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Development of an application for the differentiation of the genus of (*Centronyx bairdii*) **BAIRD'S SPARROW** based on an artificial neural network

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Regionalization of the artisan fisheries in Baja California Sur, Mexico using the social criteria of the fishing cooperatives

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ABSTRACT

Objective: To generate a proposal for regional categorization (regionalization) of fishing villages in Baja California Sur, Mexico, following social and economic fishing criteria.

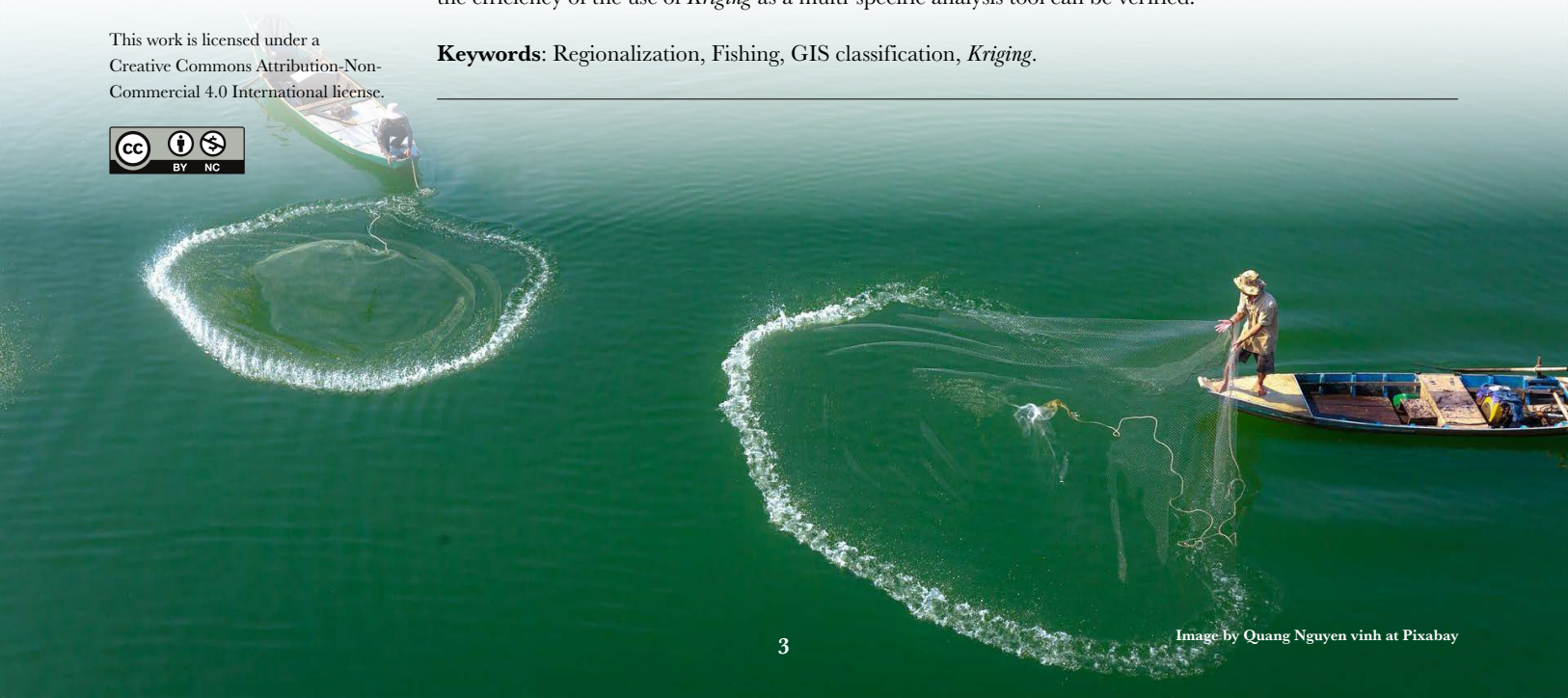
Design/Methodology/Approach: Socioeconomic data on fishing in Mexico are analyzed. This regionalization uses data collected in the field on the conditions of artisanal fishing cooperatives in Baja California Sur, Mexico (BCS). Subsequently a geo-referential methodology linked to a database was applied. Database was re-categorized by nominal or ordinal statistical values, as it was the case for each. ArcView 3.2 Geographic Information System (GIS) was used to obtain the geo-referenced classification. Then, a geostatistical analysis derived from the *Kriging* tool was applied.

Results: We obtained a regional classification of fishing in Mexico, displayed in maps with vector data. The regionalization is of a social nature, it shows a classification of cooperation level at artisanal fishing cooperatives in the fishing towns of northern Baja California Sur (BCS).

Limitations/Implications: The lack of socioeconomic data on fisheries in Mexico has been an important limitation to generate a more accurate regionalization of the Mexican coasts.

Findings/Conclusions: Analyzing the social and organizational factors of fishing is necessary for the understanding of marine socio-ecosystems in Mexico. These criteria joined to the use of computer tools allowed the regional geo-located categorization of areas with similar characteristics. Whit the use of this methodology the efficiency of the use of *Kriging* as a multi-specific analysis tool can be verified.

Keywords: Regionalization, Fishing, GIS classification, *Kriging*.



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INTRODUCTION

The services that nature provides to society can be classified as provisioning, regulation and cultural (Cervantes and Ramírez, 2012). Each of these services is always approached from the utilitarian point of view as human beings, which organically alters the natural biological system of ecosystems to obtain profit and commodities.

The State of Baja California Sur (BCS) is characterized by having the widest coastline in the entire Mexican Republic with 2,131 km in length (INEGI, 2010) which, together with the great diversity of marine fauna, many of them usable in fishing extraction and with a high economic value, give the state a great fishing potential. Fishing and activities that take place at sea are the main economic activity of this state.

The level of social organization in which the fisheries sector operates is a key to make the better management projections and operations that research institutions may offer. The relationship that exists between nature and society is undeniable, since they are not independent entities, but on the contrary, "humanity depends on nature and the supply of services that nature generates" (Cervantes and Ramírez, 2012).

The case-study is delimited to ocean bank fisheries, it aims for a regionalization based on those differences in social organization found among the operative artisanal fisheries in the northern zone of the western and eastern coastlines of the state; to reassess the importance level that social organization generates in the extractive activity of fishery products in the area.

Regionalization criteria in this study is defined by the level of communal organization that artisanal fishing cooperatives (Sociedades Coorperativas de Producción Pesquera - SCPP) show, particularly those found on the coastline of the northern zones of BCS state.

MATERIALS AND METHODS

Regionalization is based on social aspects that have a clear impact on the geographical environment in which the economic population of this sector operates. As they are people who have their lives in common on land, but their job object is at sea, it is necessary to observe the organizational procedures that they perform in order to carry out their common activity.

In the first instance, the entire organization and social life of coastal fishermen is centered on the community, on the land where their daily life occurs. The organization, transfer, marketing, and management of fishery products are made on mainland. Because of that, organizational and community impacts reflect on the infrastructure actually existing in town. This is, the settlement of a given SCPP is a perfectly locatable geographical point on the mainland; where the effects of their organization forms, being legal or informal, will have immediate repercussions on their population settlement, the fishing village.

Socio-economic data of fishing villages were compiled by public participation methodologies, which provide technical certainty and reduce privileged access to the process (SEMARNAT, 2006; Espejel *et al.*, 2006). Likewise, these participatory processes can incorporate the local and traditional ecological knowledges, as complementary sources of information (Espinoza-Tenorio *et al.*, 2010; Moreno-Báez *et al.*, 2010).

Therefore, through an on-site participants survey at each locality in the case-study and a Likert-type questionnaire, the conditions of basic services, road communications, and marginalization degree of housing infrastructure were defined by members of the community.

Likewise, through participant observation processes, data on the human settlement of each port were obtained. Observing the quality of basic services, the apparent wealthy level of the community, the purchasing power that at first glance stands out in the area; as well as the overall standard of living shown by the locality. These data complement those collected through the Likert questionnaire, and together render an accurate image of the cooperative situation in the study area.

Afterwards, the operant fishing cooperatives were located with GPS in each town, to generate a geospatial database compatible to visualize in ArcView 3.2 (Figure 1).

The GIS database input were those field collected data. A questionnaire was applied in order to record 18 cooperative indicators (Table 1) in the SCPP of these localities: Puerto San Carlos, Puerto Adolfo López Mateos, Punta Chale, Punta Abreojos, La Bocana, San Juanico, El Cardón, Estero el Dátil, Guerrero Negro, Punta Chivato, San Juaniquito, El Saucito, Arroyo Hondo, Santa Inés, and La Ventana, among other towns in the BCS state. These indicators are the foundation for the study delimited by fishing cooperatives. They are based on the knowledge, understanding, and practice of cooperative values, as well as on the economic and social impact that the organization has on the community.

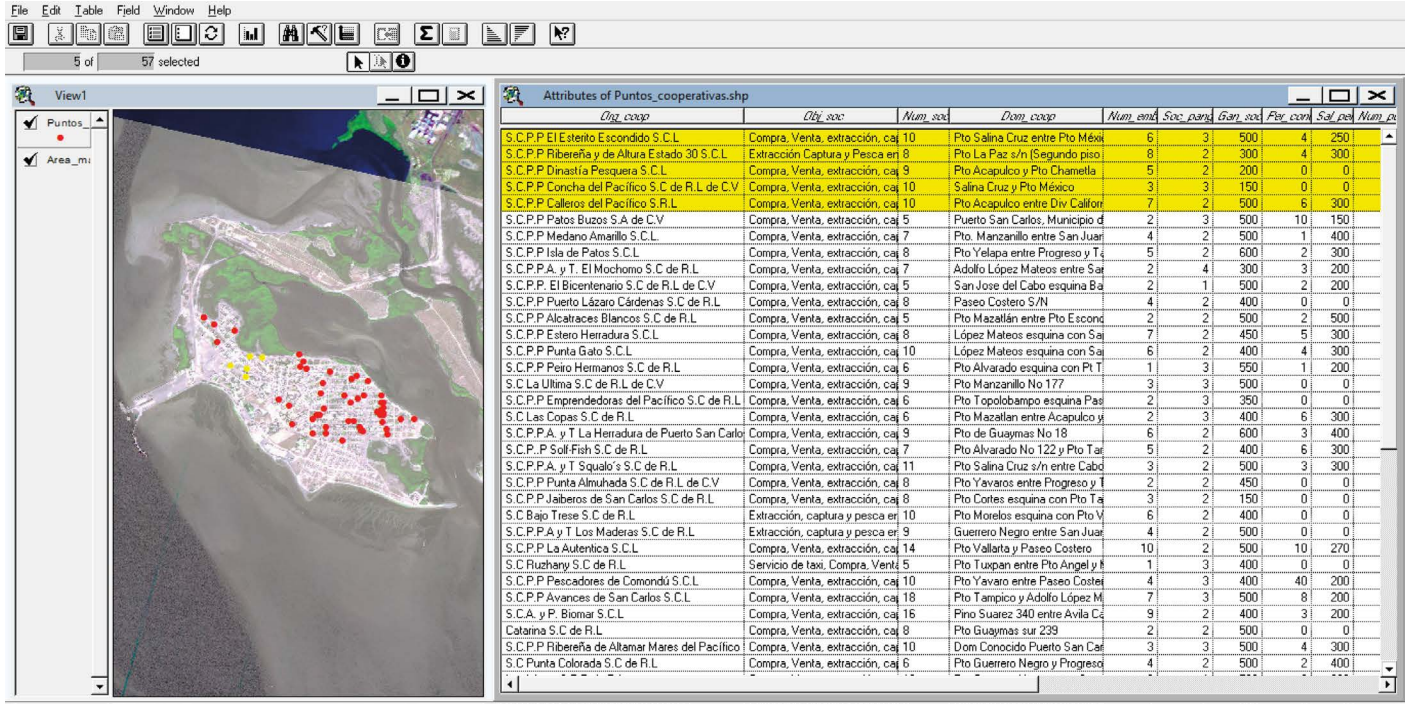

Figure 1. The locality of Puerto San Carlos, BCS, Mexico, georeferenced via its SCPP database.

Table 1. Cooperative indicators collected in the surveys in different towns of Baja California Sur, Mexico.

Organization starting-up	Teamwork
Work plans	Group
Partners	Evaluation of results
Ranked knowledge	Commercialization
Link with institutions	Extraction
Studies / culture	Supports
Management	Increase in infrastructure and equipment
Organization of activities	Individual benefits
Decision making	Community benefits

This study includes cooperative participation as human labor, fair and cooperative, equitably redistributed among all members of the community. This is made to achieve increase in the quality of life of members and extended to the population where the fishing cooperative is located.

The process of value estimation given to each locality was obtained through this formula:

$$V = \frac{\sum_1^n \frac{(P + C + G)}{3}}{n}$$

Where: V=Obtained Value of the level of cooperative participation in each fishing locality, categorized into three classes (high=3, medium=2, low=1); n=The number of cooperatives visited in each of these localities; P=Average value of the knowledge and practice of the cooperative values and principles, as expressed by the cooperative partners; C=Wealthy level, as observed within a range (low, medium, and high), that was classified based on the housing and utilities infrastructure at the locality; G=Average value of profit on the fishing product extracted by fishing partner in each locality.

After obtaining the value of V for each locality, a geostatistical Kriging interpolation methodology (Bosque, 1997) was applied, which acts under spatial delimitation algorithms based on the categorization and prediction of polygons built based on points of similar value (Villatoro *et al.*, 2008) and geospatial proximity assuming a correlated point distribution (García *et al.*, 2010; Murillo *et al.*, 2012; Paredes *et al.*, 2013). Output is then, a regionalization map of the artisanal fishing cooperative participation (Figure 2).

RESULTS AND DISCUSSION

A clear and contrasting difference was found between the fishing communities of the North Pacific region along the western coast of BCS, and the communities located in the southern area of the western coast.

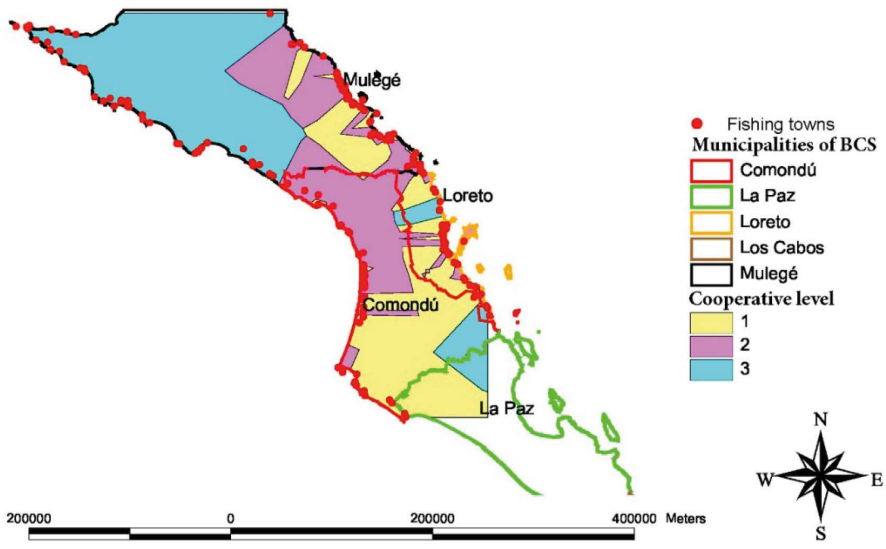

Figure 2. Regionalization by level of cooperative participation in artisanal fishing communities in Baja California Sur, Mexico.

The region classified as **High=3 Cooperative participation** has localities that host a minimum of 1 and a maximum of 3 SCPPs. These are large cooperatives with a large conglomerate of members. The fishing products obtained here are of great commercial value, identified species such as abalone, lobster, shrimp, squid, flake and geoduck. The marketing of these products is carried out directly by the cooperative without the need for intermediaries, and they manage to reach international markets.

The level of infrastructure of the organization is wide, it is shown in large buildings that function as offices and warehouse. They have a large vehicle park with which they deliver to the markets where the international costumer expects the product as fresh as possible to make shopping as living products.

The level of quality of life in the fishing villages in this region is high, they have all basic services, electricity, water, telephone and signal for mobile phones. In addition, housing shows their high value, people's property there is classified as luxury items. But it is this which shows the great economic capacity that a well-organized management, by this type of stakeholders can offer for the fishing community development.

The opposite occurs in the area categorized as **Low=1 Cooperative participation**. In these locations there is a highly concentrated population density, a lot of SCPP are merely family business with little involvement of active partners in each Organization and cooperating participation is nonexistent and decisions are pertaining to the commissariat. There is great competition between existent SCPPs for fishing and sale spots and the product; consequently, fishermen become victims of business intermediaries who buy the product on the beach and devalue the sale.

The localities have a well-structured road network with asphalt layer, basic services are available to the entire population, housing is of medium-scale, and opportunities to obtain a better quality of life through artisanal fishing are less.

In the region classified as **Medium=2 Cooperative participation**, an advanced cooperative organization with community principles and values is shown. The number of cooperatives that appear in each locality ranges from one to two. And access to the community, and the commercialization of the fishing product are undergoing improvement, and certification processes, respectively. That is, they are seeking to trade directly with international markets.

In addition to this, those localities extract certain species targeted as high commercial value without governmental permission. This is relevant because it demonstrates a weak linkage, just emerging with government institutions. This area is undergoing the process of consolidating as high cooperative participation.

CONCLUSIONS

Regionalization of fisheries in the northern coast of Baja California Sur, Mexico, under social and cooperative criteria, allows us to observe the benefits that the good practices of cooperative participation can generate. The main indicators that allowed regionalization were the organizational level; the infrastructure of the locality; the purchasing power of the fishermen; their legal status (species extraction permits and credentials for the boats); the management capacity; and link with the institutions and other organizations; as well as the practice of cooperative values by the organization and coastal fishermen. The high cooperative participation is demonstrated in the communities located northern in the state. Communities such as Guerrero Negro, Punta Abreojos, and La Bocana. It is characterized by levels of extensive management, international marketing, well-grounded housing infrastructure and labor; their cooperative values are well-known and well-practiced by coastal fishermen. The medium cooperative participation is characterized by the coercive capacity of partners, which it has been achieved due to excellent organization. However, the relationship with the institutions, the acquisition of fishing permits, and the credentials of the boats takes more time than which would be expected. It is concluded that management and legal permits processing capacity are impaired. The low cooperative participation is located in the southern part of the study area. Towns like Puerto San Carlos and Puerto Adolfo López Mateos show a lacking sense about cooperative participation. The level of social organization is low because there are many those so-called family cooperatives. They are worked on an individual basis; commercialization of fishing products and marketing are carried out on the beach. In addition, the competition among cooperatives is high. It becomes necessary to set up basis to analyzes with a systemic approach that combine the multiplicity of quantitative and qualitative variables in the fishing operations context.

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Production and competitiveness of Mexican floriculture

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ABSTRACT

Objective: To analyze the international commercialization competitiveness of the main flowers grown in Mexico compared to United States of America (USA).

Design/methodology/approach: The cumulative growth rate of the production variables of the main flowers cultivated in Mexico from 2000 to 2020 was calculated. The country's flower trade balance was evaluated. The revealed comparative advantage index (IVCR) of the Mexican floricultural sector was compared with the American IVCR.

