2010). On the one hand, the seasonal anestrus stage (long days) takes place during spring and summer, with low levels of melatonin secretions. On the other hand, the reproduction stage (short days) takes place in autumn and winter, with high levels of melatonin secretion (Bittman and Karsch, 1984; Arroyo, 2011). In this regard, Arroyo *et al.* (2007) determined that Suffolk

sheep, located in central Mexico (19° N) have a clear and defined seasonal anestrus, during winter and spring.

Partida *et al.* (2013) reported different feeding systems: range, concentrate, and mixed. This study found that production units with range sheep have seasonal anestrus mainly during spring. The reproductive activities of most animal species are inhibited during certain periods of the year. This is a common process that guarantees the survival of the litter, because it prevents births during unfavorable periods. Consequently, births take place at the end of winter or the beginning of spring, when the weather is more favorable for the development of the litters (Ramírez-Ramírez *et al.*, 2021). In this regard, González *et al.* (2014) pointed out that wool sheep give birth during spring, when the native grasses from which they graze reappear thanks to the rains of the season. This study did not analyze the estrus and births data to determine the seasonal anestrus period; however, the data about estrus and birth seasons reported by the producers were used to infer that the reproduction season took place in summer. Meanwhile, regarding the two production units that use concentrate feedings under a shed-based system, one bred wool sheep with a seasonal anestrus, while the other had hair sheep without seasonal anestrus. In this regard, Arroyo *et al.* (2007) found that, under a constant nutritional plan, Suffolk sheep have ovarian inactivity periods from February to June. These findings match the results obtained in this study with wool sheep fed with concentrates under a shed-based system. In addition, these authors mentioned that, under a control feeding regime, Pelibuey sheep have a constant ovulatory activity throughout the year. These results also match the findings of this research regarding hair sheep. Consequently, the breed variable influenced the surveyed production units.

Regarding breed, all the wool sheep production units of this study reported seasonal anestrus during spring. In this sense, ewes from most breeds are seasonal breeders, with ovulatory cycles in autumn and winter and anovulatory periods (seasonal anestrus) in spring and summer (Kopycinska *et al.*, 2022). Interestingly, Mediterranean wool sheep breeds have seasonal breeding patterns, mainly regulated by the changes in the photoperiod (Bittman and Karsch, 1984). Sheep from high latitudes (>35°) have a two-period seasonality of reproduction during a year: one mating season and one reproductive inactivity season, which is mainly ruled by the photoperiod (Bittman and Karsch, 1984; Arroyo, 2011).

Meanwhile, the Katahdin and Dorper hair sheep production units recorded no seasonal anestrus in this study. In this regard, González *et al.* (2014) mentioned that, at 23° 53' N, hair sheep such as Dorper and Katahdin can reproduce in spring. Meanwhile, Arroyo *et al.* (2007) reported that Pelibuey hair sheep can ovulate throughout the year at 19° N. For their part, Juárez *et al.* (2018) pointed out that, at 21° N (subhumid tropics), Pelibuey sheep do not have seasonality of reproduction; however, they have a higher follicular atresia during spring. In this regard, Macías *et al.* (2015) mentioned that, at 32° N, Pelibuey sheep may not have estrus periods in winter and spring, under Mexican arid conditions. Gastelum *et al.* (2015) studied the circannual estrus of Pelibuey sheep at 32° N and found that the estrus activity diminishes from January to June, under Mexican arid conditions. This reduction can be related to the individual sensitivity of some Pelibuey sheep to the photoperiod.

The social environment of the sheep in this study was closely related to the seasonal anestrus, with and without a ram in the flock. The social interaction between ewes and rams modifies the reproductive cycle of ewes. This phenomenon is a consequence of the pheromone-driven "male effect." Exposing an ewe during its seasonal anestrus to a sexually active ram can usually result in a fast increase of its LH pulse frequency (Delgadillo *et al.*, 2008). This stimulus triggers the ovulatory activity and the estrus signs in ewes (Abecia *et al.*, 2024). Meanwhile, Arroyo (2011) reported that the social signs largely influence ewes with a marked seasonality, because the separation and subsequent incorporation of the ram in an ewe flock can synchronize the reproductive cycle of ewes. On the contrary, the year-long presence of a ram within a flock result in larger anestrus periods. According to Delgadillo *et al.* (2008), the "male effect" requires certain conditions, such as separating the rams from the flock, in order to prevent any chemical, visual, audio, and tactile interaction. This study did not include the evaluation of these conditions; however, De St Jorre *et al.* (2012) have proven that separating the ram from the flock is unnecessary, because the introduction of a new sexually active male in the flock promotes a good response from the ewes. Both the presence and the absence of a ram in a flock makes seasonal anestrus possible, because factors such as the ram stimulus quality, age, body condition, and nutritional and genetic conditions of the ewes significantly impacts the response to the "male effect" (Abecia *et al.*, 2024). Although no differences were recorded regarding the presence of the estrus with or without rams in the flock, this practice —separating and subsequently introducing a ram to the flock— can prevent the pharmacological manipulation used to control the reproductive activities of ewes, because the socio-sexual factors that drive the introduction of a ram in the flock can stimulate ovulation in ewes (Hawken and Martin, 2012) and speed up puberty in female lambs. Finally, it is an efficient and sustainable system to increase the productive lives of ewes, simultaneously preventing the use of hormonal treatments (Abecia *et al.*, 2016).

CONCLUSIONS

Seasonal anestrus appears in spring and is influenced by the season of the year, feeding type, breed, and social environment of wool sheep production systems in Singuilucan, Hidalgo. In conclusion, determining the factors that influence seasonal anestrus is fundamental to developing recommendations aimed to improve productivity in sheep production systems.

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