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Advances in the Characterization of Creole Cattle from Nayarit, Chihuahua, and Baja California Sur

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ABSTRACT

Objective: This manuscript aims to contribute to disseminating the research conducted on creole cattle from Nayarit, Chihuahua, and Baja California, as these regions have been the focus of numerous studies. These studies include identifying the areas of opportunity that need to be addressed for the conservation of this zoogenetic resource present in Mexico.

Description: Cattle farming in Mexico began with the arrival of the first bovines from the Iberian Peninsula to New Spain over 500 years ago. These cattle established itself in various regions of the country, developing specific characteristics that have allowed it to adapt primarily to harsh environmental conditions. As a result, these bovines are considered a productive alternative in various agroecological environments to address the challenges of climate change and mitigate the negative effects on the ecosystem.

Limitations: To date, research on the morphological, productive, and genetic characterization, as well as the production environment of Creole cattle in Mexico, remains limited. Therefore, it is necessary to develop studies in this area to contribute to the conservation of this resource and, above all, to identify mechanisms for its rational use that justify its existence in a modern economic and productive environment.

Conclusions. The documentary review conducted to present the current state of research on creole cattle herds in Nayarit, Chihuahua, and Baja California Sur revealed that the studies have primarily focused on productive aspects in various environments. Therefore, it is necessary to encourage research directed towards other productive areas of cattle, such as reproduction, animal health, and adaptation, in order to develop strategies that contribute to the conservation of this zoogenetic resource.

Keywords: creole cattle, zoogenetic resources, Coreño, Raramuri, Chinampo.

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INTRODUCTION

It is estimated that the global population will grow by approximately 2.1 billion people between 2015 and 2050, which will result in a higher demand for animal-derived food [1]. According to the Second Report on the State of the World's Animal Genetic Resources

for Food and Agriculture, the projected production of ruminant meat is between 60 to 75 million tons between 2030 and 2050 for developing countries, which, due to population growth, may be insufficient [1]. Livestock farming impacts highly relevant sectors such as: food security, the economy, highly marginalized communities, and the cultural development of peoples [1].

Animals, particularly Creole breeds, could adapt to numerous adverse environments, including challenging environmental conditions and areas with scarce food resources [1]. Since the arrival of cattle in Mexico in 1521, they have faced environmental conditions such as the humid tropics, arid environments, extreme temperatures, and new diseases [2]. The first cattle populations from the Iberian Peninsula arrived via the port of Veracruz, spreading across the Mexican plains to New Galicia (now the Sierra Madre Occidental region shared by the states of Durango, Jalisco, Nayarit, and Zacatecas) and New Vizcaya (now Chihuahua) [2,3].

After more than 500 years, natural selection has played a crucial role in enabling these animals to develop traits of hardiness and adaptability [3]. Regarding the conservation of these zoogenetic resources, over the past decade, FAO and SAGARPA have initiated efforts to bring together stakeholders involved in livestock production and the identification of genetic diversity. This led to the development of a report that describes the main breeds present in our country [4], including creole breeds. In the country, there are creole cattle herds in different regions, notably in Chihuahua, Nayarit, and Baja California, which have been studied primarily to determine their productive characteristics.

For example, the Coreño Creole breed is suggested as potentially useful as a maternal breed in beef production when crossed with other breeds [5]. On the other hand, the Creole cattle of Chihuahua represent a genetic alternative for sustainable livestock farming, addressing the challenges of climate change and mitigating the degradation of grassland ecosystems, particularly in the arid and semi-arid regions of northern Mexico and the southwestern United States [6]. As mentioned, despite the academic and research work conducted to date, it is important from a zoogenetic resource conservation perspective to promote efforts to characterize the production systems of these herds. This is essential not only for their conservation but also for their utilization within the production chain. Therefore, the objective of this review is to describe the current state of research advances in the different Creole cattle herds in the states of Nayarit, Chihuahua, and Baja California Sur, as these regions have the most documented information. The aim is to identify areas of opportunity that will enable the development of strategies to contribute to their conservation.

Animal Genetic Resources in Mexico

At both the national and international levels, the demand for animal protein is increasing, necessitating the production of many breeds that are sources of genetic diversity and capable of adapting to the planet's changing conditions [1,7].