Results: Mexican floriculture has expanded in the last two decades; therefore, the 2000-2020 cumulative growth rates of the production variables in most of the flowers studied were positive. It is also a high-income activity. Although only 10.11 thousand ha are used by this sector, the four species of flowers analyzed had a 5.51-billion Mexican pesos production value (2020). Likewise, its trade balance has been in surplus and, in most of the years analyzed, its balance was greater than 90% of the value of exports. In addition, it is competitive in the international market: in 2020, the IVCR of Mexican flowers in the US market was 0.96 and, in the overall period of this study, it has been greater than 0.8.

Study Limitations/Implications: Changes to the Harmonized System Codes hinder the evolutionary analysis of the tariff codes. The IVCR determines if the national market is competitive or not in the international market, but it does not establish which factors would provide competitiveness to the country.

Findings/Conclusions: Floriculture in Mexico has increased in the last two decades. The production value of all the flowers studied increased during the period analyzed. In general terms, the Mexican floricultural market is competitive in the international market; additionally, the different Mexican flowers included in this research have a competitive advantage in the US market.

Keywords: production, trade balance, revealed comparative advantage index, growth rate.

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INTRODUCTION

Floriculture in Mexico is a high-income activity that creates more than 250 thousand direct jobs and almost a million indirect jobs. Women are in charge of 60% of its production (SADER, 2021). This is a very important activity in rural areas of the country. According

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to the production value, the main flowers harvested in the Mexican market in 2020 were chrysanthemums, roses, sword lilies, and carnations with 1.91 billion, 1.79 billion, 1.13 billion, and 661.34 million Mexican pesos, respectively (SIAP, 2021).

In 2020, 3,203.35 ha were used to plant and harvest chrysanthemums, obtaining 12.522 million grosses. The average yield was 3,909.33 gross per ha and the average rural price obtained by the floriculturist was $152.97 per gross. The main chrysanthemum-producing states were the State of Mexico (11.73 million grosses), Puebla (673,000 grosses), and Morelos (100,870 grosses) (SIACON, 2021).

In the same year, roses were planted and harvested in 1,741.90 ha and 1,654.90 ha, respectively, obtaining 9.08 million grosses of this flower. The average yield was 5,488.32 gross per ha and the average rural price obtained by the floriculturist was $197.82 per gross. The main rose-producing states were the State of Mexico (7.08 million grosses), Puebla (655.90 thousand grosses), and Morelos (583.18 thousand grosses) (SIACON, 2021).

Also in 2020, 4,558.32 ha were used to plant and harvest sword lilies, obtaining 5.11 million grosses. The average yield was 1,121.55 gross per ha and the average rural price obtained by the floriculturist was $222.28 per gross. The main sword lily-producing states were Puebla (2.08 million grosses), State of Mexico (1.79 million grosses), and Morelos (595.39 thousand grosses) (SIACON, 2021).

And finally, in the same year, 609.9 ha were used to plant and harvest carnations, obtaining 4.46 million grosses. The average yield was 7,317.28 gross per ha and the average rural price obtained by the floriculturist was $148.19 per gross. The main carnation-producing states were the State of Mexico (4.02 million grosses) and Baja California (439.86 thousand grosses) (SIACON, 2021).

The Mexican flower export amounted to $44.39 million dollars (January-August 2021), a significant increase compared to the total value of 2020, which was $35.96 million dollars (SIAVI, 2021). However, the Consejo Coordinador Empresarial of the State of Mexico reported that, in the same year, sales dropped by 80% in the flower-growing zone of the state, as a consequence of the COVID-19 crisis (El Universal, 2020). The main cause of the impact on the sector was the imbalance of the supply chains, as a result of the quarantine in many regions of the world (WB, 2020). The floriculture importance for Mexico lies in the foreign currency generation and the employment demand in the country's rural areas. Therefore, the trend in the production variables of the main flowers harvested in the Mexican market should be evaluated, in order to determine if the activity is competitive at an international level.

The objective of this research was to compare the international commercialization competitiveness of the main flowers grown in the Mexican market with the USA, which is the main commercial partner of Mexico in floriculture. In addition, the production variables behavior of chrysanthemums, roses, sword lilies, and carnations from 2000 to 2020 was studied, in order to establish these crops' trends.

In 2020, roses accounted for 19.87% of the total value of Mexican flower exports, chrysanthemums, 5.36%, Madonna lilies, 5.01%, carnations, 1.87%, and other fresh flowers, 54.59%. Therefore, the competitiveness of Mexican floriculture in the international market

was evaluated with regard to these groups of flowers, which together accounted for 86.70% of the value of the country's flower exports (SIAVI, 2021).

MATERIALS AND METHODS

Quantitative research, with a longitudinal or evolutionary scope, was carried out (Hernández *et al.*, 2010). We studied the behavior of the production variables for the 2000-2020 period, while the Mexican market competitiveness in the international flower market was analyzed for the 2008-2020 period, taking into consideration the modifications that the flowers tariff codes underwent in July 2007.

The production variables values of the main flowers harvested in the Mexican market (chrysanthemums, roses, sword lilies, and carnations) were obtained from the Sistema de Información Agroalimentaria de Consulta (SIACON). The following variables were analyzed: sown and harvested area (ha), yield (gross per ha), average rural price (pesos per gross), volume (gross), and production value (thousands of pesos). The cumulative growth rate of these variables from 2000 to 2020 was estimated, using the following formula (Pérez *et al.*, 2010, Rivera-López and Gutiérrez-Hernández, 2019):

$$t_{t,0} = \left(\frac{x_t - x_0}{x_0} \right) 100$$

Where: $r_{t,0}$ is the percentage growth rate of each production variable analyzed; x_t is the value of the variable in the year 2020; x_0 is the value of the variable in the year 2000.

The Mexican flower trade balance was estimated based on the statistics of tariff code 0603 "Flowers and buds, cut for bouquets or decorations, fresh, dried, bleached, dyed, impregnated, or otherwise prepared". The data were obtained from the Sistema de Información Arancelaria Vía Internet (SIAVI) and the study period covered from 2008 to 2020. The independent variables in this section were the export and import values, for both of which the American dollar was used as the unit of measure.

For the analysis of the competitiveness of Mexican flowers in the international market, the SIAVI database was consulted. The overall competitive advantage of the Mexican floricultural sector was estimated based on tariff code 0603. Subheading 11 was used to analyze roses, 12 for carnations, 14 for chrysanthemums, 15 for Madonna lilies, and 19 for other types of fresh flowers —including sword lilies, baby's breath, sea lavender, gerbera daisy, English daisy, anthurium, bird of paradise, etc. As a consequence of the modifications made to tariff code 060310 ("Frescos") in July 2007, the analysis period of the Mexican flower competitiveness was carried out from 2008 to 2020.

The revealed comparative advantage index (IVCR) was proposed by Balassa (1965), with the aim of establishing whether or not the specialization of its international trade gives a country any competitive advantage. A given point (year) was taken as reference (Ramírez-Padrón *et al.*, 2018). The IVCR of the different flower types traded in the international market was estimated based on the trade flows of Mexico with its main trading partner

for each flower; the following general formula was used (Durán-Lima and Álvarez, 2008; Rivera *et al.*, 2020):

$$IVCR_i = \frac{X_{ij} - M_{ij}}{\left| X_{iw} + M_{iw} \right|}$$

Where: $IVCR_i$ is the revealed comparative advantage index of each type of flower; X_{ij} is the value of the exports of each type of flower from Mexico to market j; M_{ij} is the value of the imports of each type of flower by the Mexican market from country j; X_{iw} is the value of the total exports of each type of flower from Mexico to the world market (w); M_{iw} is the value of the total imports of each type of flower in the Mexican market from the rest of the world (w).

RESULTS AND DISCUSSION

Mexican floriculture has expanded in recent years, as evidenced by the positive cumulative growth rates achieved by the main flowers produced in the country from 2000 to 2020. The production value of the four studied flowers experienced a considerable increase during the analysis period. The same phenomenon has been recorded for the average rural price of Mexican flowers.

Most of the area used to sow and harvest flowers in Mexico is used for sword lilies; in the study period, these variables increased more than for other flowers (Table 1). The area planted and harvested with roses in the country has experienced a positive trend and increased by more than 450% in the last two decades (Table 1). A worrisome situation is the decrease in the average yield of the chrysanthemum production; during the analyzed period, it contracted by 25% regarding the value of the year 2000 (Table 1). Finally, the production of carnations in the country has a negative trend, although the average rural price of this flower has increased by more than 300% (Table 1).

Mexican floriculture is a high-income activity. In 2020, the four species of flowers analyzed had a production value of $5.51 billion pesos, using only 10.11 thousand ha. Consequently, the average income from floriculture production surpasses $500 thousand pesos per cultivated flower hectare.

Throughout the analysis period, the trade balance of floriculture in Mexico has been in surplus; the Mexican market is a net flower exporter (Figure 1). In 2017, the Mexican flower exports recorded their highest value (more than $40 million dollars). In 2008, the highest flower import value so far was recorded ($3.6 million dollars). Mexico's flower trade balance has been higher than 90% of the exports value in most of the studied years. Consequently, we can reaffirm that the Mexican market is a net flower exporter.

From 2008 to 2020, the US market has been the destination of more than 95% of Mexico's flower exports; therefore, it can be considered the main trading partner. In general terms, Mexican floriculture is competitive in the North American market; in 2020, the IVCR was 0.96 and was higher than 0.8 in the study period (Figure 2).

Table 1. Production variables growth rate of the main flowers cultivated in Mexico.

Flower	Year	Sown area (ha)	Harvested area (ha)	Production (millions gruesas**)	Yield (gruesas/ha)	Average rural price ($/gruesa)	production value (millions $)
Chrysanthemums	2000	1,876.50	1,876.50	10.01	5,335.72	68.07	681.56
	2020	3,203.35	3,203.35	12.52	3,909.33	152.97	1,915.69
	TCA (%)	70.71	70.71	25.07	−26.73	124.72	181.07
Roses	2000	294.00	294.00	1.92	6,531.91	174.25	334.63
	2020	1,741.90	1,654.90	9.08	5,488.32	197.82	1,796.72
	TCA (%)	492.48	462.89	372.96	-15.98	13.53	436.94
Gladiola	2000	754.00	754.00	0.80	1,061.14	95.45	76.37
	2020	4,558.32	4,558.32	5.11	1,121.55	222.28	1,136.36
	TCA (%)	504.55	504.55	538.97	5.69	132.88	1,387.95
Carnations	2000	724.00	724.00	8.68	11,993.14	35.22	305.78
	2020	609.90	609.90	4.46	7,317.28	148.19	661.35
	TCA (%)	−15.76	−15.76	−48.60	−38.99	320.76	116.28

Source: The table was prepared by the authors, based on SIACON statistics (2021).
TCA: cumulative growth rate of each variable from 2000 to 2020.
** gruesa = 144 commercial stems

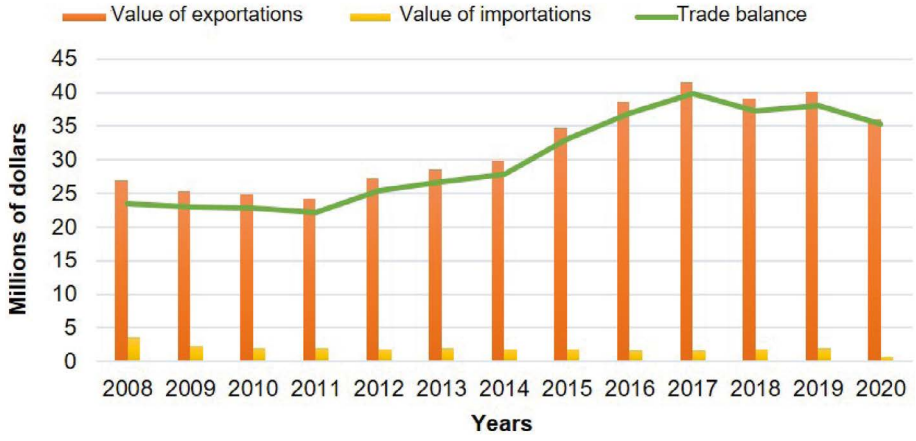
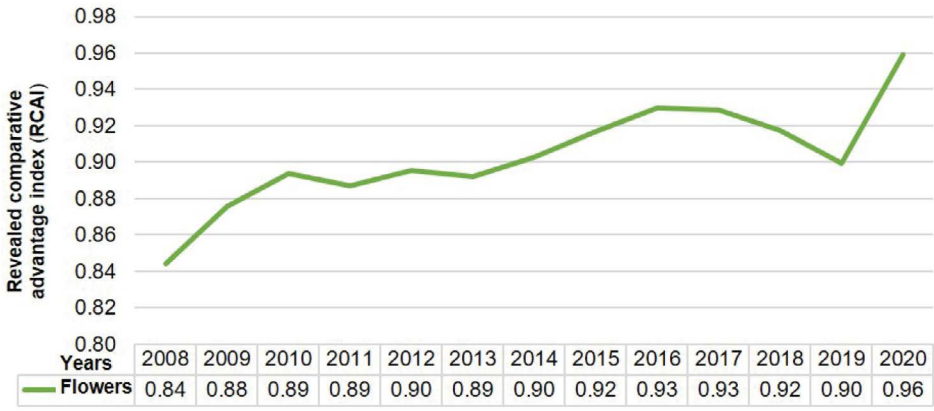


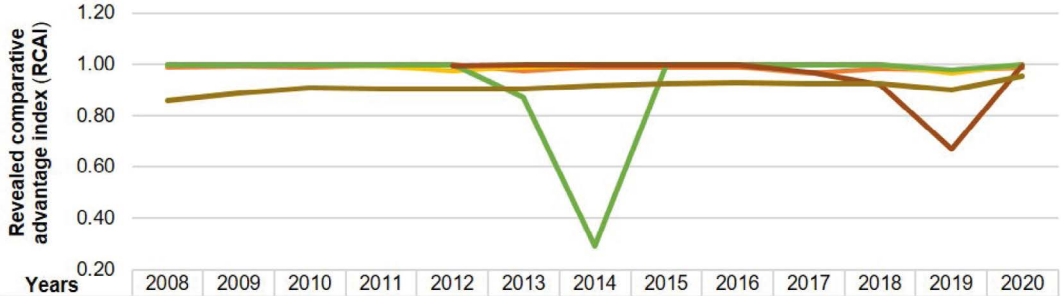
Figure 1. Trade balance of floriculture in Mexico. Figure prepared by the authors, based on SIAVI statistics (2021).

From 2008 to 2020, the value of the IVCR of each type of flower has been close to one in most years (Figure 3). In the case of roses and carnations, the lowest IVCR value in the analysis period was 0.97, showing that these Mexican flowers are competitive in the US market. However, chrysanthemums show how vulnerable the Mexican floricultural export sector is to changes in the North American demand for its products. In 2014, chrysanthemum exports to the US decreased considerably and a 0.29 IVCR was recorded. However, the value of Mexican exports for that year was higher than in 2013, since chrysanthemums were exported to the Canadian market.



Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Flowers	0.84	0.88	0.89	0.89	0.90	0.89	0.90	0.92	0.93	0.93	0.92	0.90	0.96

Figure 2. Mexican IVCR regarding the US. Tariff code 0603. The figure was prepared by the authors, based on SIAVI statistics (2021).



Years	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Rose	0.99	0.99	0.99	1.00	1.00	0.97	0.99	0.99	0.99	0.97	0.98	0.98	0.98
Carnation	1.00	1.00	1.00	1.00	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.97	1.00
Chrysanthemum	1.00	1.00	1.00	1.00	1.00	0.87	0.29	1.00	1.00	1.00	1.00	0.98	1.00
Lily					1.00	1.00	1.00	1.00	1.00	0.97	0.92	0.67	0.99
Rest	0.86	0.89	0.91	0.90	0.90	0.91	0.92	0.92	0.93	0.92	0.92	0.90	0.95

Figure 3. IVCR of Mexican export flowers regarding the US.

The first Madonna lilies were exported to the US market in 2012; since then, this market has consumed almost 100% of the Mexican exports. In 2019, Mexico imported $331,567 dollars of this flower from the US, which diminished the country's competitiveness, consequently reducing the IVCR. Finally, the Mexican market is competitive with respect to the US market, regarding other flower exports: the lowest IVCR value was recorded in 2008 (0.86). Mexican competitiveness has increased since that date.

CONCLUSIONS

In the last two decades, Mexican floriculture has increased, particularly regarding the growth in the production volume of roses and sword lilies. Another relevant variable for flower production in the country is the production value: sword lilies, roses, carnations, and chrysanthemums experienced a considerable increase of this value in the analyzed period. The creation of jobs in this sector is important for the development of the rural areas where Mexican flowers are grown.

Mexico is a net exporter of flowers, and this is reflected in the trade balance of this product group. All the flowers analyzed in this research prove that the Mexican market has comparative advantages regarding the USA. However, the dependence of the national flower sector is worrisome, since any change in the North American demand has a direct impact on exports and indirectly affects the Mexican producer. Mexico needs to diversify its client base, but distances and transportation times limit the export of fresh flowers from the country.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

New findings in the searching of an optimal diet for the axolotl *Ambystoma mexicanum*: protein levels

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ABSTRACT

Objective: To determine the protein nutritional requirements in juvenile axolotls (*Ambystoma mexicanum*) based on four isocaloric diets (8% lipids) with 30, 35, 30, and 45% protein.

Design/methodology/approach: Six axolotls were used per test, during a period of 81 days. The diets were prepared using fishmeal as a protein source and fish oil as a lipid source. The feed was supplied every 48 h with 4% of the weight of the biomass of organisms per experimental reservoir. Four biometrics were performed throughout the experiment and growth parameters were determined: height, weight gained per day, specific growth rate, survival, Fulton's K, and protein efficiency rate. The digestibility of each of the diets was also determined.

Results: There were significant differences in the growth and survival of the axolotls, the diet with 45% protein showed the best growth results.

Limitations/implications: No more protein levels could be tested, due to the number of organisms available for bioassays.

Findings/conclusions: Diets for the axolotl (*A. mexicanum*) containing 45% protein level promote good development and survival. This allows for improved cultivation and management plans for the species.

Keywords: Caudata, nutrition, digestibility, axolotl, amphibian.

INTRODUCTION

Aquatic animal husbandry requires a thorough understanding of their nutrition, which is relatively new compared to the nutrition of terrestrial farm animals. Aquatic species

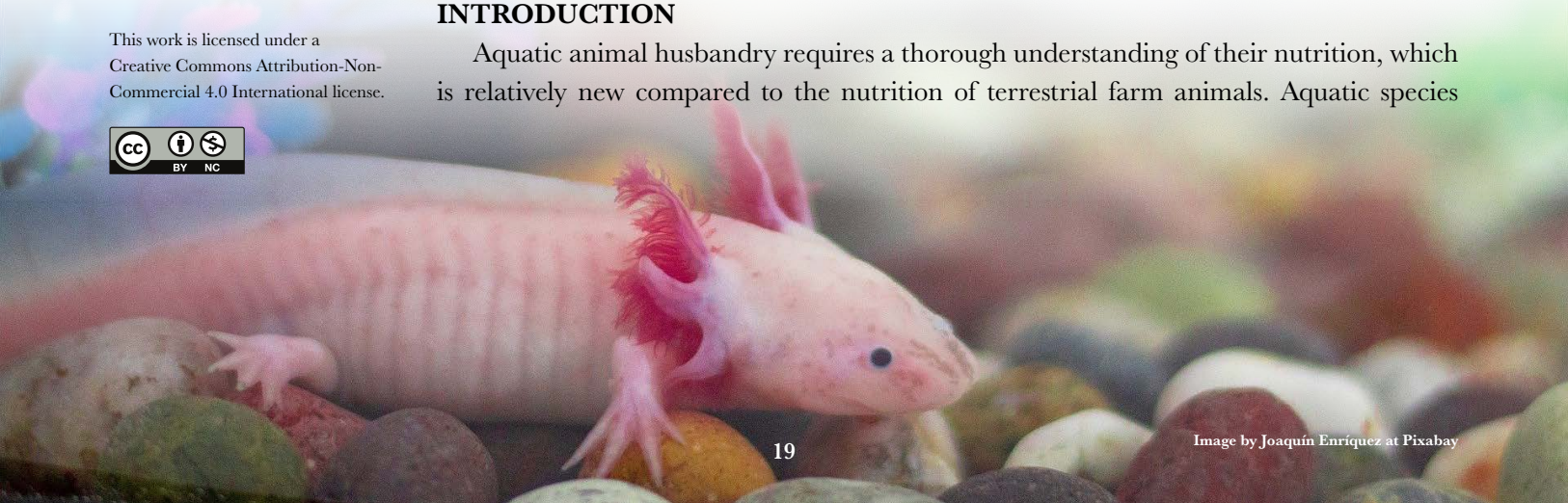

Image by Joaquín Enríquez at Pixabay

require protein, lipids, carbohydrates, vitamins, minerals and other food additives to meet the physiological needs for growth and reproduction just like terrestrial species. However, there are immense differences between the two since, due to the great diversity of farmed aquatic animals, their nutritional requirements can be radically different (Hertrampf and Piedad-Pascual, 2000).

