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Characterization of hair-sheep production systems in the Mexicali Valley, Baja California, Mexico

Caracterización de los sistemas de producción de ovinos de pelo en el Valle de Mexicali, Baja California, México

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ABSTRACT

The present study describes the main characteristics of hair-sheep production systems in the State of Baja California, Mexico. Information related to the sheep production system was gathered by surveys applied to sheep farmers taking into consideration several aspects of general management such as type of production system, sire's selection, feeding practices, and breeding. A principal component analysis was performed to assess and find the better-defining variables. The results suggest that there is an opportunity area for hair-sheep production system in Baja California. Also, specific variables allow the better stratification of production systems. Some limitations are highlighted that must be resolved to encourage the development of hair-sheep meat production in the northwest of the country.

KEY WORDS: Animal production, Arid zones, Dorper, Ovine, Pelibuey, Principal Component Analysis.

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RESUMEN

El presente estudio describe las principales características de los sistemas de producción de ovinos de pelo en el Estado de Baja California, México. La información relacionada con el sistema de producción ovina se recopiló mediante encuestas aplicadas a ovinocultores tomando en consideración diversos aspectos de manejo general como son el tipo de sistema de producción, selección de sementales, prácticas de alimentación y crianza. Se realizó un análisis de componentes principales para evaluar y encontrar las mejores variables definitorias. Los resultados sugieren que existe un área de oportunidad para el sistema de producción de ovinos de pelo en Baja California. Asimismo, variables específicas permiten una mejor estratificación de los sistemas de producción. Se destacan algunas limitaciones que deben ser resueltas para impulsar el desarrollo de la producción de carne de ovino de pelo en el noroeste del país.

PALABRAS CLAVE: Análisis de componentes principales, Dorper, Ovino, Pelibuey, Producción animal, Zonas áridas

Introduction

Hair-sheep production systems in Mexico are mainly carried out in extensive and backyard systems; however, there are some intensive production systems with a high level of technification, for example, automated facilities and heavy machinery for handling supplies. Despite the high adaptability of sheep, this activity has not managed to establish itself as a primary economic activity (Aguilar-Martínez *et al*., 2017). Instead, it is characterized as a traditional activity closely linked to the degree of development of populations. It is possible to consider sheep production as a subsistence activity, with little or no organization and investment in development technologies.

Sheep were probably imported to the American continent between the 17th and 18th centuries, during the slave trade era, with Barbados and Brazil being the first places where they were settled. Later, sheep gradually spread to other countries in Central and South America (Aguilar-Martínez *et al*., 2017). Currently, in Mexico, there is an excellent diversity of sheep breeds distributed according to the productive potential of each breed and the regional climatologic conditions (Herrera Haro *et al*., 2019). In the case of Northwest Mexico, specifically in the Mexicali Valley area, Baja California, the use of Dorper, Katahdin, and Pelibuey breeds is preferred, because these breeds and their crosses show good productive performance, despite the adverse climatic conditions of this region (Avendaño *et al.,* 2004; Macías-Cruz *et al*., 2010).

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There are reports of satisfactory performance of crosses between breeds such as Dorper and Katahdin in sheep under stable conditions in the Mexicali Valley (Macías-Cruz *et al*., 2010).

In Mexico, sheep production is a traditional activity closely linked to the cultural development of communities. In rural areas, sheep breeding is essentially an artisanal and subsistence activity. This production structure has prevented the consolidation of attractive and permanent business alternatives, as well as the establishment of livestock production as a commercially important activity. The low productivity of the species is since that most farms are extensive, with little technology and minimal organization of production and processing.

Sheep production in Baja California is considered a complementary activity to family income and with little use of productive and reproductive technologies (Martínez-Partida *et al*., 2011). Despite its importance, the particular characteristics of sheep production systems in the region are unknown, so it would be essential to carry out a diagnosis of the situation of sheep farming in Baja California in order to establish strategies to enhance the development and productivity of this production system. Therefore, the objective of this study is to describe the characteristics of sheep production systems in the State of Baja California, Mexico, and to identify the main limitations and opportunities for their development.