In 2012, FAO and SAGARPA presented the Methodological Document for Calculating the Livestock Diversity Subindex. From this report, 54 cattle breeds were identified, including 10 Creole breeds: Creole de Rodeo or Rarámuri, Creole del Golfo, Ganado de Lidia, Creole Chinampo, Creole Coreño or del Nayar, Frijolillo, Cuernos Largos, Creole Lechero Tropical, Romosinuano, Mixteco, and Nunkiní [3,4,8]. In this regard, the National Institute for Forest, Agricultural, and Livestock Research (INIFAP) has three Creole cattle populations: Creole Coreño or del Nayar, Creole de Rodeo or Rarámuri, and Creole Chinampo [9]. In 2007, FAO published "The State of the World's Animal Genetic Resources for Food and Agriculture," which warns that zoogenetic resources are being lost at an accelerated rate. As a result, the publication of the Global Action Plan for Animal Genetic Resources for Food and Agriculture and the Interlaken Declaration was carried out. The Interlaken document establishes as a strategic priority the creation or enhancement of *ex situ* conservation programs and justifies this as follows: "*ex situ conservation measures provide a safeguard against losses of zoogenetic resources in the field, whether due to erosion or as a result of emergencies.*

Ex situ measures complement in situ measures, with which they should be linked where appropriate. ex situ collections can also play an active role in strategic genetic improvement programs" [10]. Depending on their ability to produce offspring with favorable characteristics, various sources of animal germplasm (semen, embryos, oocytes, somatic cells) can be cryopreserved and potentially utilized under different schemes depending on the purpose of regeneration [11].

In this regard, the National Center for Genetic Resources (CNRG) of INIFAP was established as a strategy to contribute to ensuring food security in Mexico through the *ex situ* conservation of cryopreserved animal germplasm, which includes semen, embryos, oocytes, and somatic cells [10]. In the area of zoogenetic resources, semen and embryos of Creole cattle breeds Coreño and Chinampo are preserved. Currently, INIFAP is making efforts to conserve germplasm from different Creole cattle breeds to serve as a backup for the populations in the field.

Creole Cattle Chinampo

The Creole Chinampo cattle of Baja California Sur are cattle whose ancestors were introduced to the Baja California Peninsula in 1697, where the various breeds were exposed to the desert and dry environment of the region for many years [7]. It is a small animal, highly resistant to extreme aridity, where it is capable of surviving and reproducing. It is practically the only breed that survives the harsh environmental conditions of the Baja Californian desert, demonstrating the hardiness characteristics of locally adapted breeds; these cattle are also resistant to both internal and external parasites as well as various diseases. Additionally, it is a docile and long-lived animal [9]. These cattle are primarily used for meat, milk production, and work. Chinampo cattle are employed in extensive grazing systems in marginalized areas that are unsuitable for breeding specialized breeds [12]. Espinoza *et al.* (2011) characterized the coat coloration in Creole Chinampo cattle, finding that the predominant coloration was a combination of white and red, followed by solid red, and then black, white with black, white with tawny, brindle or red striped with black, and other color combinations in lower proportions [13]. Regarding coat colorations, there are other designations such as: Overos, Blacks, Bays, Tawny, Mecos (spotted), Yaguané, BON and BOM, Creams, Browns, Rosillos, and Barrosos [3].

In another study, body weight was also characterized, observing values in females ranging from 115±12 kg for one-year-old animals to 255±9 kg for animals over six years old. On the other hand, the body weight of males varied from 130±8 kg in one-year-old animals to 345±15 kg in bulls of four years or older. In general, the average weight of females is 255 kg, and 345 kg for males [14].

Regarding hair length, three categories were determined: 1) short hair estimated at 0.5 cm or less; 2) medium hair from more than 0.5 cm to one centimeter; and 3) long hair of 1.1 cm or more [3].

Concerning the tail tassel, it was classified as follows: 1) short tassel (but not absent, which is a trait, rat tail, associated with thermoregulation in brindle cattle); 2) medium tassel; and 3) heavy tassel, typical of *Bos taurus* of European origin and present in current Spanish breeds; indicating poor adaptation to the tropics [3].

On the other hand, the estrous behavior of the cows was studied, and it was concluded that, in the presence of the male, the cows concentrated their estrous behavior into a shorter period and increased the proportion of estruses with a duration of <8 hours. The presence of the male influenced the onset time of estrus, which occurred in the morning [13].

Regarding the suckling habits of Creole Chinampo calves, it was observed that they follow a pattern similar to that reported in other beef breeds (with higher frequency of suckling during the early morning and afternoon hours). Additionally, the frequency and duration of suckling decrease by 180 days. It was also found that females suckled more frequently than males [15]. In another study, the response to physiological variables (rectal temperature and respiratory rate) related to heat tolerance was compared between Chinampo and Jersey or Holstein cows, concluding that Chinampo cows were more heat-tolerant than Jersey or Holstein [16,17].