The nutritional requirements of the different species are a function of several factors, such as: migratory habits, adaptations to the temperature of the environment, type of feeding, stage of life, sex, type of feeding in their natural environment. As well as the behaviors that are directly related to the collection, search and ingestion of nutrients (Gutiérrez-Espinosa *et al.*, 2019; Masabanda *et al.*, 2021; Puchades-Murgadas, 2021). A poorly structured diet can lead to infectious diseases, malnutrition, erratic swimming, and even death (Slight *et al.*, 2015). Most of the studies related to the nutrition of organisms are focused on mammals and birds and in the case of aquaculture to the most popular species with high commercial value. There are few studies that address rearing methods and the development of experimental diets that enhance the growth of amphibian (Bonnet *et al.*, 2002). For the particular case of the genus *Ambystoma*, there are no studies that address the development of inert diets for maintenance in captivity and some enthusiasts limit themselves to giving general recommendations (McWilliams, 2008) or establish feeding habits in free life or in captivity, based on organisms of their habitat (Zambrano *et al.*, 2011). The possibility of having a specific diet for this species, considered in danger of extinction, is of priority importance to develop adequate culture and management plans. Therefore, we aimed to evaluate the effect of four isocaloric diets (8% lipids) with 30, 35, 30 and 45% protein.

MATERIALS AND METHODS

Organism obtention

The juveniles of the axolotl (*Ambystoma mexicanum*) were obtained by donation from the production center Axos-PIMVS, located in Tepic, Nayarit, Mexico. They were transported individually, in plastic bags inside coolers (with coolant gel) to maintain an optimal temperature for transport to the Laboratory for Water Quality and Experimental Aquaculture (LACUIC) belonging to the University of Guadalajara in the city of Puerto Vallarta, Jalisco, Mexico. An average initial size of 17.4±4.2 g and an initial length of 12.2±1.0 cm were recorded for the experimental axolotls. Once in the laboratory, the organisms were quarantined for their observation and monitoring, which consisted of individually separating the axolotls in 500 mL plastic containers. As prophylactic treatment, a commercial medicament was administered (Azoo Diesase Treatment®) in a dose of 1 mL per 10 L of water over a period of 45 days. During quarantine and experimental development, a temperature of 19.0±1.2 °C was maintained in a room with a controlled environment. The axolotls were fed a commercial brand of trout diet (Silver cup®) with 55% protein and 12% lipids, with a particle size of 5.5 mm. Water exchanges were carried out with filtered water previously dechlorination with sodium thiosulfate.

Conditions of the experimental units

Six organisms (measured and weighed) were placed per experimental unit (80 L tubes with a working volume of 25 L). Each treatment was tested in triplicate, with a total of 72 organisms. The bioassay lasted 81 days. During the same, four biometrics were performed, one initial, one final and two intermediate. The temperature and water quality conditions were similar to those of acclimatization. The feed was supplied every 48 h with 4% of the weight of the biomass of organisms per experimental reservoir. The non-ingested feed was removed and a 100% replacement of the water was conducted.

Experimentation

Four diets were prepared with one level of lipids (8%) and four levels of protein (30, 35, 40, and 45%), represented as follows: P30/L8, P35/L8, P40/L8 y P45/L8, with fishmeal as a source of protein and fish oil as a source of fat (Table 1). The ingredients were weighed on a microbalance [Nimbo NBL® (d=0.0001 g)] and mixed in a food processor (Kitchen Aid®) for a period of 15 min until the desired consistency was achieved; The mixture was pelleted in a food mill with a 5.0 mm sieve and allowed to dry in an oven (Novatech®) at 65 °C for 24 h. The feed was cooled and was packed in plastic bags at −4 °C for its conservation and later use.

Proximal analysis

Proximal analyses of the experimental diets were performed according to the protocols established by the A. O. A. C. (1995).

Table 1. Formulation and proximal composition of the experimental diets for juvenile axolotls (*Ambystoma mexicanum*).

Ingredients (g 100 g^{-1})	Experimental treatments			
	P30/L8	**P35/L8**	**P40/L8**	**P45/L8**
Fish meal	36.4	44.0	51.6	59.1
Corn meal	16.0	16.0	16.0	16.0
Fish oil	4.9	4.3	3.7	3.1
Corn starch	33.8	26.8	19.9	12.9
Grenetin	5.0	5.0	5.0	5.0
Vitamins and minerals	3.0	3.0	3.0	3.0
Vitamin C	0.5	0.5	0.5	0.5
Sodium benzoate	0.2	0.2	0.2	0.2
Alpha tocopherol	0.01	0.01	0.01	0.01
Proximal composition (% basis in dry matter)				
Total protein (%)	30.9±0.1	34.9±0.9	40.7±0.1	45.1±0.9
Total lipid (%)	7.6±0.1	7.4±0.8	7.9±0.2	7.6±0.3
Total ashes (%)	11.1±0.1	13.4±0.4	14.2±0.5	15.2±0.4
Nitrogen Free Extracts (ELN)	50.2	44.1	37.0	32.0
Diet digestibility (%)	nd	87.3±0.8	84.0±0.3	77.6±0.1

Values are expressed as mean and standard deviation, nd=The collected feces were not sufficient for this treatment.

Diet digestibility

To determine the digestibility of the diets, feces were collected (using a siphon) for 30 days. Once the feces were collected, they were kept in plastic containers and frozen at −20 °C until subsequent analysis. The determination of the apparent digestibility coefficient (ADC) of the nutrients of the feed was carried out with the determination of acid-insoluble ashes of the food and feces, with the method proposed by Tejeda-de Hernández (1992) modified by Montaño-Vargas *et al.* (2002).

The acid insoluble ashes (CIA) were determined with the following formula:

$$CIA(\%) = ((Ash\ weight\ g - melting\ pot\ weight\ g)/Dry\ sample\ g) \times 100$$

The apparent digestibility (DA) was determined with the formula:

$$DA(\%) = 100 - ((100 \times \%\ ash\ in\ food)/\%\ ash\ in\ stool)$$

Biological indices

After 81 days of experimentation, the following growth rates were determined:

Survival was calculated using the formula:

$$SE(t_i) = SP(t_i) \times SP(t_2) \times SP(t_1)$$

where $SP(t_i)$=mean population survival in the interval $(t_i - 1, t_i)$,

The specific growth rate was calculated with the formula:

$$(SGR\ \%\ weight\ increase\ per\ day) = [(\ln W_f - \ln W_i)/t] \times 100$$

where W_f=final weight (g); W_i=initial weight (g); t=time (days).

$$Size\ Heterogeneity = CV_{wf}/CV_{wi}$$

where: W_f=final weight; W_i=initial weight.

$$Food\ Conversion\ Factor\ (FCA) = M_i\ (g)/Gp\ (g)$$

where: M_i (g): ingested food; Gp (g): weight gain.

$$Condition\ factor\ (K) = (W/L^3)$$

where: w=wet body weight g; L=length cm.

Statistical analysis

The response variables were final weight, final length, total weight gain, weight gained, weight gained per day, specific growth rate, and survival. To determine the statistical differences among treatments, an analysis of variance was used (ANOVA). In the case of significant differences among the treatments ($p<0.05$) in some variables, a post-hoc Tukey test was used. The tests were carried out with the statistical program Statistica 6.1.

RESULTS AND DISCUSSION

Originally, a duration of 65 days had been established for the development of the bioassays. However, at the end of this period, it was observed that there was an overlap in the final weights in the P35/L8 and P30/L8 diets. Therefore, even though the effect of the diets with higher percentages was already evident at 65 days, it was decided to extend the feeding period by two weeks, with the intention of observing if there was any significant variation. At 81 days, a trend was observed that showed that diets with low percentages of protein can negatively affect the proper development of axolotls.

The results obtained in the present study, show that with a level of 45% protein, the best growths, specific growth rate and survival of *A. mexicanum* were achieved. Figure 1 shows the growth of juvenile axolotls during 81 days of experimentation using four levels of protein and the same level of lipids. Regarding the weight gained after 81 days of experimentation, the treatments showed statistically significant differences ($p<0.05$). The organisms fed with the P45/L8 and P40/L8 treatments obtained a higher average weight of 39.7±11.2 and 34.4±12.1 g, respectively. Comparing the results obtained in this study with others previously published with *A. mexicanum* is practically impossible. Although there are works that address the problem of the nutrition of the species, most only provide general information without proposing a specific formulated diet based on ad hoc scientific studies. Much of the information published on the feeding of *Ambystoma*

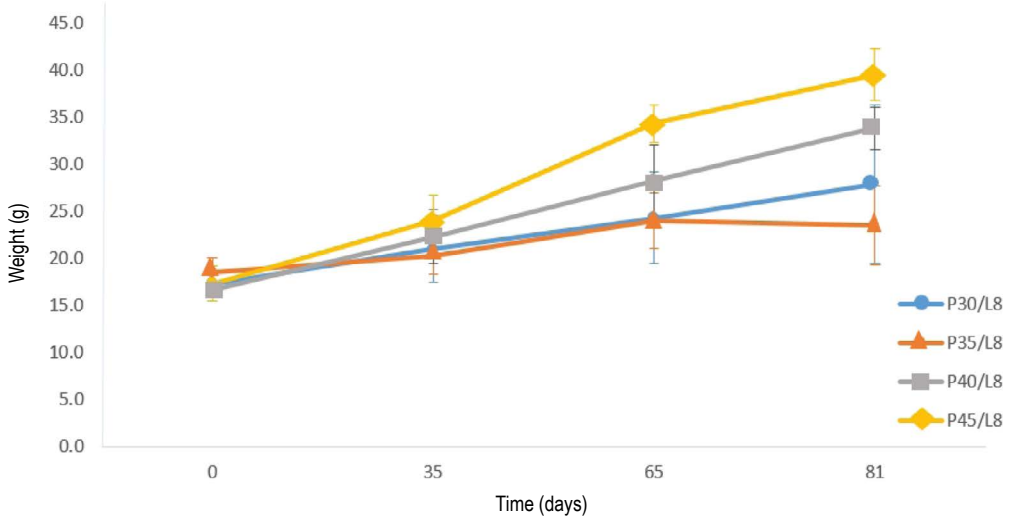

Figure 1. Weight of juvenile axolotls (*Ambystoma mexicanum*) during a period of 81 days of experimentation, fed with four different diets of P30/L8, P35/L8, P40/L8, and P45/L8 (protein/lipids, %). P=Protein. L=Lipids. 30, 35, 40, and 45% of protein. 8% of lipids.

is aimed at establishing the diet of animals in the wild or under laboratory conditions, trying to emulate natural conditions, always with consistent diets of living organisms typical of their habitat (Sarma *et al*., 2017), the behavior and predation preferences of such organisms (Zambrano, 2011; Chaparro-Herrera *et al*., 2013). The feeding of this species will depend on the stage of development and the size of the organism, feeds mainly on living organisms such as the small planktonic crustaceans *Daphnia*, the aquatic crustaceans *Artemia*, and the algae cyanobacteria *Arthrospira* (*Spirulina*), and some small insects, even fish fillet and chicken meat (García *et al*., 2003). It is advisable to give some live food adding calcium carbonate in the diet to increase the level of this mineral in the body and thus have a balanced diet (McWilliams, 2008). Likewise, the mixed diets tested in *Ambystoma* are less effective compared to solid diets, made up of a single high-quality product (Wildy *et al*., 1998; McWilliams, 2008). Recently, Ocaranza-Joya *et al*. (2021) evaluated the attractiveness and palatability of various oils in *A. mexicanum*, to determine if they were feasible to be used as attractant additives for species-specific diets. The authors found that krill and chicken oil were effective in promoting the feeding of the tested axolotls. Among the few works that evaluate the performance of diets on the growth of the amphibian clade Caudata, specifically *A. mexicanum*, the one by Slight *et al*. (2015), who studied diets based on i) bloodworm, ii) *Daphnia* and iii) mixed diet of both organisms (alternating their offering to axolotls). The highest growth was achieved with the single bloodworm diet and the lowest with *Daphnia*, intermediate growths resulted with the mixed diet. Also, Del Carmen *et al*. (2015) studied the effect of diets, in which they include three probiotics isolated from the same gastrointestinal tract of *A. mexicanum* and added to their diet. It was determined whether these had a beneficial effect on their growth and survival. The vehicle used for the dosage of the probiotics was the live crustacean *Artemia franciscana* metanauplii. Probiotics were shown to improve axolotl development and survival. The two studies mentioned above are a sample that, despite its great importance as a model organism, species at risk and even ornamental, there are no studies aimed at evaluating specific formulated foods for this or another species of *Ambystoma*.

Feeding with live feed is the usual way in which these animals are kept in captivity, with the implications that this entails in technical resources to maintain support cultures, increased space for facilities and additional financial requirements. In an attempt to address the lack of information on amphibian nutrition, Ferrie *et al*. (2014) mention that the nutritional requirements of the Anura order have been the most studied and that for species whose requirements are unknown, those published for "related species" are used, taking as a reference those of the National Research Council (NRC). In this way, theoretical diets formulated for the various species of amphibians that are poorly understood could be designed. The choice of "related species" may be based on environment, life stage, metabolism or feeding habits in wildlife. These authors suggest that for amphibians in general, the model species that can be used to establish, in a preliminary way, the nutritional requirements are cats and dogs (carnivore and omnivore, respectively), fish (omnivores and carnivores), poultry (requirements for egg production and uric acid excretion) and rats (basic omnivore model). The same authors comment that integrating

all the NRC recommendations into a single set of nutrient recommendations for amphibians can provide valuable guidance for offering adequate diets for amphibians; however, they also mention that it is a challenge due to the differences between species. Undoubtedly, trying to establish a diet based on theoretical data can be economical in time, maintenance of organisms and development of growth bioassays with different diets, with the possibility of obtaining favorable results. Unfortunately, the substitution of nutritional experimentation for a set of theoretical data obviates, as the authors of the aforementioned study well mention, the extreme differences that may exist between species, especially in feeding behavior and specific nutritional requirements for growth and reproduction. Even so, they propose a protein percentage of 44% for amphibians in general, which coincides with what was found in the present study. McWilliams (2018) also mentions that for aquatic salamanders, as insectivores, a natural percentage of protein would be between 30 and 60%.

Regarding the development of nutritional research in amphibians, anurans have had a better performance in the production of scientific publications, probably due to their commercial importance as food. Schiesari *et al.* (2009) and Ruibal and Laufer (2012) mention that the diet of amphibians is based on algae and detritus due to their oral disc, but it has been verified by stomach analysis that their feeding range can include organisms with a higher level in the trophic chains. The bullfrog (*Lithobates catesbeianus*), consumes on average between 25 and 35% of the protein in the diet, however, few are the species in which research has been developed to determine their nutritional needs. Carmona-Osalde *et al.* (1996) evaluated the nutritional requirements in bullfrog tadpoles, where they used isocaloric diets (6.0% lipids) and four protein levels (30, 35, 40, and 45%). They evaluated the effect of different protein levels on the metamorphosis and growth of the tadpoles. Obtaining as a result that a 45% protein level was statistically different from the other treatments ($p<0.05$) reflected in better metamorphosis rates, better weight gains and growth of the animals. Result that coincides with the most effective protein percentage found in the present study. Olvera-Novoa *et al.* (2007) evaluated the optimal level of protein in growth for bullfrog juveniles, with different protein levels (20, 28, 34, 42, 50, and 58%), using fish meal as the main protein source. They evaluated survival, growth and feed efficiency after 60 days of experimentation. It was observed that the highest growth was reached with the 58% protein diet, although there was no significant difference between the diets that contained 42 and 50% protein, all treatments showed a survival of approximately 83% except for the treatments that contained 20 and 28% protein. They conclude that diets with protein levels between 20 and 34% affected the growth of the bullfrog significantly ($p<0.05$) and that levels greater than 42% showed a better development of the organisms. This coincides with the results of the present study, since after 81 days of experimentation the organisms fed the P45/L8 diet presented the highest weight gain, the best specific growth rate and survival ($p<0.05$).

Determining the digestibility of nutrients in diets provides the first indication of their nutritional value and is considered the first step in their quality assessment (Rahman *et al.*, 2016). In this study, an apparent digestibility was obtained in a range of 77.6 to 87.3%, and the best digestibility was presented by the 35P/8L diet with $87.3\pm0.8\%$,

(Table 1) this coincides with that reported by Vásquez-Torres *et al.* (2013), where they mention that a good apparent digestibility in fish ranges from 76.6 to 84.0%, having fish meal as a protein base in food, which contains a high level of essential amino acids and essential fatty acids for animals, so it is considered an essential product and is classified as a high impact raw material in the development of balanced diets (Coronel-Rodríguez, 2015).

Another very important response variable is the condition factor (K) since this parameter provides information on the strategy that the organism has to grow, its nutritional status and the feasibility of reproduction when it reaches adulthood, describing the relationship length-weight and the well-being during nutrition studies (Cifuentes *et al.*, 2012). A K close to or greater than 1.0% reflects that the organism is in a zero or low state of stress, which indicates that the organisms are kept in suitable conditions for their development. In the present study, all the treatments presented a K greater than 0.94%; being the 45P/8L treatment the one that presented a K greater than 1.04%. These results coincide with those found in other freshwater organisms typical of cold water such as rainbow trout, fed with 46% protein in a growth ration, reporting a K of 1.13% (Morales and Quirós, 2007). Regarding the feed conversion factor and the protein efficiency rate, the best results were obtained by the 35P/8L diet with 2.8±0.3 and 45P/8L with 4.7±0.9 g (Table 2).

Table 2. Biological indices of juvenile axolotls *Ambystoma mexicanum* fed four experimental diets with different protein levels (30, 35, 40, 45% and 8% of lipids) in: weight, length, survival, weight gained, weight gained per day, condition Index (Fulton K), specific growth rate (TCE), specific growth factor (FCE), protein efficiency rate (TEP) during and Food Conversion Factor (FCA) in 81 days.