Material and Methods

The Mexicali Valley is classified as hot dry and very extreme, with a wide temperature range from -6.0 °C to 50 °C and annual precipitation of 540 mm (INEGI, 2017). During the period between April and June 2018, nineteen farms located in rural and semi-urban areas of the Mexicali Valley were visited and surveys were applied to sheep producers (Figure 1). The surveys consisted of 70 items designed to evaluate the characteristics of sheep production systems concerning animal selection and management, feeding, reproduction, sale, and diseases, among others. The information was edited and organized to identify descriptive characteristics of the sheep production systems.

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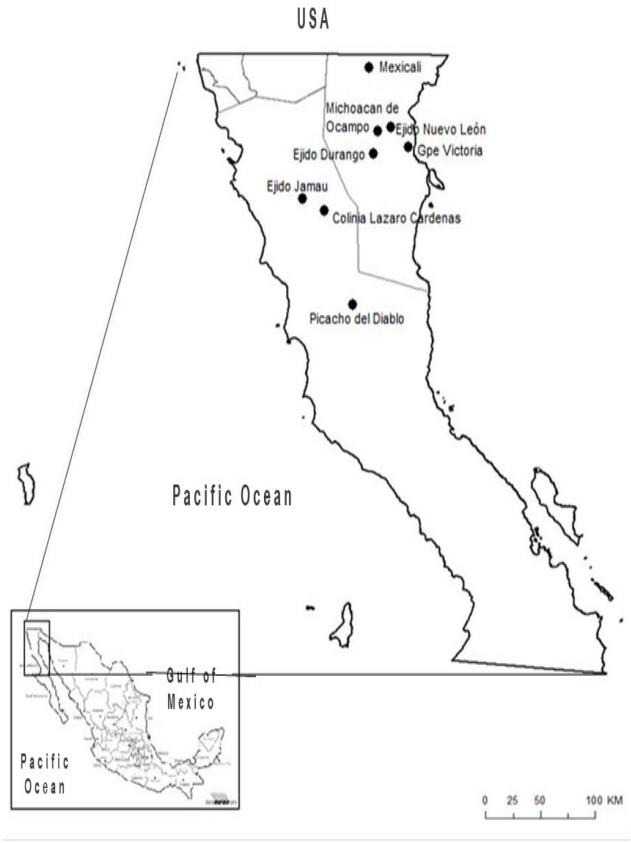

Figure 1. Location of the surveyed sheep farms in the State of Baja California, Mexico.

Also, a principal component analysis was performed to find the best variables to describe the farms evaluated. Twenty-three variables were selected for analysis: herd size (nanimals), veterinary expenses (expenses), event records (records), mating records (records2), estrus synchronization (syncho), number of rams (nrams), use of artificial insemination (AI), duration of mating season (tmating), SINIIGA record (siniiga), extensive or intensive breeding system (fsystem), weaning (weaning), animal stratification (anstrat), animal fattening facilities (fatfacilities), machinery availability (machinery), feed formulation (feetbalace), feed formulation machinery (feedmachiner), forage reserve availability (foragereserve), feed supplementation (feeduppl), growth enhancer use (growthenhan), taildock management (taildock), and government or institutional advice (govadvise). Covariates, eigenvectors, cumulative variances, and principal components were estimated by variables and farms. The analysis was performed using the PRINCOMP procedure of the SAS v.9.4 software (SAS Institute Inc., Cary NC, USA).