A broader study on the genetic characterization of 26 Creole cattle breeds from 10 Latin American countries included five Creole breeds from Mexico [16]. These authors used 19 microsatellites to estimate genetic diversity as a basis for implementing conservation and sustainable management programs. They reported that, in the case of Mexican cattle, Creole breeds from Puebla, Chihuahua, Baja California, and Nayarit formed a cluster with the Creole Cuernos Largos from South Texas, indicating a close genetic relationship between populations from geographically adjacent regions [18].

Creole Coreño Cattle

The Creole Coreño cattle are found in the Sierra Madre Occidental region shared by the states of Durango, Jalisco, Nayarit, and Zacatecas, and are generally managed by indigenous Coras, Huicholes, and Tepehuanos [19]. This cattle is primarily used for the production of cheese and meat for self-consumption, in addition to being used as support animals in agricultural work due to their docile temperament under frequent handling conditions [19].

In 1982, a Coreño Creole cattle herd was established with the support of INIFAP and the Board of Trustees for Livestock Research (Patronato para la Investigación Pecuaria - PAIPEME) of organized cattle producers [3]. This herd originated from the acquisition of 50 cows and 10 bulls from the Sierra Madre Occidental region, which were settled at the El

Verdineño experimental site of INIFAP, located in the municipality of Santiago Ixcuintla, Nayarit, at 21° 42' north latitude and 105° 07' west longitude, with a tropical climate, an altitude of 60 meters above sea level, and an average annual temperature and precipitation of 24 °C [20]. With the establishment of this herd, studies began on the productive, reproductive, and genomic characterization of Creole Coreño cattle, seeking to assess the potential of this breed. For more detailed information on these investigations, refer to Martínez *et al.* (2021), who conducted a comprehensive review on the characterization of Creole Coreño cattle. Therefore, only notable points are addressed here [19,21].

In reproductive characterization, comparative studies between Guzerat heifers and Creole Coreño heifers in tropical conditions have shown that Creole Coreño heifers had their first calving earlier (1,392±38 days) compared to Guzerat heifers (1,655±31 days) [22]. This indicates greater reproductive efficiency in Creole Coreño heifers compared to Guzerat, as heifers that calve at a younger age produce more calves during their productive lifespan [23]. Furthermore, it was found that Creole Coreño cows had higher rates of conception, calving, and weaning (60%, 59%, and 52%, respectively), compared to Guzerat cows (46%, 42%, and 38%, respectively) [24]. On the other hand, superovulation studies in Creole Coreño heifers and cows demonstrated that it is feasible to use reduced doses of FSH (140 to 200 mg) without affecting the response to superovulation or embryo production [25]. In this same study, embryo production ranged from (1.1±0.7 to 2.9±0.7), indicating that Creole cattle, on average, have a lower production of transferable embryos compared to other breeds such as Nelore (10.3±10.3) and Red Angus (5.9±1.1) [25,26,27]. This may be due to endocrine failures caused by ovarian overstimulation resulting from superovulation protocols when applied to small-sized females; additionally, older females show decreased embryo production [25].

On the other hand, in terms of productive characterization, the production and composition of milk have been evaluated, revealing lower total and daily milk production in Creole Coreño cows (805 kg and 3.90 kg, respectively) compared to Guzerat cows (949 kg and 4.5 kg, respectively) [18]. This could explain the lower weaning weight of Creole Coreño calves (153.50 kg) compared to Guzerat calves (177.42 kg) [5].

Research conducted at INIFAP suggests that this cattle breed may play a significant role as a maternal breed in crossbreeding with bulls of other breeds within the context of commercial beef production. This is since females of this breed exhibit better fertility and maternal ability, which can translate into an increase in weaned calf weight per cow [5,28]. Additionally, it has been observed that carcasses from steers derived from Creole Coreño cows, Creole Coreño × Guzerat crosses, and Guzerat × Creole Coreño crosses inseminated with Angus bull semen are of good quality and performance compared to steers derived from Guzerat cows inseminated with Angus bull semen [5].

In the context of physical characterization, there is limited information regarding morphological measurements and phenotypic characteristics of Creole Coreño cattle. Available data include birth weight (29 kg) and weight at 3.5 years (500 to 550 kg) [3]. Regarding coat color, Alba (2011) describes 28 animals observed at El Verdineño, and photos of animals at Mesa de Nayar, finding 10 bayos (3 hoscos, 2 zainos, one with a white breastbone, 2 with a star, and 2 with white and speckled arlequin patterns of the base color), 2 reds (both with a star and white belly), 1 brown (with a lighter dorsal stripe), 1 barcino (or meco), 7 overos (2 red, 3 black, and 1 bay), 1 BON (partially dominant white with black ears), 1 with a black lateral color, 2 blacks (one zaino and another with white spots on the belly), and 2 barrosos (typical black dilution) [3].