	Experimental treatments			
Biological indices	P30/L8	P35/L8	P40/L8	P45/L8
Starting weight (g)	17.3 ± 3.5^{a}	18.5 ± 5.0^{a}	16.55 ± 4.7^{a}	17.2 ± 3.6^{a}
Final weight (g)	27.9 ± 7.2^{b}	24.8 ± 9.1^{b}	34.4 ± 12.1^{ab}	39.7 ± 11.2^{a}
Final weight (cm)	12.3 ± 1.1^{a}	12.5 ± 1.0^{a}	12.0 ± 1.1^{a}	12.1 ± 0.9^{a}
Final length (cm)	14.3 ± 1.1^{a}	13.8 ± 1.5^{a}	15.0 ± 1.7^{a}	15.6 ± 1.5^{a}
Total weight gain (%)	61.3 ± 4.4^{b}	35.3 ± 19.8^{b}	102.5 ± 40.1^{ab}	120.1 ± 23.7^{a}
Gained weight (g)	10.6 ± 1.0^{b}	6.5 ± 3.7^{b}	17.2 ± 7.3^{ab}	22.2 ± 3.6^{a}
Weight gained per day (g day^{-1})	0.1 ± 0.0^{b}	0.1 ± 0.0^{b}	0.2 ± 0.1^{ab}	0.2 ± 0.0^{a}
Specific growth rate	0.2 ± 0.0^{b}	0.1 ± 0.1^{b}	0.3 ± 0.1^{ab}	0.4 ± 0.1^{a}
Survival (%)	83.3 ± 0.0^{a}	88.8 ± 9.6^{a}	77.7 ± 9.6^{a}	88.8 ± 9.6^{a}
Weight gained per day (g day^{-1})	0.1 ± 0.0^{b}	0.1 ± 0.0^{b}	0.2 ± 0.1^{ab}	0.2 ± 0.0^{a}
FCE (%)	0.08	0.11	0.09	1.51
TCE (%)	0.15±0.0	0.29±0.0	0.23±0.1	0.37±0. 0
Fulton K (%)	0.95±0.05	0.94±0.10	0.98±0.11	1.04±0.15
TEP (%)	4.6±0.4	3.7±0.3	4.0±1.3	4.7±0.9
FCA (%)	2.6±0.0	2.8±o.3	2.6±0.3	2.0±0.3

Means with different superscripts within a row are significantly different (one-way ANOVA, $p<0.05$).

CONCLUSION

According to the results obtained in this study, it is recommended to include a level of 45% protein in the diets of *Ambystoma mexicanum* juveniles. These results contribute to the formulation of specific diets for the optimal development and nutrition of the axolotl in captivity conditions, which allows to expand the knowledge about the species to improve management and cultivation plans.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Limitations for the production of creole pork in the cooperative sector of eastern Cuba

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ABSTRACT

The objective of this research was to determine the controversial situations in the production of Creole pork in the cooperative sector in Cuba, through the application of a participatory diagnostic system. Interviews were conducted with 50 Creole pig producers belonging to the Cuban Cooperative Organizations of the Holguín municipality. The Vester matrix was used to classify the problems according to their degree of causality, and a SWOT matrix exercise, which was determined through the development of meetings, the application of participatory techniques and group discussions as rural extension work. The 10 main controversial situations were identified, of which four were active problems, four passive, one critical problem and one indifferent. In the evaluated Creole pig breeding systems, the treatment of residuals is null, manure and urine remain in the pens all the time. Reproduction controls are not carried out, affecting the genetic and productive potential. In all cases, the type of reproduction is direct mounting without control. Vaccination and deworming schemes are scarce. One of the demands of the Creole pig breeders surveyed was training in technical, productive and reproductive aspects of animal management.

Keywords: Creole pig, family production, participatory diagnosis, backyard breeding, agricultural extension.

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INTRODUCTION

The origins of the Cuban Criollo pig date back to the Spanish conquest and have been successfully adapted to the agro-climatic conditions of the island, forming part of the peasant folklore. However, after the introduction of intensive breeding systems with selected breeds, Criollo pig breeding has been considerably reduced, so the Cuban government has implemented programs for the conservation of the Criollo breed in the different institutions of the cooperative sector (Velázquez *et al.*, 1998, Martínez *et al.*, 2005).

Image by Anne and Saturnino Miranda at Pixabay

In addition to contributing to the supply of animal protein for the communities, Criollo pig breeding has become a source of additional economic income for farming families (Ramos-Canché *et al.*, 2020). Therefore, it is necessary to identify viable strategies that make possible the traditional maintenance of the Criollo breed (Vadell, 2008). Emphasizing the use of joint tools between the productive sector and governmental bodies, in order to establish diagnoses that allow the formulation of efficient solutions for the sustainable breeding of the Criollo breed of pigs in the productive sectors (Velázquez *et al.*, 2008; Velázquez, 2008). Therefore, the objective of this research was to determine controversial situations in Creole pig production in the cooperative sector of the municipality of Holguín through the application of a participatory diagnostic system.

MATERIALS AND METHODS

The research was carried out with 50 producers of Creole pigs belonging to the Cuban Cooperative Organizations (CCO): Basic Unit of Cooperative Production (UBPC), Cooperative of Agricultural Production (CAP) and Cooperative of Credit and Service (CCS), belonging to the Ministry of Agriculture of Providencia Holguin, Cuba.

A semi-structured interview was applied with the objective of knowing productive, reproductive, management, housing and producers' perception of the limitations, strengths, threats and opportunities of Creole pig production in the municipality of Holguin.

The interviews were carried out in field visits to Creole pig producers of the CCO. In addition, the information was validated through field visits and direct observation (Pozo-Leyva *et al.*, 2021a). Subsequently, a meeting was held with 10 managers, CCO producers and specialists from government organizations to analyze the results and identify the problems that influence Criollo pork production (Velázquez, 2008 and Velázquez *et al.*, 2008).

Classification of controversial situations according to causes and consequences

The causes and consequences of the problems were identified by applying the Vester Matrix. This matrix is a tool developed by the German scientist Frederika Vester. It has been applied in participatory research with producers to facilitate the understanding of controversial situations in a simple and practical way (Velázquez, 2008 and Velázquez *et al.*, 2008), in addition to its multiple uses in development, security and risk management projects, as well as in regional and environmental planning in various productive sectors (Gabriel *et al.*, 2017).

Of the controversial situations identified through the interview, the 10 most common were used to form a matrix. On the X axis as well as on the Y axis, the problems were placed from 1 to 10. Subsequently, the X axis was crossed with the Y axis, assigning a value to each problem identified, according to the causality or direct or indirect consequence of each problem on the X axis, on each of the other problems on the Y axis. A numerical value was given to the interaction of each problem situation where:

0=It is not a cause of the problem.
1=It is an indirect cause of the problem.

2=It is a moderately direct cause of the problem.
3=Direct cause of the problem.

Subsequently, the values assigned for each problem on both the X and Y axis were added (Velázquez, 2008 and Velázquez *et al.*, 2008), as shown in Table 1.

The sum of the X-axis constitutes the active problems corresponding to the appreciation of the degree of causality of the problem on the others. The sum of the Y-axis makes up the passive problems, corresponding to the appreciation of the degree of causality of the other problems on the analyzed problem and the level of consequence. Higher scores mean that the problem is a direct consequence of the other problems (Velázquez, 2008 and Velázquez *et al.*, 2008).

Strengths, Weaknesses, Opportunities, Threats and Opportunities (SWOT) Analysis Matrix

The SWOT analysis is the tool most commonly used by decision makers in strategic management processes (Moghaddaszadeh *et al.* 2015). This matrix makes it possible to relate the internal environment to the external environment within a productive organization, identifying key factors for decision-making in a simplified way (Domon *et al.*, 2019; Forleo and Palmieri, 2019). It has as inputs, on the one hand: the results of the internal analysis, where the strengths are the positive internal factors that can help the increase of Creole pig production. Weaknesses constitute the negative internal factors that hinder the development and perpetuation of Creole pig breeding in the municipality.

The external analysis identifies the opportunities that are the circumstances that can be taken advantage of for the maintenance of the production system over time and the threats are the external limitations that intervene in the sustainable production of Creole pigs. The general problem is the strategic situation that the organizational system must change to reach the desired state, successfully fulfilling the mission (Geoheritage, 2020).

Table 1. Application of the Vester Matrix to the main controversial situations.

Problem	1	2	3	4	5	6	7	8	9	10	Summation
1-Technologies not appropriate to the stages of swine and agricultural production.	0	2	1	3	1	1	3	1	1	2	15
2-Lack of control of reproductive and productive indicators.	1	0	0	0	0	1	0	1	1	0	4
3-Unstable allocation of food by CCO.	1	0	0	0	0	0	0	0	0	1	2
4-Non-compliance with biosafety standards.	1	0	1	0	0	0	1	0	0	0	3
5-Lack of knowledge of producers.	3	3	0	3	0	1	1	1	1	1	14
6-Lack of training and extension of the CCO.	3	3	0	3	3	0	1	2	2	3	20
7-Lack of veterinary assistance.	2	3	0	3	2	3	0	1	3	3	20
8-Lack of a sense of ownership of the CCO by the producers.	3	2	0	2	3	3	3	0	1	3	20
9-Genetic potential.	1	0	0	0	0	1	1	0	0	0	3
10-Lack of knowledge of ration formulation.	1	0	2	0	1	1	1	0	0	0	6
Summation	16	13	4	14	10	11	11	6	9	14	

RESULTS AND DISCUSSION

General information on Creole swine production systems

Of the 50 Creole pig producers interviewed, 13.5% were women and 86.5% were men. Of the 144.13 ha of land owned by the respondents, 30.4 ha are dedicated to raising Criollo pigs. The productive sector has 725 Creole pigs, of which 16.3% are dedicated to reproduction with an average of 7.9 offspring per farrowing and lactation of 48.8 days on average.

Sixty percent of the breeding systems are extensive, 30% are backyard breeding and 10% are semi-extensive. The construction characteristics of the few facilities that exist are rustic, with dirt floors and wooden walls or live fences. There is no waste treatment; manure and urine remain in the corrals all the time, whether they are permanent corrals or resting corrals, mainly at night.

Problem bank and classification by application of the Vester Matrix

As shown in Table 2, four active, four passive, one critical and one indifferent problems were obtained. The four active problems are those with a high active total and a low passive total; they represent the problems that have a strong influence on the others, but are not caused by others. The four passive problems are those that have a low active total and a high passive total, do not strongly influence other problems, but are caused by most of the other problems.

The critical problem has a high number of both active and passive problems. It represents the problem that is an appreciable cause of causation on the other problems and which in turn is caused by the other problems. The indifferent problem has a low active and low passive, representing problems that have no causal effect on the analyzed set and are not caused by any of these problems.

Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis

Table 3 shows the SWOT analysis made to CCO through field visits to determine the strengths, weaknesses, opportunities and threats facing Criollo pork production in Holguín province. The four strengths identified are made up of internal factors, the five weaknesses partially or totally limit the correct functioning of the product systems, the four

Table 2. Classification of problem situations according to causes and consequences.

Active Problems	Passive Problems
5- Lack of knowledge of the producers.	2-Lack of control of reproductive and productive indicators.
6- Lack of training and extensionism of the CCO.	4-Compliance with biosecurity norms.
7- Lack of veterinary assistance.	9-Genetic potential.
8- Lack of sense of ownership of the CCO towards the producers.	10-Unknowledge of ration formulation.
Critical Problems	**Indifferent Problems**
1-Technologies not appropriate to the two phases of swine and agricultural production.	3-CCO unstable food allocation.

Table 3. Determination of weaknesses, threats, strengths and opportunities.

Strengths	Threats
Single state purchaser.	Diseases.
Human resources.	Climate.
Pricing.	Production costs.
Movement of elite producers.	
Weaknesses	**Opportunities**
Lack of training.	Demand.
Lack of technical knowledge.	Low competition.
Lack of biosecurity.	Delivery of land.
Lack of reproductive control.	State Priority Program.

opportunities are made up of those factors outside the production systems, while the three threats are made up of the limitations that could slow down the production process.

General information on Creole pig production systems

Creole pig raising is not the main economic activity of the producers, since they are more involved in the production of cow's milk and agricultural products. The main crops grown include corn, sugar cane, squash, cassava, sweet potatoes, beans, plantains, soybeans and sorghum to a lesser degree. This corresponds to the work carried out by Vadell (2008) in Uruguay, who states that Creole pig production is characterized by small backyard productions, with less than 50 head per production unit and an average of 8.8 live-born offspring per farrowing. On the other hand, it mentions that pig breeding is not the main productive activity, since the producers' main source of income is the sale of milk and vegetables.

Intensive pig breeding systems have substantially replaced traditional systems, putting at risk the perpetuation of creole breeds, which are at a disadvantage in terms of productive and reproductive efficiency (Cardozo and Rodríguez, 2010). Although the Criollo pig shows early sexual maturity, it has a low reproductive potential with less than 2 farrowings per year, as well as long lactation periods and low weaning weights (Linares *et al.*, 2001, Ramos-Canché *et al.*, 2020), which corresponds to the results of this research.

One of the benefits of Creole breeds is their adaptation to different environmental and climatic conditions and greater hardiness (Ramos-Canché *et al.*, 2020). This implies greater resistance to the presence of diseases and their low requirements in terms of feeding and comfort of the facilities (Gourdine *et al.*, 2010; Linares *et al.*, 2011), compared to commercial lines, which are not very resistant to high temperatures, since above 30 °C voluntary feed consumption, live weight gain and fertility are affected (Linares *et al.*, 2011).

Another satisfactory factor is that consumers of animal products today are increasingly demanding in terms of quality standards. Consumers prioritize products with low exposure to antibiotics, steroids and hormones, which has led to an increased demand for backyard products (Ramos-Canché *et al.*, 2020). As for the consumption of Criollo pigs, consumers'

perception is that it has a greater flavor, tenderness, juiciness, nutritional value and taste stimulation to the palate. This has led to a better acceptance and demand with respect to specialized breeds of pork (Cardozo and Rodriguez, 2010; Linares *et al.*, 2011).

The results of this research are in agreement with those reported by Linares *et al.* (2011), who documented that Criollo pigs are mostly raised in extensive, semi-extensive and agro-pastoral production systems. They are well adapted to different feeding regimes and agroecological conditions, but with long lactation periods and slow growth.

Similarly, Cardozo and Rodriguez (2010) agree that most of the rearing systems are extensive, where animals are fed with local products, crop residues, seasonal fruits and vegetables, since supplementation with commercial concentrates is scarce. In addition, they commented that the facilities are insufficient and rustic. Generally, there are large corrals close to the producers' homes where the animals only spend the night. Gourdine *et al.* (2010) reported that in this type of breeding, the reproduction method used is direct mating, without establishing a control of productive and reproductive indicators, which corresponds to the findings of the research described here. This directly affects the three phases of production (reproduction, development and completion).

Problem bank and classification through the application of the Vester Matrix

Four active, four passive, one critical and one indifferent problems were obtained, which is in agreement with Velázquez *et al.* (2008) who reported that the production of Creole pigs in rural areas lacks participatory strategies, in order to promote the optimal development of production systems. In this research, the following were documented as controversial situations:

- Indiscriminate crossbreeding of the Criollo pig breed.
- Lack of economic support from breeders.
- Insufficient technical assistance, lack of training on genetic conservation.
- Lack of biosecurity.
- Lack of food support to cover the nutritional requirements of the pigs.
- Lack of productive and reproductive control.
- Deficient facilities, inappropriate management.
- The non-existence of value-added products to the Cuban Criollo pigs.

Caicedo *et al.* (2012) agree that one of the main controversial situations in the Cuban Creole pig production sector is:

- Non-compliance with swine breeding standards.
- Lack of technical advice.
- Lack of veterinary and zootechnical services.
- Lack of knowledge of the producer in genetics and reproduction.
- Deficient breeding, feeding and sanitation technologies.
- Lack of training and extension systems.
- Lack of biosecurity.

Documented that 52% of the producers carry out an inadequate management of reproductive, productive and housing indicators, and 44% do not comply with any of the biosecurity norms, which is in correspondence with the results found here.

Analysis of weaknesses, threats, strengths and opportunities (SWOT)

The four identified strengths are formed by the internal factors that can help maintain the Creole pig production systems in a positive way. On the other hand, the weaknesses are the factors that make it difficult to perpetuate Creole pig production in the municipality over time. The opportunities are the external factors that can be used in a favorable way for the strengthening of Creole pig breeding and the threats are the barriers that limit the production in an optimal way, which corresponds with previous research carried out by Geoheritage (2020), Saygin (2017) and Moghaddaszadeh *et al.* (2015).

The productive limitations are firstly related to the lack of training of producers which brings low technical knowledge for the management of swine production, implying the absence of biosecurity conditions that can directly influence with the threat of presence of diseases.

On the other hand, the lack of control of reproduction may result in a lower number of offspring per birth, inbred animals. This leads to greater susceptibility to disease and lower live weight gain, which increases production costs. All of the above is aggravated by climatic conditions, since rainfall is increasingly erratic, affecting the quantity and quality of crops used for animal feed, which corresponds to the studies carried out by Pozo-Leyva *et al.* (2021b).

Therefore, feeding strategies adapted to each production system are required, which in turn optimize the use of resources. The main action of the CCO is to create a group of specialized extensionists capable of meeting the particular demands of producers, since these rearing systems face heterogeneous environmental, social and economic challenges (Domon *et al.*, 2019). This strategic management tool allows to know the working aspects to improve the functioning of the productive systems being of great utility for the CCO managers, government entities and decision makers.

CONCLUSIONS

One of the demands of the Creole pig breeders surveyed was training in technical, productive and reproductive aspects of herd management. The use of the Vester matrix and SWOT tools constitute an effective diagnostic method for identifying problems in swine breeding. Technologies not appropriate to the stages of swine and agricultural production are the critical problem that directly affects Creole pig breeding in the municipality of Holguín.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Edible insects harvest in Pinos, Zacatecas, Mexico

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ABSTRACT

Objective: To identify the exploitation and generation of economic income derived from the harvest of escamol (*Liometopum apiculatum* Mayr), white worm (*Aegiale hesperiaris* W) and red worm (*Comadia redtenbacheri* H), during an annual season.

Design/Methodology: Surveys were applied to n=116 edible insect harvesters in n=18 rural communities, local authorities (*ejido* commissaries, auxiliary judges), buyers (intermediaries), and representatives of the stockpiling company DELIZAC. The interviews were conducted in harvesting zones (field), at the time of the delivery of the product (stockpiling), and in the homes of harvesters selected as sample in Pinos, Zacatecas, Mexico.

Results: The prices per kilogram of *escamol* and white worm, during the 2020 seasons, was US$15.00, and for the red worm, US$25.00. The harvest of edible insects was 34.6 tons with an economic spill of US$572,800.00 showing a *per capita* average income of US$965.90.

Study Limitations/Implications: The results of this study can be used to propose techniques that favor the conservation, management, and sustainable exploitation of the three species of edible insects for inhabitants of the rural zones in central-northern Mexico.

Conclusions: The harvest of edible insects in Pinos, Zacatecas, generates important economic income. Of the harvesters, 78.9% were men, 13.7% adult women, and 7.4% children. Most of the harvesting localities lack permits to carry out the exploitation.

Keywords: ecosystem, escamoles, white worm, red worm, edible insects, harvesters.

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INTRODUCTION

The arid and semi-arid zones in Mexico have very valuable resources which, if managed correctly, can generate economic benefits in the short, medium and long term. Edible insects such as the red worm, the pink maguey worm or *chinicuil* (*Comadia redtenbacheri* H), and the white worm from the maguey (*Aegiale hesperiaris* W), as well as the escamolera ant (*Liometopum apiculatum*), are important components of these regions. The ants can modify the environmental conditions to create appropriate microhabitats (Whitford *et al.*, 2008), by increasing the fertility and quality of the soil (Amador and Gorres, 2007).