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Results and Discussion

Productive characteristics of sheep farms

The number of animals in the flocks ranged from 11 to 400 head; however, the differences in flock management do not seem to be related to flock size, but rather to the priority that each producer gives to livestock production. For example, 100 % of the respondents mentioned sheep production as their secondary activity, with agriculture as their main activity (Table 1). All units carry out both fattening and breeding activities and all raise hair sheep breeds. The most popular breed in Baja California is the black-headed Dorper, followed by Pelibuey, Charolais, and Criolla to a lesser extent. This choice is probably due to the perception that, in general, hair sheep are more tolerant of Baja California's climatic conditions. The hair coat protects the animals' skin from solar radiation and helps dissipate heat by evaporation and convection (McManus *et al*., 2020). Factors such as reflectance, hair length, or number of hairs per unit area influence the ability of animals to adapt to extreme climates (do Prado Paim *et al*., 2013).

In the context of the breeding, 84 % of the producers do not know certainty the purity of their animals. The State of Baja California was identified as the location where most producers purchase their animals. Due to the extreme climatic conditions of the state, these results could suggest some degree of local adaptation to tenth arid conditions of the state. Breeder selection is based on the physical appearance of the animals, especially their sex and body condition. While a formal breeding program could ideally be applied, selection based on the physical characteristics of breeders (or artificial selection) is a practice as old as the earliest civilization. Selection criteria is usually based on the animal's resistance to different factors that condition breeds, such as parasites, diseases, environmental conditions, and even interaction with breeders (Arandas *et al*., 2017). These dynamics eventually result in the adaptation of animals to the condition in which they are found or local adaptation (Ayalew *et al*., 2023; Mariante & Egito, 2002). This is consistent with the already discussed practice of regional animal acquisition.

In terms of data records, 72 % of the farms do not collect any type of productive information, while the rest collect information on characteristics such as mating, calving dates, and birth weight. In this sense, no pattern was found that relates these practices to herd size, type of unit, or the region where the production units are located, except for some zootechnical and veterinary professionals who agree with the best practices in the production units. Only 28 % of the producers keep a record of the identity of the males and females used for mating 67 % of farmers do not use any type of making to identify the animals in their herd. Although genetic improvement is influenced by a variety of factors, such as heritability and genetic variability in the population, much of the success of long-term breeding programs depends on whether the traits targeted for improvement can be measured in the offspring (Haskell *et al.,* 2014; Shook, 1989; Weigel, 2006). Therefore, it is evident that there is a limitation in the possibility of establishing productive improvement programs through the analysis of records and even more so for the implementation of genetic evaluations. Keeping a record of the productive traits of the herd implies an important investment of both economic and human resources, which are not regularly seen as a priority by producers.

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Table 1. Characteristics of the hair sheep farms in Baja California, Mexico.

Characteristic	Category	Percentage
Type	Intensive	31%
	Extensive	69%
Weaning	1-2 months	17%
	2-4 months	33%
Data registration	No	50%
	Yes	28%
	No	72%
Feed consumption estimation	Yes	17%
	No	83%
Know with certainty the purity of the animals	Yes	16%
	No	84%
Cattle Branding	Yes	33%
	No	67%
Segmentation of the herd by sex or zootechnical purpose	Yes	67%
	No	33%
Knowledge of the medication administered to the animals.	Yes	61%
	No	39%
Synchronization of estrus	Yes	11%
	No	89%
Months of rest after delivery	0 - 1	78%
	1 - 2	22%
Supplementation of females at different stages of gestation	Yes	22%
	No	78%

In relation to the equipment available in the production units, 61 % have their agricultural machinery for farms and forage crops, which coincides with the fact that agricultural production is their main economic activity Grazing is the most popular form of sheep production in Baja California. In the Mexicali Valley, pastures are composed mainly of annual ryegrass (*Lolium arundinaceu multiflorum*) and Bermuda grass (*Cynodon dactylon*), while, in the rest of the state. Livestock are fed on wild grass. In general, the animals are released around 6:00 a.m. and guarded at 5:00 p.m. 88 % of the production units have corrals to shelter the animals during the night, where they are supplemented. The variety of feed offered is interesting: being an agricultural region, there is a large availability of agricultural residues, and if they do not meet the requirements for export, they are discarded and used by the farmers. Among these crops can be mentioned a variety