Although limited information has been generated regarding these cattle, the Association of Mexican Creole Cattle Breeders (Asociación de Criadores de Ganado Criollo Mexicano, A.C.) states that the Coreño Creole cattle meet the phenotypic description of Creole cattle in Mexico [29].

Additionally, molecular characterization studies of Coreño Creole cattle have been conducted. In a study on genetic diversity using SNP markers in Coreño Creole cattle from three locations in Nayarit —El Nayar, La Yesca, and Santiago Ixcuintla— it was found that they maintain high levels of genetic diversity and that the El Nayar population is distinct from the other two according to the estimated molecular coancestry, allowing them to be considered as two separate populations [30]. Another genetic diversity study using microsatellites showed that there has been considerable genetic differentiation among Creole cattle populations from Nayarit, Chihuahua, Durango, and Guerrero. Additionally, it was found that there is no evidence of *Bos indicus* influence in the Creole cattle from Nayarit [31], suggesting that it could be considered a well-defined Creole breed.

Unfortunately, a decrease in these cattle populations is estimated, which may be attributed to the introduction of *Bos indicus* breeds into the region [32,3]; currently, the status of Coreño populations is unknown.

The livestock industry in Chihuahua thrived with cattle descended from breeds that arrived from Spain, which had the ability to adapt to different environmental conditions and provided multiple services (meat, milk, draft power, hides, and tallow) to the growing population [30,31]. However, due to the increased demand for beef in the United States and the demarcation of lands in the region, the introduction of specialized meat breeds began in the late 19th century. This led to the decline of the Creole cattle population in Chihuahua, until it practically disappeared from regions where the main ecosystem is grassland [33,34].

Creole Cattle of Chihuahua

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At the end of the 90s, the Autonomous University of Chihuahua (UACH) [34] and the Experimental Ranch La Jornada (ERL) of the United States Department of Agriculture (USDA) in collaboration with New Mexico State University, in 2005 [33], decided to introduce a herd of Creole cattle, selected directly from the Sierra Tarahumara, not only with the aim of preservation but also for research on grazing behavior, economics, as well as productive, reproductive, and meat quality characteristics [33,34]. All this was with the purpose of demonstrating the characteristics of the Chihuahua Creole cattle that would allow its introduction into the beef production system, either as a pure breed or in various breeds.

Quintana-Gallegos and collaborators (2016) mention that the main advantages documented for the Chihuahua Creole cattle compared to European cattle specialized in meat production are: their small size, which implies lower nutritional requirements to meet their physiological needs [38], and their different grazing habits or patterns, which give them the ability to meet those nutritional requirements with less negative impact on the ecosystem [36] (Roacho-Estrada, 2023).

Quintana-Gallegos *et al.* (2016) found that F1 Angus × Creole cows in the early lactation stage had a lower weight compared to Hereford × Angus cows, as analyzed by the regression equation ($0.18x+328$ and $-0.33x+383$, for the former and latter, respectively) of body weight (kg) in the 70 days postpartum (day zero) [35]. Additionally, they observed that the concentration of β-hydroxybutyrate (an indicator of lipid catabolism) did not change over the days during the last third of gestation and early lactation (0.0001 ± 0.0002 mmol/L/d), whereas in the case of Hereford × Angus cows, an increase was observed ($P<0.01$; 0.0011 ± 0.0002 mmol/L/d) during the same period. These results indicate that the lower weight and advantages in grazing habits of Angus × Creole cows make mobilization more efficient and/or reduce excessive loss of energy reserves. During periods of lower forage availability and quality, Creole cows have more extensive exploration patterns compared to the Angus breed (6.7 ± 0.56 and 5.4 ± 0.56 km/d for Creole and Angus, respectively).

On the other hand, during periods of higher forage availability and quality, there are no differences between the two breeds. Additionally, the slope traversed, and the elevation reached by Creole cows were greater compared to Angus cows, regardless of the season [36]. The study found that European cattle spent more time grazing in open medium grassland compared to Creole cattle (10.7 *vs.* 9.9 h d^{-1}). Both breeds showed increased grazing time during periods of food scarcity. The grazing patterns and diet diversification generate differences in the ruminal microbiota of the animals; this was corroborated by Maynez-Perez *et al.* (2021) through a comparative metagenomic analysis of the 16s ribosomal gene between Creole and European cattle [37].