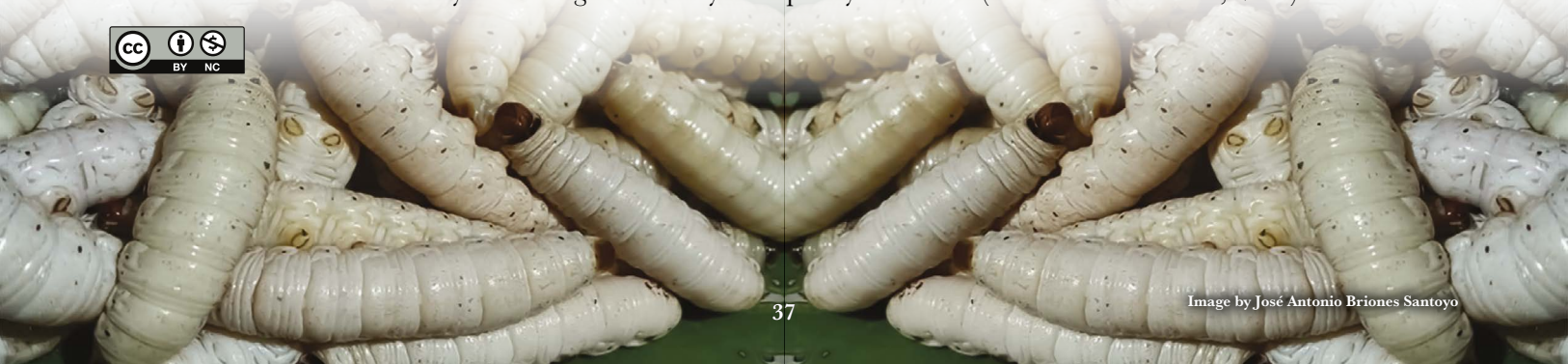

Image by José Antonio Briones Santoyo

In Mexico, the *escamolera* ant is used in the states of Michoacán, Colima, Chihuahua, Durango, Hidalgo, Querétaro and Distrito Federal (Del Toro *et al.*, 2009). Presently, harvesting also takes place in San Luis Potosí, Jalisco, Coahuila, Nuevo León and Zacatecas. In the state of Zacatecas, the exploitation of edible insects began since the 1980s. Immigrants arrived to these lands from the state of Hidalgo, they trained local inhabitants as harvesters and offered very attractive prices for *escamol*, white worm and red worm from maguey. In the municipality of Pinos, Zacatecas, Mexico, the *escamolera* ant, and also the white worm and red worm from maguey, are used since approximately 35 years. These species, although in lesser amount, are also harvested in the municipalities of Villa Hidalgo, Villa González, Noria de Ángeles and General Pánfilo Natera in the state of Zacatecas.

Escamoles are larvae and pupae from the reproductive caste of the ant *Liometopun apiculatum* Mayr. This species builds its nests in the soil or in the root system of some plants such as maguey (*Agave salmiana*), nopal (*Opuntia* spp.) and palm (*Yucca* spp.), species characteristic of the rosette-like desert shrub. Authors such as Cruz-Labana *et al.* (2018) mention that the content of macronutrients contributed by the *escamolera* ant larvae varies significantly, although not for the contents of micronutrients. Other authors, such as Rafael-Valdez *et al.* (2017) stated that the presence and foraging activity of the *escamolera* ant depend on the climate (temperature and relative moisture), vegetation, soil and its cover, anthropogenic disturbances and level of association of the ant species with some plants. Cruz-Labana *et al.* (2014) mention that the presence of the *escamolera* ant is related to some characteristics of the agaves. This relationship was corroborated by Cruz-Labana (2019) who found that the density of nests varies per type of vegetation and state of conservation.

In recent years, the municipality of Pinos, Zacatecas, has stood out due to a very important harvest of edible insects and economic income for the inhabitants of the rural zones. In this municipality, the harvest of edible insects is the only productive activity that some of the rural families practice. Therefore, the conservation, good management, development and maintenance of the habitats and colonies of edible insects are fundamental. However, currently, the native edible insects are extracted in a manner of low sustainability (De Luna-Valadez *et al.*, 2013), and the inadequate management of the land and recurring droughts have resulted in fragmentation and loss of habitat for these species.

The *escamolera* ant in the semi-arid ecosystems of the center-north of Mexico has suffered excessive extraction (Ramos Elorduy *et al.*, 2006; Ambrosio-Arzate *et al.*, 2010; Dinwiddie *et al.*, 2013) and is intensified from the lack of research directed at management and conservation (Tarango-Arámbula, 2012), primarily due to the scarce knowledge of the ecologic function of the ant and the absence of legal environmental guidelines (Ramos-Elorduy *et al.*, 2006). The *escamolera* ant, compared to the other two species of edible insects, has been studied more, highlighting aspects of foraging substrates and foraging activity (Rafael-Valdez *et al.*, 2017).

The white worm from maguey (*Aegiale hesperiaris*) is the larvae of a leaping butterfly (Hesperiidae), which develops in the leaves and roots of maguey. The white worm is abundant in the states of Hidalgo, Estado de México, Tlaxcala and Puebla (Quintero-

Salazar and Ramos-Rostro, 2018). Presently, it is used commercially in Zacatecas and San Luis Potosí, Mexico. The red, pink worm from maguey or *chinicuil* (*Comadia redtenbacheri* H), agave borer, is extracted primarily from the root system of this plant (Quintero-Salazar and Ramos-Rostro, 2018). The red worm is harvested in the states of Estado de México, Hidalgo, Puebla, Tlaxcala, Querétaro, San Luís Potosí, Jalisco, Oaxaca, Chiapas and Distrito Federal (Llanderal-Cázares *et al.*, 2010), and in recent years their exploitation has also been intensified in the states of Zacatecas, Coahuila, Nuevo León and Jalisco.

It is important to mention that although in Mexico there are different studies about the use of edible insects (Cruz-Labana, 2019, Figueroa-Sandoval *et al.*, 2018, Tarango-Arámbula, 2012; Esparza-Frausto *et al.*, 2008; Ramos Elorduy *et al.*, 2007), very few are related to the harvest and economic aspects of the three species in north central Mexico, where the economic spill has a negative impact in the conservation of these natural resources. Therefore, the objective of this study was to understand the exploitation of edible insects, their harvest and the generation of economic income from harvesting, during the 2020 seasons in Pinos, Zacatecas, Mexico. It is considered that the information from this study will serve as a basis to design conservation and non-extractive strategies that favor the permanence of the insects and of the inhabitants of rural zones.

MATERIALS AND METHODS

The study was carried out in the municipality of Pinos, Zacatecas, Mexico (22.237340 N, −101.544734 W), between February and October 2020. From the 3,135.80 km^2 of territorial area (4.45% of the state surface; COEPLA, 2020), only 14% of the surface is apt for agriculture, 79% for livestock production, and 7% for timber-yielding and non-timber-yielding forests (González-Ávila, 2011). This municipality includes 301 localities and a population of 72 241 inhabitants, the climate is dry (annual mean temperature of 16 °C), an average rainfall of 510 mm, and its geological constitution includes igneous and sedimentary rocks from the Quaternary, Neogene or Cretaceous and soils called Durisols, Regosol and Leptosol (González-Ávila, 2011; INAFED, 2020).

In this study surveys were applied with harvesters of diverse communities (Figure 1), with ejido commissaries, auxiliary judges, buyers (intermediaries) and representatives of the company DELIZAC. The interview respondents were selected randomly, that is, during visits to the communities in company of the local authority to interview people. In other localities, the interviews were conducted in the afternoon or at night in the homes of the people selected (Table 1). The communities and the number of survey respondents varied in function of the availability of time and people's willingness to cooperate.

The response variables of the study consisted in identifying via the harvesters the species of edible insect exploited, the volume (kg), the economic income generated; percentage of men, women and infants who participate in the activity, the income of intermediaries, the levels of economic profit, and description of expenditures.

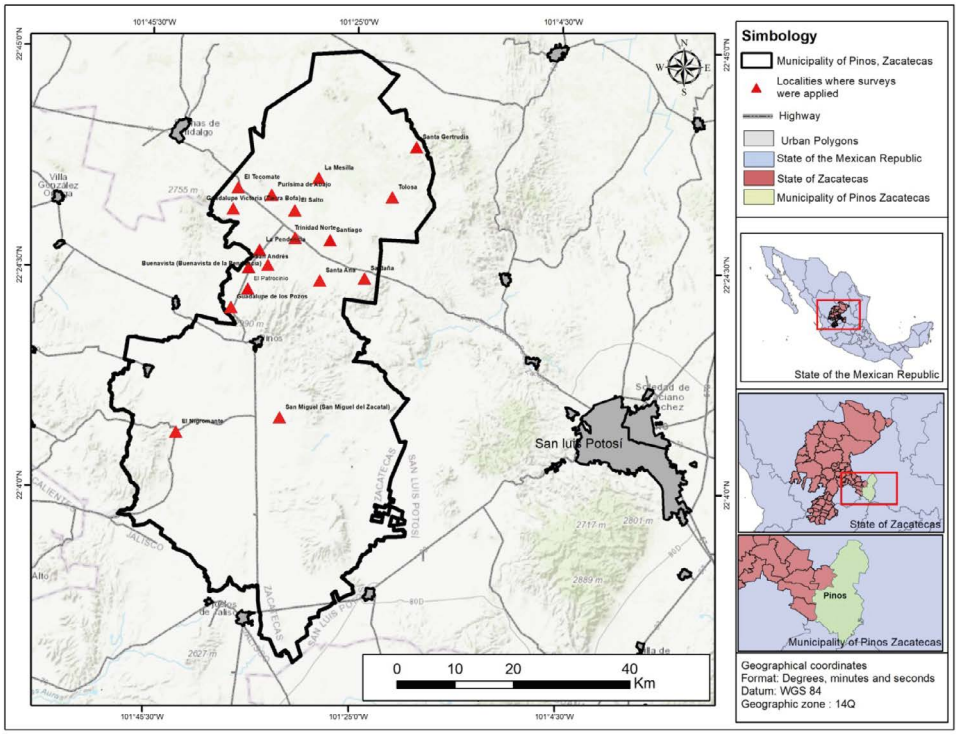

Figure 1. Location of the communities of edible insect harvesters intervened in Pinos, Zacatecas, Mexico (prepared by the authors).

Table 1. Edible insect harvesters surveyed (n=116) in the municipality of Pinos, Zacatecas, Mexico.

Locality	Sample (n)
Santiago	15
Santa Gertrudis	5
La Pendencia	5
San Andrés	10
Buenavista	3
El Patrocinio	4
Guadalupe de los Pozos	10
Saldaña	5
La Trinidad	6
Tolosa	8
Santa Ana	5
El Salto	5
La Purísima de Abajo	4
La Mesilla	5
El Tecomate	6
Guadalupe Victoria	10
El Nigromante	5
San Miguel	5
Total	116

RESULTS AND DISCUSSION

Description of survey respondents

The surveys within the sample identified harvesters (n=105), *ejido* representatives (n=8), and intermediaries (n=3). Some prior studies in Pinos, Zacatecas, by De Luna Valadez *et al*. (2013) showed that 95.1% of the harvesters were men whose age ranged between 14 and 63 years old, and 72% of them perform the harvest individually. An outstanding aspect of the information generated by De Luna Valadez et al. (2013) is that only 25% of the harvesters were *ejidatarios* or children of *ejidatarios*, 30% were settlers, and 45% came from neighboring *ejidos*.

The settler harvesters and from neighboring *ejidos* constitute a risk for the habitats and colonies of these insects, since according to the *ejido* leaders, these harvesters take harvesting to high levels of extraction.

In the 18 communities intervened in Pinos, Zacatecas, there are 593 harvesters, of which 468 are men (78.9%), 81 women (13.6%) and 44 children (7.5%) (Table 2). The insect harvesters are devoted to this activity for eight months (February-September) and during the four other months (October-February) they work in the construction tasks in the neighboring cities of San Luis Potosí, Zacatecas, Aguascalientes and Guanajuato, Mexico.

Insects represent an alternative for the human diet, and their important nutritional content stands out (Cruz-Labana *et al*., 2018), as well as their presence and easy harvest. Entomophagy takes place in developed countries as an exotic culinary alternative and in

Table 2. Edible insect harvesters per locality in the municipality of Pinos, Zacatecas, Mexico.

Number	Locality	Harvesters (n)			Total
		Men	Women	Minors	
1	Santiago	50	5	5	60
2	Santa Gertrudis	33	6	3	42
3	La Pendencia	15	0	2	17
4	San Andrés	55	10	5	70
5	Buenavista	6	0	2	8
6	El Patrocinio	10	2	2	14
7	Guadalupe de los pozos (Ejido Pinos)	27	3	3	33
8	Saldaña	20	2	0	22
9	La trinidad	25	0	0	25
10	Tolosa	55	10	2	67
11	Santa Ana	10	3	0	13
12	El salto	8	5	3	16
13	La Purísima de Abajo	10	2	1	13
14	La mesilla	11	3	2	16
15	El tecomate	25	10	4	39
16	Guadalupe Victoria	40	20	10	70
17	El Nigromante	43	0	0	43
18	San Miguel	25	0	0	25
	Total	468	81	44	593

developing countries as a survival food, as is the case of inhabitants in arid and semi-arid zones of Mexico (Tarango-Arámbula and Méndez-Gallegos, 2018).

In this study, it was found that very few harvesters include insects in their diet (≤10%). The main reason is that their consumption represents a luxury and that, if they do, they would not have money to purchase foods from the basic basket (egg, bean, tortillas for their family). For example, if a rural family decides to include insects as part of their diet and consume a kilogram of *escamol* per month, it would represent not obtaining 250 pesos (price of one kilogram of *escamol*), which is equivalent to going without the purchase of 10.4 kg of bean, 19.2 liters of milk or 7.8 kg of egg (Tarango-Arámbula and Méndez-Gallegos, 2018). This situation worsens when insect prices are elevated such as *escamol*, which during the 2022 harvest season had a price per kilogram that fluctuated between US$25.00 and US$35.00. Although some people who are not harvesters in the season buy for *in situ* consumption, it is not representative compared to what happens directly with intermediaries, and in no cases are insects an essential part of their daily diet (Tarango-Arámbula and Méndez-Gallegos, 2018).

The white and red worms constitute other dietary and economic income options. The red worm shows between 28 and 81% of protein, and represents a complementary family income through its harvest and sale (Esparza-Frausto *et al*., 2008); this worm is easy to use and can be conserved dry. The red worm is currently appreciated as food by national and foreign consumers (Hogue, 1993). To stockpile, conserve and distribute the edible insects that are harvested in the study zone, there are stockpiling centers of various sizes and capacities; however, in the community called "El Coyote", from *ejido* Santiago, there is one of the main centers for stockpiling. This center operates since more than 25 years ago and its main function is to stockpile and distribute these products to the states of Tlaxcala, Hidalgo, Estado de México and Mexico City. In this community, there is also a society led by women called DELIZAC, which is part of the stockpiling center, and in recent years they have learned to prepare dishes based on insects that are exposed in regional events and fairs.

Edible insect harvest

In this study, it was determined that during the 2020 seasons, the harvest of edible insects in the municipality of Pinos, Zacatecas, was 34.6 t. From this, 50.4% corresponded to *escamoles* and 34.1 and 15.5% to white and red worms, respectively. The three communities with highest harvest were from Tolosa (3.85 t), Guadalupe de los Pozos (3.45 t), and Santiago (3.4 t) (Table 3).

Price and profit in the sale of edible insects

The price per kilogram of species of edible insect is established by the buyer (intermediary) at the beginning of the harvest season and varies with the year and community. During the 2020 harvesting seasons, the prices for escamol and white worm per kilogram were US$ 15.00, and for red worm US$ 25.00 (Table 4). The main profits are obtained by buyers and restaurant owners in Mexico City, Puebla and Hidalgo, and range with margins between 100% and 333.3% (Table 4). Apparently, the price that is

Table 3. Edible insect harvest (2020 seasons) per locality in Pinos, Zacatecas, Mexico.

Locality	Harvest (Tons)			Total
	Escamol	White worm	Red worm	
Santiago	1.25	1.50	0.65	3.40
Santa Gertrudis	1.10	0.85	0.25	2.20
La Pendencia	0.95	0.65	0.20	1.80
San Andrés	1.30	0.90	0.40	2.60
Buenavista	0.30	0.12	0.50	0.47
El Patrocinio	0.35	0.15	0.80	0.58
Guadalupe de los pozos*	1.80	1.00	0.65	3.45
Saldaña	0.85	0.85	0.35	2.05
La trinidad	0.75	0.70	0.30	1.75
Tolosa	1.60	1.50	0.75	3.85
Santa Ana	0.70	0.45	0.20	1.35
El salto	0.60	0.40	0.15	1.15
La Purísima de Abajo	0.50	0.35	0.10	0.95
La mesilla	0.65	0.55	0.12	1.32
El tecomate	1.30	0.80	0.35	2.45
Guadalupe victoria	1.40	1.05	0.75	3.20
El Nigromante	1.20	---	---	1.20
San Miguel	0.85	---	---	0.85
Total	17.45	11.82	5.35	34.62

*Ejido Pinos.

paid to the harvester is high; however, he and his family invest a long time in the field and at home to wash and clean the product.

The expenditures that the buyer (intermediary) distributes in the harvesting and sales processes include: a) Payment for the right to harvest (renting lands for the harvest), b) Expenses for transport for the sale and stockpiling of the product in the localities, c) Expenses for electric energy in the stockpiling center, d) Expenses for transport to the final sales place, and e) Payment for workforce in the activities of cleaning and separating

Table 4. Price and profit per kilogram of edible insects from the harvester to the final consumer.

Type of insect	(US$ Dollar*)				
	Purchase price to the collector	Selling price by stockpiler	Stockpiler profit**	Retail price to the consumer	Restaurant owner profit***
Escamol	15	30	100	100	333.3
White worm	15	30	100	100	333.3
Red worm	25	60	240	150	250.0-

* US$1.00=$20.00 (Mexican pesos).
** In this percentage of profit the expenses involved in the process of harvesting and sale are not deducted.
*** This percentage of profit does not consider the costs for dish preparation or any other additional cost.

impurities. The expenses of the restaurant owners have to do with the purchase of inputs for the preparation of dishes and electric energy.

Annual average income from the sale of edible insects

The global income 2020 for the localities that harvest edible insects in the municipality of Pinos, Zacatecas, was US$572,800.00; the sale of escamol, white worm and red worm offers outstanding income for rural inhabitants of this municipality. The localities with highest level of harvesting and income during the 2020 seasons were Tolosa, Guadalupe de los Pozos, Santa Gertrudis and Guadalupe Victoria (Table 5).

The *per capita* income by locality varied from US$418.6 in the community of Nigromante to US$ 1711.15 dollars in Guadalupe de los Pozos, with a regional average income of US$965.9 (Table 6). The income derived from the sale of edible insects is generally higher than that obtained from agriculture or livestock production; in addition, insects harvesting requires a minimum of input and equipment.

Although the income from the sales of edible insects is significant, most of the harvesters were discontent, since they mentioned that they get very low payment, particularly for the sale of *escamol* and white worm (US$15.00). For example, when there is high harvesting, the price has sometimes decreased to US$ 7.5 kg^{-1}. Likewise, it is mentioned that the price of one kilogram of *escamol* and white worm has been as high as US$20.00 or US$25.00,

Table 5. Annual average income from the sale of edible insects (2020 seasons) per locality in the municipality of Pinos, Zacatecas, Mexico.