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of products such as radish, carrots, and asparagus, among others. Half of the producers have small amounts of forage in reserve, stored outdoors. Only 17 % of the producers estimate the feed consumption of their flock, which is interesting, since feed costs are mentioned as the most budget-consuming element in sheep farming and in any animal production system in general. In terms of feeding, 72 % of producers reported that they do not modify the content of the diet according to the physiological state of the animals, especially females in the last third of gestation. Only 11 % supplement the cattle in the final phase. It has been widely studied that the diet received by pregnant females influences embryonic development, especially in the last third of pregnancy; malnutrition can cause postnatal disease, slow growth and low fertility in adults (Bloomfield *et al*., 2013), although in some cases it has been pointed out that dietary restriction could favor fetal growth or birth weight of lambs (Vicente-Pérez at all., 2017), even promoting their adaptation to adverse conditions and competition for feed (Fleming *et al*., 2012) the age at which the animal ends the fettering period is between 4 and 7 months of age. Weight is the indicator to put the animal for sale or send it directly to the slaughterhouse. Only 5 % of producers add value by generating meat cuts: the rest sell live to reduce costs and logistics. During this study, the selling price per kilo of live cattle fluctuated between US$1.5 and US$2.6.

Sheep farm reproductive characteristics

An interesting aspect revealed by this study is that most producers keep all their animals together, regardless of sex or age. Only 33 % of producers (mostly small and medium farms) mentioned that they separate females with young from the rest of the flock. In ewes, males are not observed to care for the offspring, so the offspring are largely dependent on maternal care. During lactation, mothers and their offspring have a very close relationship resulting in a large investment of energy, effort, and time on the part of the females, which is rewarded with healthy offspring (Hinch & Brien, 2013). In half of the herds surveyed, calves are not weaned; the remainder are weaned between one and a half and three months of age. The mother-calf relationship is essential for newborns to acquire social skills (Napolitano *et al*., 2008). The duration of the lactation period can vary, it is known that, given the conditions, the offspring can continue suckling beyond 135 days after birth (Arnold, 1979; Basdagianni *et al*., 2019), while in units specialized in milk production, lambs can be artificially fed from birth, after receiving colostrum (Napolitano *et al*., 2008). The timing of weaning coincides with the age at which calves start consuming solid food (Freitas & Ungerfeld, 2016). On the other hand, keeping newly calved females with the rest of the herd could affect the re-establishment of postpartum reproductive activity (Freitas de Melo & Ungerfeld, 2016).

Producers use seven to twenty-five females for each male, which is within the recommended parameters (Aguerrebere, 1981; Delgadillo *et al.*, 2009). Of the total respondents, 70 % do not let the females rest before the next reproduction, and the rest of the producers (30 %) provide them with one to three months of rest for uterine recovery. Eighty-nine percent of producers do not synchronize females prior to mating, and only 11 % synchronize females using progesterone sponges. Insemination is not considered feasible by 83 % of producers, mainly due to the technical, logistical, and economic requirements involved. No producer performs pregnancy tests on females, which directly affects the reproductive efficiency of the herd; as there is a more significant number

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of days open, the number of offspring per year decreases. There is a general lack of knowledge among producers in Baja California about the controlled mating system, which would contribute to the natural synchronization of females. 84 % of producers are not interested in trying artificial insemination, the costs of the necessary equipment and access to specialized personnel are the main causes, and producers believe that the investment that artificial insemination would entail is not profitable. In addition to more controlled reproduction, artificial insemination reduces disease transmission, increases fertility, facilitates genetic improvement, and improves herd control (Shehu *et al*., 2010). This is one of the areas of opportunity where the need to implement training programs for producers becomes more evident, where the advantages of investing time, effort, and resources to optimize herd production are analyzed.