In the United States of America, a specialized market has been created for the meat of these animals [38]. However, such a market does not exist in Mexico. In this regard, the UACH has proposed a three-breed crossbreeding strategy, where F1 Angus × Creole cows are used as dams on the range, as it has been proven that the ecological behavior advantages of pure Creole are retained in these F1 cows.

Finally, these cows would be crossed with a terminal meat breed, and all offspring would be destined for supply [39]. This study shows how Piedmontese × Angus × Creole animals were highly competitive in terms of slaughter weight, carcass, and meat characteristics. An interesting aspect is that the meat from animals with a Creole component had less cutting effort (0.92 ± 0.18 kg force compared to Hereford × Angus and 0.78 ± 0.2 kg force compared to Piedmontese × Hereford × Angus). This trait had already been observed in meat from pure Creole animals, meaning that Chihuahua Creole animals produce tender meat (3.75±0.08 kg force) [40].

Regarding reproductive characteristics, a study conducted in Ciudad Juárez, Chihuahua, found that the majority (73.3%) of Creole females exhibited two waves of follicular development per cycle, demonstrating a good ovarian response. Although the size of the corpus luteum and follicles were smaller (13.0±1.0), the hormonal levels were ideal for pregnancy (6.5±0.1 ng/mg) [41]. The semen from Creole males in a confined system showed individual motility above 80% and blood testosterone levels above 3.8 ng/mL, with these values remaining constant throughout the year. In contrast, European breeds exhibited a decrease in individual motility and testosterone levels during the hot season, reaching values of 58% and 2.8 ng/mL, respectively [42].

In a grazing system with low inputs, the levels of mRNA PLCZ1 (related to fertility percentages) in the sperm of Creole bulls tended to be higher compared to Angus bulls both in winter and summer. These levels were 5.3 times higher ($p<0.05$) in winter than in summer. This indicates that environmental conditions, availability, and quality of forage can affect biochemical and molecular processes related to fertility traits and reproductive efficiency. However, further studies are needed in this regard.

Colloquially, the resistance of Creole animals to diseases has been mentioned, although studies on Creole cattle in Chihuahua are virtually nonexistent. Despite this, high diversity in the BoLA-DRB3.2 gene has been observed, and some allelic variants that had not been previously reported in other populations have even been identified [43,44]. This suggests that this cattle breed may have a higher potential to respond immunologically to a broad range of antigens.

On the other hand, as a result of combined efforts, INIFAP together with the Mexican Association of Creole Cattle Breeders (ASOCRILLO) established the Creole cattle herd at the La Campana Experimental Ranch.

In this regard, an evaluation of heifers during the growth stage showed an average daily weight gain of 680 g per day, 800 g during the development stage, and 680 g per day during finishing. As for feed conversion efficiency, the rates were 8.8, 9.4, and 8.9, respectively. In this study, the average slaughter weight was 271 kg, with a hot carcass yield of 52.70% and a cold carcass yield of 52.30% [45]. Regarding the physicochemical characteristics of the meat, *e.g.*, the luminosity was 47.7, the redness tendency was 15.5, the yellowness tendency was 17.5, water-holding capacity was 64.7%, and pH was 5.7. These values do not allow for discrimination between meat from commercial cattle and meat from Creole cattle [46].

Recently, at the La Campana Experimental Ranch, research activities with this herd have resumed. One of the main areas of interest is studying the composition of the rumen microbiota and methane emissions, in addition to analyzing the expression of genes related to heat stress, as has been done with other herds at INIFAP.

The objective of this manuscript was to present the research developed on Creole cattle, particularly in the states of Baja California, Nayarit, and Chihuahua, with the aim of identifying areas of opportunity that remain pending, such as associations between grazing patterns, rumen microbiota findings compared to other breeds, disease resistance, etc. The latter, by utilizing current molecular tools and omics sciences, studies in metagenomics, transcriptomics, etc., could be conducted to make associations with productive parameters. This would contribute to a better characterization of this resource in Creole cattle in Mexico and provide suggestions for its conservation.

CONCLUSIONS

Locally adapted zoogenetic resources are generally neglected in terms of conservation efforts, making them vulnerable and at risk of disappearing. This review has presented the documented information on Mexican Creole cattle, demonstrating that there are many opportunities, particularly from a productive aspect, as some herds have been more extensively characterized. Therefore, it is essential to support the formation and/or strengthening of specialized study groups for them *in situ* and *ex situ* monitoring and conservation. Prioritizing the genetic value of these resources through cryopreservation of animal germplasm and storage in germplasm banks is crucial. In this context, research generated by INIFAP, and other educational institutions is vital for the conservation and utilization of this zoogenetic resource in Mexico, considering factors such as population size, genetic diversity, productive behavior, and the characterization of the production system.

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