Locality	Income (US$ Dollar)			
	Escamol	**White worm**	**Red worm**	**Total**
Santiago	18,750	22,500	16,250	57,500
Santa Gertrudis	**16,500**	**12,750**	**6,250**	**35,500**
La Pendencia	14,250	9,750	5,000	29,000
San Andrés	19,500	13,500	10,000	43,000
Buenavista	4,500	1,800	1,250	7,550
El Patrocinio	5,250	2,250	2,000	9,500
Guadalupe de los pozos*	**27,000**	**15,000**	**16,250**	**58,250**
Saldaña	12,750	12,750	8,750	34,250
La trinidad	11,250	10,500	7,500	29,250
Tolosa	**24,000**	**22,500**	**18,750**	**65,250**
Santa Ana	10,500	6,750	5,000	22,250
El salto	9,000	6,000	3,750	18,750
La Purísima de Abajo	7,500	5,250	2,500	15,250
La mesilla	9,750	8,250	3,000	21,000
El tecomate	19,500	12,000	8,750	40,250
Guadalupe victoria	**21,000**	**15,750**	**18,750**	**55,500**
El Nigromante	18,000	0	0	18,000
San Miguel	12,750	0	0	12,750
Total	261,750	177,300	133,750	572,800

*Ejido Pinos.

Table 6. Total annual income by locality and per capita from the sale of edible insects in Pinos, Zacatecas, Mexico.

Number	Locality	Total anual income (US$ Dollar)	Number of harvesters	Per capita income (US$ Dollar)
1	Santiago	57500	60	958.33
2	Santa Gertrudis	35500	42	845.24
3	La Pendencia	29000	17	1705.88
4	San Andrés	43000	70	614.29
5	Buenavista	7550	8	943.75
6	El Patrocinio	9500	14	678.57
7	Guadalupe de los pozos*	58250	33	1765.15
8	Saldaña	34250	22	1556.82
9	La Trinidad	29250	25	1170.00
10	Tolosa	65250	67	973.88
11	Santa Ana	22250	13	1711.54
12	El Salto	18750	16	1171.88
13	La Purísima de Abajo	15250	13	1173.08
14	La Mesilla	21000	16	1312.50
15	El Tecomate	40250	39	1032.05
16	Guadalupe Victoria	55500	70	792.86
17	El Nigromante	18000	43	418.60
18	San Miguel	12750	25	510.00
Total		572800	593	

*Ejido Pinos.

respectively. The price of red worm has always been the highest, with an average price of US$25.00 kg^{-1}, and has shown values as high as US$50.00 and US$60.00.

The harvesters, their families and other *ejidatarios* benefit from the exploitation and sales of edible insects. The ejidos that participate in the harvest receive annually from the intermediary a payment called "Payment for the right to harvest". This resource is divided into equal parts between each of the *ejidatarios*, or from agreement in the assembly, this income can be used to conduct social work. With this payment, the intermediary acquires the rights to start and finish the extraction of insects in the lands hired. Likewise, this payment for the rent and economic support provided by the intermediary to the harvesters forces them to deliver the insects harvested, situation that fosters poaching or clandestine extraction and selling (Tarango-Arámbula and Méndez-Gallegos, 2018).

Without a doubt, insect harvesting constitutes an important source of income for the families that inhabit arid and semi-arid ecosystems. Therefore, it is important to regulate the harvest annually, since over-extraction has caused the reduction of populations and volume harvested per nest. The harvesters mention that a decade ago it was possible to find nests of *escamoles* in the fences of homes, and that, in addition, the density of the nests was higher showing a distance of less than 100 m between one and another nest. Presently, it is necessary to travel longer distances (up to one km) without finding a single

nest. Concerning this, Hernández-Roldan *et al.* (2017) report for an UMA in Pánfilo Natera, Zacatecas, between 2.7 and 5.5 nests ha^{-1}; and they recommend that in order to establish adequate conditions for *escamolera* ant nesting in degraded sites of the study area, it is necessary to regulate the animal load (large livestock) and to improve the habitat. A density of 11.9 nests ha-1 has been reported in areas with moderate disturbance (Cruz-Labana *et al.*, 2014). The harvesters informed that the harvest of *escamoles* in the past ten years has decreased approximately 50%. In this regard, Figueroa-Sandoval *et al.* (2018) found that the yield of trabeculae (nest structure) is associated more with a good quality of the nest and with a "regular" amount of ants and that, on the contrary, a bad quality of the nest is associated with a "scarce" amount of ants. The low density of nests and volume when harvesting is attributed to the inadequate management of the nest and to overgrazing of the lands where the *escamolera* ant is distributed. In contrast, the populations of white worm and their harvest has been maintained, and its harvest is the one that damages the ecosystem the least, since only one to three agave leaves (maguey) are cut to extract the worm and the mother plant remains. The harvest of red worm has also decreased, since its exploitation is performed in and inappropriate way. In this regard, Tarango-Arámbula and Méndez-Gallegos (2018) estimate that each harvester of red or white worm uses at least 50 plants of Agave, per day; this level of plant use gives an idea of the impact on natural habitats. The magueys that are used to extract the red worm are generally not replanted and the plant dies. The harvesters declare that the exploitation of red and white worms favors the maguey, particularly the red worm, and that if it is not extracted the plant could die without reaching its maturity. In contrast, Miranda-Perkins *et al.* (2013) mention that the larvae of *C. redtenbacheri* are harvested intensively since they are apt for human consumption, showing overexploitation and therefore a decrease in their populations.

From the three buyers (intermediaries-stockpilers) of edible insects interviewed, two of them state that the volume of insects harvested has increased in recent years; in contrast, the other mentions that the volume has decreased. However, the three agreed in that the demand for edible insects in Mexico is higher each day. Espinosa *et al.* (2018) mention that the demand for red worm from maguey has increased recently, which causes excessive harvesting.

According to the owners of the company DELIZAC, who work in the region as buyers of edible insects (intermediaries-stockpilers), they make the payment for the right to harvest every year, resource with which some *ejidos* perform the reforestation of maguey in degraded areas; however, the establishment of other associated forest species which are the main habitat of *escamol* should also be sought, such as palm (*Yucca* spp.), nopal (*Opuntia* spp.) as important variables in the habitat of the *escamolera* ant (Rafael-Valdez *et al.*, 2019) and as main foraging substrates the *engordacabra* (*Dalea bicolor*) (Rafael-Valdez, 2017).

In the north-central Mexico, the way in which edible insects are harvested today with high rates of extraction, place their habitats at risk, as well as the survival of the colonies and thus their abundance. Therefore, it is necessary to establish norms and regulations that allow these natural resources to be exploited in a sustainable way. Likewise, facing a growing demand, it is necessary to understand, study and analyze the system where

populations of edible insects develop and, in particular, to consider the coexistence of humans and insects in arid and semi-arid zones in the long term (Tarango-Arámbula and Méndez-Gallegos, 2018).

The current plan for exploitation of wildlife through the Wildlife Management Units (*Unidades de Manejo para la Conservación de Vida Silvestre*, UMAs) does not apply to insects. Proof of this is that from the 63 *ejidos* from Pinos, Zacatecas, only ten have an UMA registry with the Ministry of the Environment and Natural Resources, and from the 18 communities surveyed, only six (La Mesilla, El Salto, Santa Ana, Tolosa, La Pendencia and Guadalupe de los Pozos from ejido Ciudad Pinos) have an authorized Management Plan. However, only the El Salto and Ciudad Pinos UMAs are active, the others have not presented their annual reports in accordance to what the General Wildlife Law and its Regulations mark. In order to manage and conserve the species of edible insects, it is necessary to include the *escamolera* ant (*L. apiculatum*) in the NOM-059- SEMARNAT-2010 as species subject to special protection (Berumen-Jiménez *et al.*, 2021). This inclusion does not limit its exploitation; on the contrary, its inclusion establishes a call for the conservation and sustainable management of their colonies and nests (Berumen-Jiménez *et al.*, 2021).

CONCLUSIONS

In the study region, during the year of 2020, on average 18.82 tons of white worm, 5.35 tons of red worm, and 17.45 tons of *escamol* were harvested, generating US$572,800.00 with *per capita* income ranging from US$418.6 to US$1,765.15. According to the interview respondents, the prices of edible insects do not vary much year after year. However, during the last ten years the harvest of *escamol* and red worm has decreased as much as 50% and that of white worm has remained stable. Most of the harvesters disagree with the amounts that they are paid for the sale of insects, and they indicate that rather than being able to expect an increase in their income, the prices are maintained and even decrease when insect harvesting is high.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Goat milk production in Guanajuato, Mexico: Coordination mechanisms established in the agri-food chain

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ABSTRACT

Objective: To characterize the goat producers according to the industrial destinations of the milk, in order to analyze the coordination mechanisms established in the agri-food chain.

Design/Methodology/Approach: A survey was applied to 122 randomly selected goat producers. Taking into account two industrial destinations, a socioeconomic, productive, and commercial comparison was carried out, through T-tests for independent means. In order to analyze the coordination mechanisms, the data were complemented interviewing owners of collection centers and businessmen who processed milk.

Results: The producers had small herds and a basic level of education. They used family workforce. The lack of organization in the sale limited their participation in the agri-food chain coordination.

Milk processing companies coordinate their efforts, organizing the collection, reaching trade agreements, setting prices, and establishing quality rules, usually through informal agreements.

Limitations/Implications: State intervention is necessary to regulate relations between the actors of the agri-food chain.

Findings/Conclusions: The informality of coordination mechanisms favors agribusiness and turns them into forms of domination that ensure their profitability.

Keywords: Goat producers, agri-food chain, goat cheese, *cajeta*.

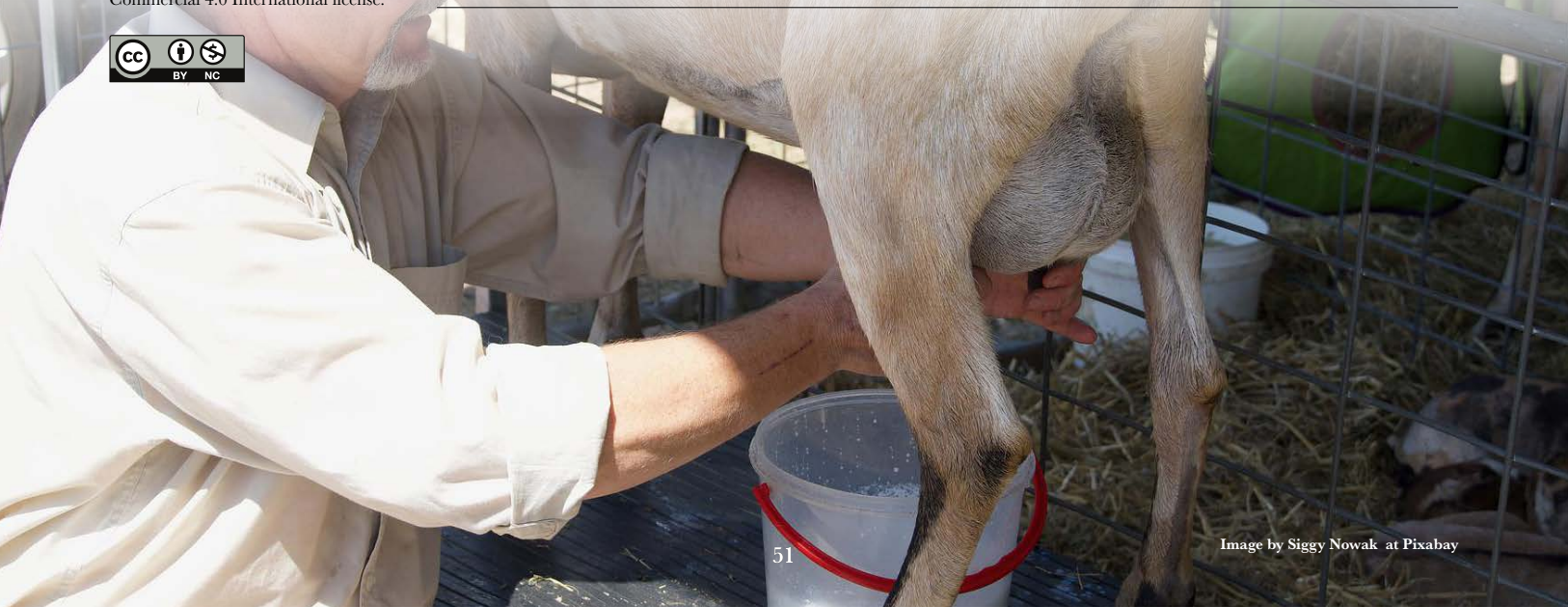

Image by Siggy Nowak at Pixabay

INTRODUCTION

The state of Guanajuato, Mexico, with a 42.3 million liters of goat milk production, ranks second in the country (SIAP, 2020). Producers carry out the activity mostly on a low scale; therefore, they diversify their income, working in agricultural production, as day laborers, and in small businesses (Iñiguez, 2013).

In addition, they are part of an agri-food chain; as suppliers, they are one of the links in different value networks. Their income depends on the decisions of companies whose economic power and position as articulating link enables them to coordinate this chain (Missohou *et al.*, 2004). This is the consequence of the oligopsony characteristics of Guanajuato's milk market, which is controlled by few companies. The power of this companies limits the value rate obtained by the producers (Escareño *et al.*, 2012; Oseguera *et al.*, 2014).

Very few producers have improved their insertion in the chain. Those who have chosen alternative methods engage in a different marketing channel: they sell their production to manufacturers of artisanal *cajeta* (a Mexican Candy traditionally made with goat milk and sugar; it has a liquid and thick consistency and is optionally seasoned with essences, spices, and liqueurs) or add value by processing it into cheese (Santos-Lavalle *et al.*, 2018). However, this has not happened with the bulk of goat producers.

Within the previous context, the objective of this work was to characterize the goat producers according to the main industrial destinations of milk in Guanajuato, in order to analyze the coordination mechanisms established in the agri-food chain.

MATERIALS AND METHODS

The research was conducted in Guanajuato, Mexico. The agri-food chain approach proposed by the Inter-American Institute for Cooperation on Agriculture (IICA) was used. This approach includes the set of actors and activities around a product in a given space (Herrera and Burgeois, 1996).

The field work was carried out from January to April 2019. The information was collected through semi-structured interviews with 122 goat milk producers, who were selected through a simple stratified sampling.

The sampling frame consisted of 408 producers who supplied goat milk to collection centers in five of the municipalities with the highest production in the state: 1) Santa Cruz de Juventino Rosas, 2) Apaseo El Grande, 3) Salvatierra, 4) Tarimoro, and 5) Valle de Santiago. At the same time, they supply the main agribusinesses that transform milk into gourmet cheeses or *cajeta*.

The variables related to the producers and their production system focused on socioeconomic, productive, and marketing aspects of milk. The analysis was focused on two groups of producers that are distinguished by the industrial destination of their product: cheese and *cajeta*.

Independent mean t-tests were performed to identify significant differences between the groups. A correlation matrix was carried out according to the Pearson coefficient to identify the variables with the greatest association with the industrial destination of the milk: experience of the producer, liters produced per goat, production system, sale price

per liter, price-setting body or individual, and potential penalization for low quality milk. Statistical tests were performed in the SPSS software.

Additionally, to understand the coordination mechanisms of the agri-food chain, interviews were conducted with owners of collection centers and with representatives of the main companies that processed goat milk.

RESULTS AND DISCUSSION

Producer profile and production system by industrial destination

The two industrial destinations of goat milk were the production of gourmet cheeses and the production of *cajeta*. The first destination included the largest companies, Interdeli, S. A. P. I de C. V. and Alimentos Carol, S. A. de C. V., operated in Queretaro. In the second, PROLECO S. P. R. de R. L. —supplier of Dulces Coronado, a subsidiary of Bimbo S. A. de C. V.— was found in Lagos de Moreno, Jalisco.

No significant statistical differences were found in the age and education of the producers; however, there was a difference between groups regarding the years of experience ($p<0.05$). Producers who sold their milk to the cheese industry were less experienced and were the most numerous; it can be surmised that they found this activity more attractive.

Regardless of the industrial destination, there were no differences in the number of workers and the type of workforce, which were mainly family-based. Escareño *et al.* (2011) pointed out that family members are an important source of workforce.

No differences were found in the number of milking goats; however, there were differences in milk production per goat ($p<0.05$), although milk production was inversely related to the industrial destination ($r=-0.351$). On average, the group that sold to the candy industry produced 0.46 liters less milk (Table 1).

The producers in this group were the most experienced; however, more years in the activity do not mean higher productivity. In contrast, Salinas *et al.* (2015) consider experience as an intangible value and a factor related to productivity: goat farmers with more experience obtained 23.4% more milk.

Table 1. Comparison of variables per industrial destination group of goat milk in Guanajuato, Mexico.

Variable	Production destination	
	Candy industry (n=22)	**Cheese industry (n=100)**
Producer age (years)	51.22±14.69 a	49.36±15.26 a
Schooling (years)	6.40±3.28 a	5.9±3.84 a
Experience (years)	23.59±15.84 a	15.14±13.94 b
Number of workers	1.86±0.77 a	2.25±1.08 a
Number of family members involved	1.86±0.77 a	2.15±1.08 a
Number of milking goats	16.41±8.82 a	20.12±22.17 a
Producción por cabra (litros/día)	1.71±0.79 a	2.17±0.77 b
Precio pagado al productor ($/litro)	5.80±0.32 a	6.55±0.34 b

Means with different letters in each row indicate differences between groups ($p<0.05$).

The average production per goat (1.7 liters of milk) observed in the first group surpasses the results of Escareño *et al.* (2011), who reported 1.5 liters per goat in low-intensity and grazing-dependent systems.

In this study, the difference in production was attributed to the feeding system. In this regard, an inverse relationship was found with the destination industry (−0.340); that is to say, the stabling system was associated with the group that supplied the cheese industry, while the extensive pasture grazing system was related to the cajeta industry.

Most of the producers who sold to the cheese industry kept the goats in stable conditions (63%); this system was associated with the number of milkings (r=0.322). In this group, the implementation of two milkings per day was higher (31 *vs.* 10%). Both situations favored a higher production of milk per goat.

These results are logical, given the conditions of Guanajuato. Along with the traditional system of small herds in communal pastures, there is a stabling system production, while large-scale companies employ more innovations. The same thing happens in other parts of Mexico: the deterioration of the pastures makes it necessary to supplement the diet with grains, cut-and-carry forage, or through agricultural by-products (Wurzinger *et al.*, 2013; Salinas *et al.*, 2015), leading producers one step closer to complete stabling.

To contextualize, Ruiz-Zarate *et al.* (2012) report significantly higher milk yields (3.0 liters/days) in Saanen goats, under stabling conditions, than in this study. These results make it clear that there is a gap in the adoption of innovations.

Iñiguez (2013) argues that the production intensification processes increase if the production system interacts with the industry. Similar conclusions have been found in other countries (Ådnøy, 2014; Dubeuf *et al.*, 2018).

However, based on the prices, Dulces Coronado prefers to be supplied by producers with extensive grazing systems.

Coordination mechanisms

Large-scale goat milk processing companies have managed to coordinate the agri-food chain through four lines of action: 1) the organization of the collection, 2) the achievement of commercial supply agreements, 3) the ability to set prices, and 4) the establishment of quality rules.

In a first approximation, these coordination mechanisms enable the integration of the links of the chain: *i.e.*, its structural development as a system. Additionally, they make it work to fulfill the essential purpose of generating food.

1) The organization of the collection

The agribusinesses had a supply system at their service. Although they did not own that service, they took part in its creation. Those services consist of strategically located collection centers with cold tanks; additionally, these centers are complemented by people who follow established collection routes.