Regarding sanitary management, 28 % of the units have an in-house veterinarian and the rest contract professional services as needed. Concerning medications, 94 % of the producers vaccinate and deworm their herd with ivermectin; however, 39 % of the producers, mostly small and medium-sized, are unaware of the type of medication that veterinarians administer to the animals. The importance of this information has several implications, among them secondary reactions such as the generation of resistance to antibiotics and dewormers that could affect livestock farming in the state in the long term. Expenditure on medicines varies according to production units, as does the dose used, the route of administration, and the duration of treatment. The annual investment amount for medical care varies between $27 and $1,500 (dollars), depending on herd size, with most units in the range of $250 to $600 (dollars) per year. Respiratory diseases were identified as the main health affectation of the herd in Baja California. 67 % of the producers do not detail cattle; those that do, only shed females between one and two months of age. Mortality is recorded mainly in newborn lambs, with 10 % being the average mortality rate among all production units. The death of lambs before weaning is a widely studied phenomenon worldwide. In a study conducted in Minnesota, USA, necropsies were performed on more than 2,000 deceased lambs and the causes of death were found to be, in decreasing order: malnutrition, pneumonia, wounds, and intestinal problems (Refshauge *et al*., 2015; Holmøy, 2017; Yapi *et al*., 1990). Hygiene habits in production units could be an important factor in disease prevalence due to the time interval for cleaning pens, feeders, and drinkers. In this context, it was found that 44 % of the producers remove the substrate from the corrals once every six months and 28 % do it once a year, while the rest wait up to two years to do it, without finding any relation with the size of the herd. The manure from the cleaning of corrals is incorporated into the grazing plots by 78 % of the producers, the rest is piled on land adjacent to the production unit.

On the other hand, the selection criterion for selling animals is body weight (approximately 30 kilograms) in 89 % of the cases and the age of the animal in the rest. Feeding costs were identified as the greatest challenge facing the production system for 50 % of the low-income producers or those who do not have their forage production due to forage transportation costs. The total production of sheep is marketed at the state level, mainly in the city of Tijuana, where it is distributed in the form of typical dishes, so it can be assumed that the lack of market mentioned by the producers is linked to a deficient organization in the marketing chain. Twenty-two percent of the producers attribute other factors such as the scarcity of breeders, low sales prices, and lack of technology and training as a major challenge.

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Interestingly, principal component (PC) analysis revealed that multiple variables are necessary for the definition of Baja California hair sheep flocks (Figure 2). Ten PCs were necessary to explain 98 % of the variance (Supplementary Information Figure a), however, the first three PCs explain 63 % of the total variance. In general, most of the variables had significant eigenvalues for each PC (Supplementary Information Figure b), however, the first component shown in Figure 2a, explains 34.6 % of the variance, aggregating the most correlated variables, expenses, number of animals and number of rams as common and most important descriptors of sheep production systems. These variables showed a consistent pattern of correlation among all CPs (Supplementary Information Figure c).