Collection centers have developed over time as independent companies, in response to the arising demand and because some of them acquired equipment with the support of the government or leading companies. Most of them (19 out of 21) fulfill the function of

intermediaries between milk producers and processing companies, consolidating themselves as one more link. As a consequence of the lack of producer initiatives to organize the collection (with two exceptions), the position occupied by intermediaries is essential to capture small volumes from a large number of producers (Jaligot *et al.*, 2016) and to spread the policies of processing companies.

2) Commercial supply agreements

The processing companies needed to ensure the supply of milk, taking into account the following conditions: a price they were willing to pay; a volume that met their schedule; a certain quality level; and a guarantee of exclusivity. Therefore, supply agreements with collection centers were essential.

Overall, these agreements were established verbally (*i.e.*, they were informal). In practice, there was a tendency to maintain stable relations, to respect commitments to supply a single agribusiness, and to apply its price and quality policies.

Similarly, commercial transactions between the collection center and the producers were carried out informally. Exclusivity was also sought, and power was exercised to establish price and quality conditions; the producers accepted this situation in which they had no influence, because they are the most numerous, dispersed, and disorganized link (Iñiguez, 2013).

3) Price setting

An inverse relation was found between the destination industry and the price per liter of milk received by the producers ($r=-0.539$) and differences between groups were observed ($p<0.05$). The cheese industry paid a better price for the milk it acquired; therefore, most producers-maintained relationships with these companies. Meanwhile, the lower price received by the group that supplied the candy industry was attributed to greater intermediation.

The price variation also depended on the organizational level of the producers; in two collection centers of organized producers obtained a higher sale price (15.3% higher) from Carol S. A. de C. V. Cooperation increases the power of negotiation with chain agents (Trienekens, 2011) and increases the value obtained (Sahlu and Goetsch, 2005).

However, in most of them, the lack of organization for the sale of milk was evident. Therefore, because of their dependency on intermediaries, many producers do not receive the full wealth they should (Ortiz *et al.*, 2008) and do not have enough power to negotiate prices.

This study did not only look into the price, but also pondered who establishes it. Eighty percent of the respondents mentioned that the price per liter of milk was decided by the buyer, 17% indicated that it was a mutual agreement with the buyer, and 3% considered that it was established by the market.

An inverse relationship ($r=-0.308$) was identified between who defines the price and the industrial destination, with differences between groups ($p<0.05$). Most of those who destined the milk to the cheese industry agreed that the buyer (*i.e.*, the collection center) decided the price (86 *vs.* 59%).

Olhagaray and Espinosa (2007) reached a similar conclusion: the collectors determine the price of goat milk. That is to say, the producers identify the agent with whom they establish an immediate relationship as the buyer and do not mention the processing companies or any other intermediary that may be present in the chain.

Some testimonies from owners of collection centers confirmed that agribusinesses set the prices for the collection centers and these, in turn, set prices for milk producers. The price remains constant throughout the year and is set without considering production costs, seasonality of supply, and industrial quality of goat milk, which is superior to cow milk (Dubeuf *et al.*, 2004).

4) The quality of the milk

Processing companies establish quality criteria and an evaluation system as a requirement to buy milk from each supplier. Both the cheese and the cajeta industries consider acidity, adulteration with water, and the presence of antibiotics as quality parameters. Ninety-three of the interviewees were aware that it was an essential requirement and that they would not sell if they did not comply with it. Nevertheless, more than 60% said they had been penalized. The non-compliance penalization was associated with the industrial destination, and it had an inverse relationship ($r=-0.335$). It was more frequent among producers that supplied cheese companies (93.8 *vs.* 85%); therefore, the *cajeta* industry seems less strict.

A large part of the producers lacks the conditions to meet the established quality requirements, given the limited technological inputs at their disposal (Iñiguez, 2013). For example, goats are milked by hand when they are still inside the stable (Escareño *et al.*, 2011), not in specific milking areas, and under unhygienic conditions (Gómez-Ruiz *et al.*, 2012). It could not be otherwise, given the lack of training and resources to invest in facilities and appropriate equipment.

The poor operation was not solely the responsibility of the producers; it was observed on the routes to the collection centers and even from there to the processing companies. In the first case, the collector carried out a superficial evaluation of the milk, but transportation did not include conservation management (Ortiz *et al.*, 2008), which probably led to the proliferation of bacteria (Olhagaray and Espinoza, 2007).

In addition, quality monitoring was interrupted in the collection centers, because they did not carry out daily samples per producer and not all of them had the required laboratory equipment (only two in the cheese agroindustry). Consequently, shipments were rejected in all of them, causing economic losses even to the producers, who sometimes were not paid for the milk.

The processing companies evaluated the milk in the collection center before each shipment, but failed to routinely carry out a microbiological count before they accepted or rejected the milk. The requirements are temperature below 3 °C; acidity of 14-15 °Dornic (microbiological contamination); fat between 2.1 and 2.9%; protein between 3.2 and 3.5%; and no water or antibiotics adulteration.

Therefore, informal agreements for the application of quality standards do not guarantee milk quality. On the one hand, it is doubtful that leading companies care about consumer health. On the other hand, the collection centers are not interested in equipping

themselves and do not follow quality evaluation routines. Finally, the producers do not have the conditions to comply with the required parameters.

Although prices do not promote milk differentiation based on its quality (Gómez-Ruiz *et al.*, 2012), there are opportunities for future progress, as long as appropriate regulations are applied with equity (Iñiguez, 2013).

CONCLUSIONS

In the agrifood chain of goat milk in Guanajuato, Mexico, the processing industry companies generate the demand for milk and the policies for its operation. The coordination mechanisms that they establish allow them to control the rest of the actors, ensuring the profitability of the investments. The coordination of the chain with informal agreements is essentially beneficial for the companies that concentrate power. However, it is incapable of ensuring quality and favors the unequal distribution of wealth. We suggest changing to formalized agreements and contracts, as well as developing regulations, with the intervention of the chain's own agents and a determined participation of government entities.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Seasonal abundance of waterfowl for hunting in the southern portion of the Malaga wetland, Durango, Mexico

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ABSTRACT

Objective: To estimate the composition and winter abundance of waterfowl for hunting in a Wildlife Conservation Management Unit (UMA), within the Malaga wetlands complex, Durango, Mexico.

Design/Methodology/Approach: In the winter of 2019, waterfowl for hunting were identified and quantified in an UMA of the Malaga wetlands complex, Durango, Mexico. The birds were counted with the point count methodology in five repetitions, in order to estimate their specific richness and abundance in each one. These variables were compared using the Kruskal-Wallis test ($p<0.05$).

Results: A total of 21,620 birds from 18 species were registered. The most frequent families were the Anatidae, Rallidae, and Gruidae. *Anser albifrons*, *A. caerulescens*, and *Anas crecca* were the most abundant species. This abundance increased according to the number of tests. Therefore, the highest proportion of birds was recorded in the last sampling ($p<0.05$).

Study Limitations/Implications: This study provides baseline demographic information for this group of birds that inhabits the Durango wetlands. However, long-term monitoring is necessary to determine the demographic dynamics of these species.

Findings/Conclusions: The study site is diverse and important for the waterfowl for hunting that spend the winter in Durango, Mexico.

Keywords: Durango wetlands, demography, Anatidae, Rallidae, Gruidae.

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INTRODUCTION

All over the world, wetlands provide outstanding environmental services (flood control, carbon capture, filtration and cleaning of water bodies, among others) and host diverse fauna and flora species (Wetlands International, 2006). One of the wetland-dependent

Image by Astrid Zellmann at Pixabay

biological groups are waterfowls (Blanco, 1999; Fonseca *et al.*, 2012; Lovvorn and Crozier, 2022) which consume and contribute organic matter and take shelter in these ecosystems (Blanco, 1999).

In Mexico, migratory waterfowl use wetlands during their winter stay (Chacón de la Cruz *et al.*, 2017; eBird, 2021), generating diverse landscapes, as well as diversity and abundance patterns (Chacón de la Cruz *et al.*, 2017). During this period, some species are exploited for hunting purposes and can provide, through the Wildlife Conservation Management Units (SEMARNAT, 2000), an economic benefit for rural Mexican communities (Segovia-Castillo *et al.*, 2010). In this sense, the presence of species with greater hunting interest is associated with the habitat conditions and the characteristics of the birds (Gatto *et al.*, 2005; Chacón de la Cruz *et al.*, 2017); therefore, their study is an important element for wetlands conservation. However, despite the decrease in their extension in recent years, knowledge about these ecosystems in intercontinental territory is scarce, especially those found in northern Mexico (Landgrave and Moreno-Casasola, 2012).

The study of some wetlands in the state of Durango is limited to the floristic (Heynes-Silerio *et al.*, 2017), geological (Quiroz-Jiménez and Roy, 2017), avifaunal (Chacón de la Cruz *et al.*, 2017), and environmental governance description (Madrazo and Ortiz, 2018). The small Malaga wetlands complex stands out from the rest as a host of great biological diversity (Heynes-Silerio *et al.*, 2017); consequently, it is considered to be of high ecological, environmental, and economic value. Additionally, its resources can be put to good use. However, despite its importance, there is scarce knowledge about waterfowl for hunting associated with this environment and their description could represent a valuable input for this site. Therefore, the objective of this work was to estimate the composition and winter abundance of waterfowl for hunting in an Wildlife Conservation Management Unit, located within the Malaga wetlands complex, Durango, Mexico.

MATERIALS AND METHODS

Study area

The study was conducted at the "Los Álamos" Wildlife Conservation Management Unit (UMA) (SEMARNAT–UMA EX–0097–DGO) in Durango City (Figure 1). This site is a 275-ha marshy wetland located in the southern portion of the Malaga wetlands complex, whose tributaries derive from the city's wastewater treatment plant and dry up during the dry season. This area is associated with anthropogenic livestock activities and has two types of vegetation: xeric scrub (genera *Acacia*, *Prosopis*, and *Sporobolus*) and aquatic vegetation layers of the genus *Eichhornia*.

Sampling

The determination and quantification of waterfowl for hunting was carried out during the pre-hunting season of the winter of 2019. The birds were identified using the point count methodology (Ralph *et al.*, 1996; Gerardo-Tercero *et al.*, 2010), with the help of 10×42 Nikon® and 10×42 Eagle Optics® binoculars and with the support of the identification keys proposed by Sibley (2014). The observations were made between 6:00 a.m. and 12:00 p.m. in five monitoring sessions (October 5, 12, 19, 26, and November 2, 2019); only those

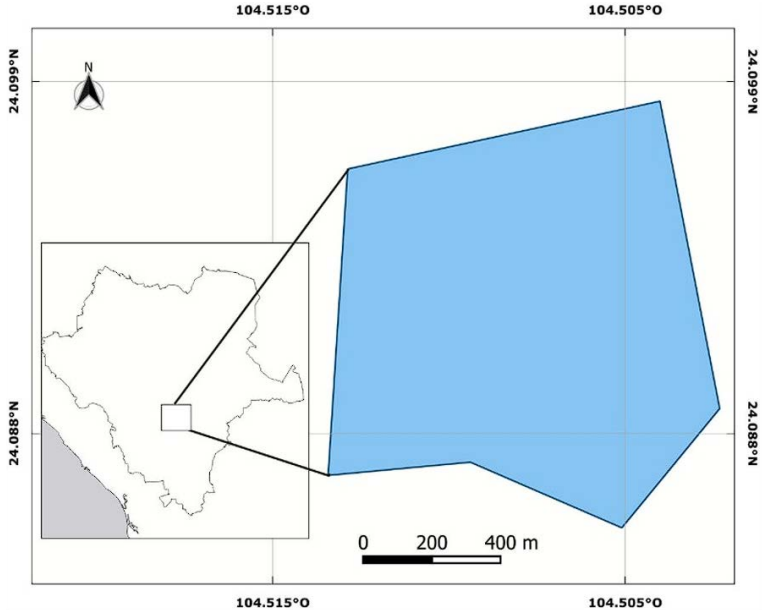

Figure 1. Location of the "Los Álamos" Wildlife Conservation Management Unit, Durango, Mexico.

species that strictly belong to the aquatic orders Anseriformes and Gruiformes, as well as the families Anatidae, Rallidae, and Gruidae, were included. The classification and nomenclature system proposed by the American Ornithologist Union (AOU, 2016) was used.

Data analysis

Specific richness (number of waterfowl species of hunting interest) and proportional abundance (proportion of records of each species with respect to the total number of records obtained) were estimated in each sampling. The species richness mean values of each sample were compared using the Kruskal–Wallis test ($p<0.05$). This analysis was conducted using the Vegan package (Oksanen *et al.*, 2007), of the R 4.0.5 software (R Core Team, 2021).

RESULTS AND DISCUSSION

In the "Los Álamos" UMA of Durango City, 21,620 waterfowl ($\bar{x}$ =4324; Table 1) of 18 species of interest to hunters were registered during the five samplings (Figure 2). The most representative family was Anatidae (16 species), followed by Rallidae and Gruidae. The most abundant species was *Anser albifrons* with an average of 870 records (20.12% of the total number of birds observed), followed by *Anser caerulescens* with 846 (19.57%), and *Anas crecca* with 827 (19.14%). In contrast, the species that obtained fewer records were *Dendrocygna autumnalis* and *Aix sponsa* (Table 1).

These abundance results are higher than the records for larger wetlands located in central-southern Mexico (Fonseca *et al.*, 2012; Ayala-Pérez *et al.*, 2013; Mera-Ortiz *et al.*, 2016). Although the description of waterfowl for hunting that winter in northern Mexico has been little studied and these results, therefore, cannot be compared with

Table 1. Proportional abundance of waterfowl for hunting registered in the "Los Álamos" UMA, during five samplings.

Family species	Code*	Samplings					Abundance (%)
		1	2	3	4	5	
Aix sponsa	WODU	0	0	0	0	6	0.03
Anas acuta	NOPI	53	428	293	304	169	5.77
Anas crecca	GWTE	240	982	679	626	1611	19.14
Spatula cyanoptera	CITE	139	162	341	265	103	4.67
Anas discors	BWTE	96	224	149	231	337	4.80
Anas diazi **	MEDU	363	227	215	482	807	9.69
Anser albifrons	GWFG	0	501	638	2020	1192	20.12
Anser caerulescens	SNGO	0	35	146	609	3440	19.57
Aythya affinis	LESC	0	3	6	7	36	0.24
Aythya collaris	RNDU	0	0	14	23	24	0.28
Anser rossii	ROGO	0	2	68	0	292	1.67
Dendrocygna autumnalis	BBWD	4	7	3	0	3	0.08
Mareca americana	AMWI	2	163	53	172	74	2.15
Mareca strepera	GADW	0	79	22	138	351	2.73
Oxyura jamaicensis	RUDU	29	42	86	82	70	1.43
Spatula clypeata	NSHO	121	246	213	212	204	4.61
Rallidae *Fulica americana* **	AMCO	48	201	90	89	162	2.73
Gruidae *Antigone canadensis*	SACR	0	0	0	47	19	0.31
Total records		1095	3302	3016	5307	8900	100

*American Ornithologist Union. ** Resident birds

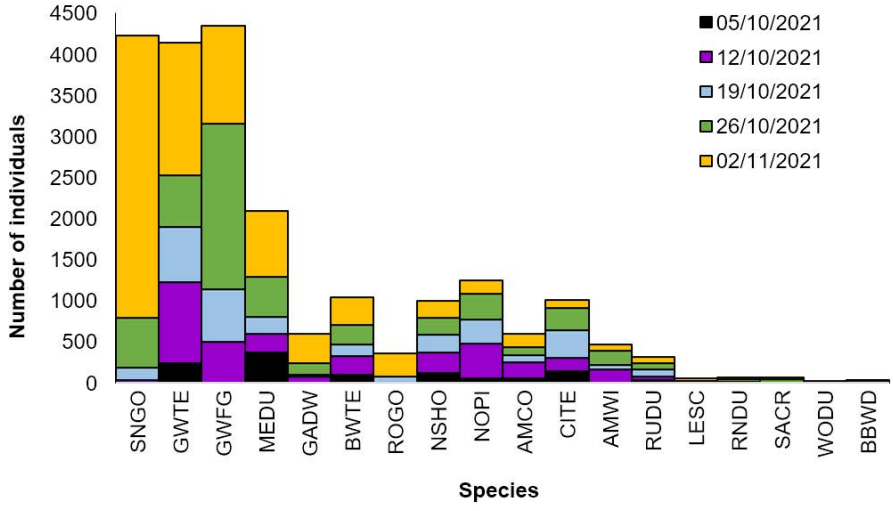

Figure 2. Seasonal abundance of waterfowl for hunting in the "Los Álamos" UMA, Durango, Mexico, during five samplings. SNGO: *Anser caerulescens*; GWTE: *Anas crecca*; GWFG: *Anser albifrons*; MEDU: *Anas diazi*; GADW: *Mareca strepera*; BWTE: *Anas discors*; ROGO: *Anser rossii*; NSHO: *Spatula clypeata*; NOPI: *Anas acuta*; AMCO: *Fulica americana*; CITE: *Spatula cyanoptera*; AMWI: *Mareca americana*; RUDU: *Oxyura jamaicensis*; LESC: *Aythya affinis*; RNDU: *Aythya collaris*; SACR: *Antigone canadensis*; WODU: *Aix sponsa*; BBWD: *Dendrocygna autumnalis*.

studies carried out in similar places and conditions, this study site can be considered as abundant and diverse.

The abundance of birds increased as more samples were obtained. Consequently, the last sampling recorded the highest bird proportion ($p<0.05$; 41.17%; Figure 1). This abundance increase pattern can be associated with normal migratory movements during the winter period (Recher, 1996), habitat characteristics such as the water body size (Colwell and Taft, 2000), or food availability (Taft *et al.*, 2002; Kingsford *et al.*, 2004). In addition, this group of birds stands out from others that inhabit the same ecosystem, given the sustained demographic growth that its populations have experienced (Rosenberg *et al.*, 2019).

Meanwhile, cryptic birds (such as *A. sponsa*) were recorded in lush and inaccessible areas of the UMA; therefore, their abundance in the site might be underestimated. It should be noted that hunters are more interested in this species and consequently a more intensive monitoring is recommended.

Finally, most of the aquatic species that were recorded in the "Los Álamos" UMA have been observed in larger wetlands in Durango (Sullivan *et al.*, 2009) and in other larger water bodies in Mexico (Mera-Ortiz *et al.*, 2016; Hernández-Colina *et al.*, 2018). Therefore, the diversity and abundance in the study site can be attributed to the high floristic diversity of the surrounding areas (Heynes-Silerio *et al.*, 2017), rather than to its extension. This phenomenon probably extends to diverse biological groups.

CONCLUSIONS

The demographic information of the avifauna provided by this research is a reference for the state of Durango and recognizes the study site as diverse and important for waterfowl of hunting interest. However, to determine seasonal diversity and demographic patterns, birds monitoring in the study area is recommended, before, during, and after the hunting season.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Effect of different stocking densities in juveniles of American crocodile (*Crocodylus acutus*, Crocodilia, Crocodylidae) in captivity

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ABSTRACT

Objective: To evaluate the effect of different stocking densities:12 (D12), 18 (D18) and 24 (D24) individuals m^{-2} (ind m^{-2}) on growth (weight and length) and survival in juvenile river crocodiles (*Crocodylus acutus*).

Design/methodology/approach: The crocodiles were cultured in each treatment by triplicate for 43-d in nine plastic tanks and fed a diet based on a mix of beef liver, fish and commercial dog food.