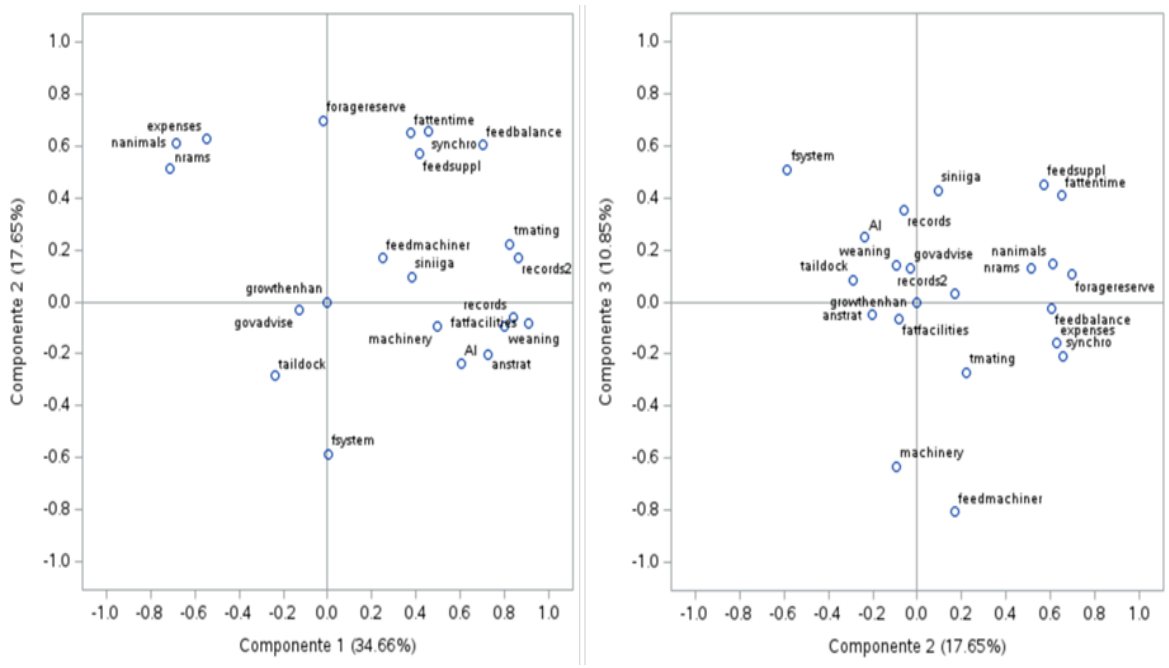

Figure 2. Principal component graphic of the main characteristics that define hair sheep production systems in Baja California, Mexico.

In the same dimension of component 1, at least two clusters are observed, adding for component 2, fattening time, feed formulation, feed supplementation, availability of forage reserves and estrus synchronization. In Figure 2b, it can be observed that component 3 explains 10.8 % in combination with component 1. In this graph, the dimension of component 3 allows distinguishing the availability of machinery in the production systems as defining variables for stratification purposes.

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It is important to note that the present study revealed the heterogeneity of sheep production in Baja California. Animal management is not related to the breed used, the number of animals per flock or the area devoted to the activity; in fact, the production system is hardly discriminated throughout all the CPs evaluated. Some of the findings, such as the origin of the animals or the selection based on phenotypic characteristics, are indicators of a possible local adaptation of the animals that could be used to optimize regional production.

There is a possibility that, upon understanding the advantages, producers would be willing to change some of their flock management habits and start recording data to optimize hair sheep production and increase profitability. The information reported in this study can be used for the establishment of extension and technical assistance programs by governmental or agricultural education agencies, considering that the greatest proportion of limitations is associated with the lack of knowledge of better management in the reproductive, genetic, and nutritional areas. On the other hand, some characteristics, such as the number of animals and expenses, seem to be variables that comparatively and significantly determine the differences between ranches and could be used for characterization and stratification purposes.

Conclusions

The lack of knowledge about the technical, physiological, and metabolic aspects of hair sheep forces producers to manage their flocks empirically. To a large extent, activities in production units follow a trial-and-error model. There is a pressing need to raise awareness about the importance of data recording, mating control, weaning, feeding strategies in the last third of gestation proper nutrition of the flock in general, selection and improvement, and proper sanitary and veterinary management as areas of opportunity for improvement. For stratification purposes, the variables related to the size of the farm by number of animals and the expenses that are closely related are more important. It is evident that there is a need to generate an approach so that professionals, researchers, government, and educational institutions are linked and seek that the production of hair sheep reaches its maximum potential in Mexico.

Authors´ contribution

Authors 1 (ALLR) and 3 (RFG), Methodology development, fund acquisition, writing and manuscript preparation; Author 2 (GMPB), Methodology validation, data management and analysis, writing and manuscript preparation; Authors 2, 4, 5, 6 and 7 (JVA, JMG, JGMM and VMM), Results analysis, writing, revising and editing.

All authors of this manuscript have read and accepted the published version of the manuscript.

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Conflict of interest

The authors declare that they have no conflicts of interest

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