Results: At the end of the experiment, there were not significant differences among treatments in the growth variables, recording a low increment in weight and total length (38.99±8.96 g and 4.19±1.36 cm; mean ± SD) in all densities as well as overall survival of 62.02±7.67% (mean ± SD). The stocking density of 24 ind m^{-2} was significantly higher in biomass production by m^2 for the stocking densities of 18 and 12 individuals ($p<0.05$).

Limitations on study/implications: The development of culture techniques is a tool to assess the potential of this ecologically important species for its conservation and eventual commercialization.

Findings/conclusions: It can be recommended a stocking density of 24 ind m^{-2} (D24) to optimize the use of space and infrastructure profitability.

Keywords: diet, experiment, juveniles, growth, husbandry, survival.

Image by WikiImages at Pixabay

INTRODUCTION

The American crocodile (*Crocodylus acutus*) is distributed from Mexico to Peru on the Pacific coast, and from southern Florida to Venezuela in the Atlantic coastal areas (Pérez *et al.*, 2009; Thorbjarnarson, 2010). It is a species threatened mainly by illegal hunting, but also by the destruction and contamination of the ecosystems where they inhabit (Pérez *et al.*, 2009; García-Grajales *et al.*, 2012). In Mexico, this species is categorized as "a species subject to special protection" (SEMARNAT, 2010). Crocodile farming arose because of the demand for skins and meat, and in early stages of their life cycle to be sold as pets (Nickum *et al.*, 2017) due to its high farming potential (Pérez *et al.*, 2009; Grobler, 2012; Isberg and Shilton, 2013; Blessing *et al.*, 2014; Brien, 2015; Brien *et al.*, 2016; Nickum *et al.*, 2017). Crocodile farming has been reported to alleviate the negative effect of overfishing on wild populations, as it provides a steady stream of legally sourced commercial products such as skin, which reduces poaching (Nickum *et al.*, 2017). It also enables the repopulation of the species in the natural environment and reduces the risk of extinction (Pérez *et al.*, 2009; Barrios-Quiroz and Casas-Andreu, 2010).

The research that focused on crocodilian cultivation aspects is useful, so that in addition to their conservation these animals can be exploited in Mexico through the Management Units for the Conservation of Wildlife (WMUs), which provide economic benefits to rural areas by generating sources of employment and economic resources for the use of its inhabitants (Retana-Guiascón *et al.*, 2011; Álvarez-Peredo *et al.*, 2018). They contribute to the conservation of protected species by promoting their breeding and the legal use of their resources within protected areas, thus creating a sustainable balance (Gallina and Escobedo-Morales, 2009). Among the advantages of WMUs are increasing the population of key species or species in some risk category, since they can function as centers for the conservation of genetic material.

Understanding the role of stocking density in a species' behavior is important because each species can show a positive, negative or neutral effect to this condition of captivity by the increase in aggression, which leads to a loss of the quality of the specimens for marketing. Thus, optimizing production by optimizing stocking density will allow better growth and survival (Brien *et al.*, 2016). Most of the studies related to crocodilian cultivation have been carried out on newborns, with a stocking density between 10 and 15 individuals m^{-2} (ind m^{-2}) (Meraz *et al.*, 2008; Barrios-Quiroz and Casas-Andreu, 2010; Bagatto *et al.*, 2012; Brien *et al.*, 2016; Nickum *et al.*, 2017; Isberg *et al.*, 2018), where is it reported 1.9 g d^{-1} growth and survival around 80%. However, this may vary depending on the species, stage, and husbandry conditions (Brien *et al.*, 2016). On the other hand, stocking densities of less than 10 ind m^{-2} present mortality around 70% and an increase in growth of up to 3.71 g d^{-1} (Pérez *et al.*, 2009; Blessing *et al.*, 2014). Poletta *et al.* (2008), Brien *et al.* (2016) and Ciocan *et al.* (2018) tested stocking densities higher than 15 ind m^{-2}, and recorded growth of 1.66 g d^{-1} in early stages of *Crocodylus porosus* and *Caiman latirostris*, respectively, in newborns of up to 1 year of age.

Compared to other aquatic reptiles such as turtles, some studies reported that low densities increase growth. These studies have been reported in the soft-shelled turtle (*Pelodiscus sinensis*) in China, where stocking densities ranging from 3 to 10 ind m^{-2} have

better growth performance compared with 12 to 96 ind m^{-2} (Chen *et al.*, 2007; Jing and Niu, 2008; Zhao *et al.*, 2019). However, there have been cases where this trend is not consistent, as in the marine species *Chelonia mydas* (Kanghae *et al.*, 2016). The objective of the present study was to determine the effect of different stocking densities (12, 18, and 24 ind m^{-2}) on the growth and survival in juveniles of *C. acutus* maintained in captivity.

MATERIALS AND METHODS

The present study was conducted with a total of 135 one-month-old individuals (101.86±3.04 g; 32.55±0.14 cm; mean ± SD) of *C. acutus*. The crocodiles used in this study were born at the River Crocodile Rescue and Conservation Center "KIEKARI" (Registry PIMVS: DGVS-PIMVS-IN-1043-NAY/08), located in the Ejido "La Palma" municipality of San Blas, Nayarit, Mexico (21° 32' 25.17" N; 105° 13' 15.19" W). The experiment lasted for 43 d and was carried out from October to November 2017 within the facilities of the "KIEKARI" Center. All applicable international, national and/or institutional guidelines for the care and use of animals were followed by the authors. The juveniles were kept into a conditioned space with a temperature of 30±0.3 °C. Nine plastic tanks of 250 L capacity and 0.25 m^2 were used for the experiment. These tanks were filled to a depth of 5 cm with chlorine-free fresh water. Each tank had a dry area using a wooden platform (0.3 m^2), and a net was placed on top of each tank to prevent escaping.

During the experiment, the crocodiles were fed twice a week. The composition and protein sources of the diet were: fresh beef liver (20%), fresh ground whole fish (65%), and commercial dog food (15%). The ingredients were crushed and mixed in a meat grinder (SANITARY®, model 1275) until a uniform paste was obtained. The proximal composition of the mix was 68% protein and 4.63% fat.

Crocodiles were fed at 15% of their wet biomass. The calculation of the feeding percentage, was adjusted according to mortality and fortnightly growth. The food was placed on the 0.3 m^2 wooden platform to avoid disintegration, leaching, and contamination of the tank water. The food was offered for 2 h, after which the uneaten food was removed and weighed. Cleaning of the tanks and dry areas was carried out weekly, together with a total replacement of the water, and the crocodiles were cleaned with running water. A total of 135 individuals were placed in nine 250 L tanks for 43 d. Three stocking densities (12, 18, and 24 crocodiles m^{-2}; 10, 15, and 20 crocodiles per tank, respectively) were tested in triplicate. The response variables recorded were: 1) survival (%)=100−(# of individuals initial−of individuals final/# of individuals initial)*100; 2) size change (cm d^{-1})=final length−initial length/days of the experiment; weight change (g d^{-1})=final weight−initial weight/days of the experiment; 3) specific growth rate (SGR)=[(ln final weight−ln initial weight)/days of experiment]*100; food consumption (FC)=(food supplied−unconsumed food)/individuals in the tank; 4) food conversion factor (FCF)=food consumed/increase in weight; initial and final stocking density (crocodiles m^{-2}); 5) percentage change in stocking density (%)=initial stocking density−final stocking density; and 6) final biomass produced by m^2 (g m^{-2})=final stocking density *(initial weight per individual−final weight per individual).

The total length and wet weight of each individual of the total population of crocodiles was registered at the beginning of the experiment, and every 15 d following. The total length was calculated from the tip of the tail to the tip of the mouth using an ichthyometer (accuracy 1 mm). The wet weight was recorded with an electronic scale with a precision of 1 g. Additionally, the replica's total biomass per treatment and survival were recorded at the end of the experiment with a hook scale (precision of 1 g), where the individuals were placed on a weighing net. The total biomass was divided by the number of organisms to obtain the average weight per individual per replicate and treatment.

The Kolmogorov-Smirnov test was used for normality ($\alpha=0.05$) and the Bartlett test to determine homoscedasticity ($\alpha=0.05$). The variables in percentage rates (survival and stocking density change) were transformed with the arcsine function to its square root prior to its analysis. A one-way analysis of variance (ANOVA) was used for survival, initial stocking density, final stocking density, percentage of stocking density change, biomass/m^2, initial weight, final weight, weight change per day, SGR, initial length, final length, length change, food consumption and FCF. We used a Tukey's multiple mean comparison test to identify differences among treatments ($p<0.05$). All tests were performed through the statistical program SPSS Statistics for Windows, version x.0 (SPSS Inc., Chicago, Ill., USA; IBM Inc., 2020).

RESULTS

At the end of the 43 d of experimentation, not significant differences were observed among the treatments (mean ± SD) for survival (62.04±7.67%), initial and final weight (101.86±2.19 and 140.86±8.75 g, respectively; Figure 1), weight change (0.91±0.21 g ind^{-1} d^{-1}), SGR (0.75±0.15), start and end length (32.55±0.14 and 36.74±1.37 cm, respectively), length change (0.10±0.03 cm ind^{-1} d^{-1}), food consumption (11.36±0.87 g ind^{-1} d^{-1}) and food conversion factor (13.03±2.61) ($p>0.05$; Table 1). The final stocking density of crocodiles had significant differences with a higher value in D24 (15.60±2.40 ind m^{-2}) compared to D18 and D12, which were statistically similar (10.40±1.39 and 7.60±0.69 ind m^{-2}, respectively; $p<0.05$). The final biomass generated per square meter was significantly different among treatments ($p < 0.05$) with 578.52±156.21 g m^{-2} in D24, similar to D18 (421.11±87.72 g m^{-2}) and different to D12 (291.36±59.13 g m^{-2}), which was similar to D18. At the end of the bioassay, the three treatments presented an average weight gain of 38.99±8.96 g, while the length had an increase of 4.19±1.36 cm.

DISCUSSION

There were no significant differences in crocodile survival by treatment, indicating that the stocking densities tested did not influence this factor in the present study. The overall survival of 62% obtained differs from that reported by other studies (Brien *et al.*, 2014; Brien *et al.*, 2016), who reported 28 and 36% survival in early stages of *C. porosus* cultured in captivity, evaluating the effect of stocking density on growth. Contrarily, Meraz *et al.* (2008), recorded 74% survival in their American crocodile growth monitoring study of *C. acutus* during his first year of life in captive conditions.

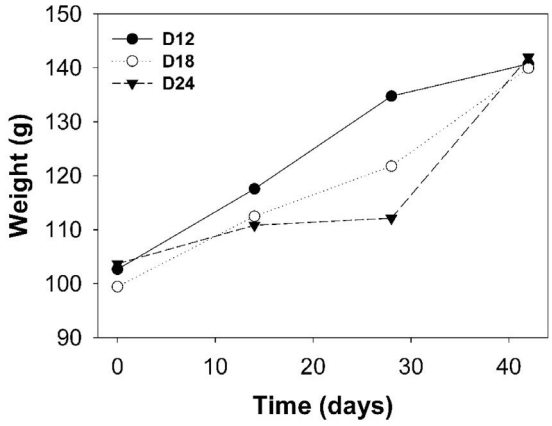

Figure 1. Wet weight (mean ± SD of three replicates per treatment) of juveniles of American crocodile (*Crocodylus acutus*) cultured in three stocking densities 12, 18, 24 ind m^{-2} (D12, D18, and D24 respectively). Crocodiles were fed a diet (68% protein and 4.63% lipid), at a ratio of 15% body weight (BW) per day adjusted daily based on growth and mortality.

Table 1. Survival, initial and final stocking density, decreased stocking density, final generated biomass, weight change, initial and final wet weight, initial and final length, length change, food consumption, food conversion factor (mean ± SD. of three replicates per treatment) of juveniles of *C. acutus* cultured in three stocking densities 12, 18, 24 ind m^{-2} (D12, D18, and D24 respectively).

Variables	D12	D18	D24
Survival (%)	63.33±5.77^{a}	57.78±7.70^{a}	65.00±10.00^{a}
Initial stocking density (ind m^{-2})	12.00±0.00^{c}	18.00±0.00^{b}	24.00±0.00^{a}
Final stocking density (ind m^{-2})	7.60±0.69^{b}	10.40±1.39^{b}	15.60±2.40^{a}
Stocking density decrease (%)	36.67±5.77^{a}	42.22±7.70^{a}	35.00±10.00^{a}
Final biomass generated (g m^{-2})	291.36±59.13^{b}	421.11±87.72^{ab}	578.52±156.21^{a}
Initial weight (g)	102.50±0.87^{a}	99.42±2.47^{a}	103.67±3.94^{a}
Final weight (g)	140.69±5.38^{a}	139.93±6.46^{a}	141.94±15.24^{a}
Weight change (g ind^{-1} d^{-1})	0.89±0.13^{a}	0.94±0.17^{a}	0.89±0.35^{a}
SGR	0.74±0.10^{a}	0.79±0.13^{a}	0.72±0.25^{a}
Initial length (cm)	32.53±0.15^{a}	32.49±0.10^{a}	32.63±0.16^{a}
Final length (cm)	37.06±0.38^{a}	37.44±0.64^{a}	35.73±2.13^{a}
Length change (cm ind^{-1} d^{-1})	0.11±0.01^{a}	0.12±0.02^{a}	0.07±0.05^{a}
Food consumption (g ind^{-1} d^{-1})	11.90±1.09^{a}	10.87±0.55^{a}	11.30±0.85^{a}
Food conversion factor	13.50±1.05^{a}	11.73±1.68^{a}	13.85±4.41^{a}

Different superscripts per variable show statistical differences among treatments ($p<0.05$).

Ganswindt (2012) reported that stress is a leading cause of death in captive grown *Crocodylus niloticus*, which was identified as a syndrome that threatens the physiological and physical integrity. The author attributes this problem to social conditions, such as stocking density, mating season, and environmental conditions such as temperature fluctuations and availability of food resources. Pérez *et al.* (2009) reported that excessive noise is a stressor causing mortality in early-stage crocodilians, while Brien *et al.* (2014) attributes the leading

cause of mortality in captivity to a growth retardation syndrome (GTS), which can occur due to various factors, including various aspects of breeding, such as stocking density. The GTS leads to starvation and immune decline, conditions that eventually caused mortality in his study. In general, these factors can only lead to a stress response when conditions are poorly controlled. In the present study, temperature and food control were maintained to rule out these sources of stress. The mortality reported in the present project was possibly related to the inherent mortality rate in the early stages of crocodiles due to the initial handling weight of the crocodiles; the latter has been reported as a causal factor of death in early-stage *Crocodylus porosus* in captivity (Brien *et al.*, 2014). These values could explain the similarity in overall survival reported in the present study.

The absence of significant differences in final weight among the treatments in the present study is consistent with that reported by Brien *et al.* (2016). These authors tested four different densities (3.3, 6.7, 13.3, and 20 ind m^{-2}) in the early stage of *C. porosus* and reported that 6.7 ind m^{-2} grew faster than (6.12±1.24 cm) the density of 20 ind m^{-2} (2.33±0.63 cm). These results differ with Poletta *et al.* (2008), in an experiment testing three densities (8.3, 16.66, and 25 ind m^{-2}) for three months in the early stages of *C. latirostris*. These authors reported significant differences between higher and lower density, and obtained approximately 60 g and 5 cm total gain with a high density and approximately 150 g and 12 cm total gain in the low density. Pérez *et al.* (2009) reported the influence of two diets (marine fish and a mix of marine fish, beef liver, and beef lung) in the early stage of *C. acutus* in a period similar (50 d) to the present study; however, with different density (4 and 10 ind m^{-2}). The authors found significant differences in total length (17.2±0.8 cm) and wet weight (167.4±7.9 g) and the best performance in low density and a mix of marine fish, beef liver, and beef lung.

The results obtained in the present study showed that the stocking density did not influence the growth and survival of the crocodiles under the experimental conditions described. Several authors suggest that there may be an "optimal" density for the culture of the early stages of crocodilians. However, the optimum value is different for each species, which depends on the culture conditions and handling. Poletta *et al.* (2008) reported for *Alligator mississippiensis* the optimum stocking density at 10 ind m^{-2} during the first year of life and a range of 10-17 ind m^{-2} for *Crocodylus johnstoni* in the first three months of life. The National Resource Management Ministerial Council (2009) advises that in the first months of life, the stocking density does not exceed 10-15 ind m^{-2}.

Evidence of the optimal stocking density in crocodile culture is still under research. The results of the present study agreed with Meraz *et al.* (2008), who also did not report significant differences in the effect of stocking density in the early stages of *C. acutus*; however, they used lower densities. Other authors such as Pérez *et al.* (2009) and Hernández-Hurtado *et al.* (2012) reported better growth in the same species using lower densities (4.1 and 0.61 ind m^{-2}, respectively).

In the production of this species in early stages it is convenient to maintain a higher density per area unit to optimize its performance, although it is necessary to generate knowledge so that the conditions can be established in which a decrease in density can be carried out to continue with the culture. The crocodile farming industry requires strategies

that reduce costs and labor and increase growth and profit margins, thus obtaining better profitability from infrastructure (Charruau *et al.*, 2010; Blessing *et al.*, 2014). Barrios-Quiroz and Casas-Andreu (2010) mentioned that culturing these animals is a costly process, and it is essential to know about the diet and adequate stocking density, which will allow maintenance a higher number of individuals per area unit to increase production. The generation of knowledge on culture techniques for *C. acutus*, such as the determination of the optimal stocking density for each developmental stage, could allow a better production in Mexico through the implementation of Wildlife Management Units (WMUs). Besides, the WMUs are centers for the conservation of endangered or threatened species and can be an alternative for the generation of economic resources in rural communities, within the framework of legality (Gallina and Escobedo-Morales, 2009; Retana-Guiascón *et al.*, 2011; Álvarez-Peredo *et al.*, 2018).

In some other crocodilian species, the economic and social conditions that exist in their range deplete the natural populations. Therefore, captive breeding is an essential tool to avoid overexploitation and support the species' repopulation. Barrios-Quiroz and Casas-Andreu (2010) mentioned that density influences individuals' growth in a considerable way. It is preferable to use newborn individuals since they present a better response than animals extracted from wild populations, in which there is higher mortality caused by stress.

The growth rate in wild crocodile populations is a vital parameter because if the animals grow faster, they are less predated, and survival increases (Charruau *et al.*, 2010). In agreement with the previously mentioned study, growth is a determining factor in the fertility of individuals, since through this parameter age can be estimated, and therefore, appropriate decisions regarding the management, conservation or exploitation of wild populations can be made, which could also be applied to crocodiles in captivity (García-Grajales *et al.*, 2012).

The diet we used with the combination of beef liver, fish, and dog food was similar to that used by Barrios-Quiroz and Casas-Andreu (2010) in the early stage of *Crocodylus moreletti*. These authors reported different diets, all constituted by mixtures of red meat, chicken liver, or fish. As a result, weight increased at the end of the experiment (9 months), approximately 78.42 g with the diet of red meat, chicken liver, and fish. Comparing our study with Barrios-Quiroz and Casas-Andreu (2010), in the present study a higher growth was obtained in 43 d (around 40 g) in the best treatment, compared with the 78 g obtained in 270 d in their study. Brien *et al.* (2016) mentioned that the growth rate in *C. porosus* decreased significantly after 21 d, and most of the offspring either lost or maintained their weight. Contrarily, Brien *et al.* (2014) indicated that newborns' growth rate can be extended 90 d or more, depending on diet quality. Therefore, it is possible to expect a similar effect in the early stage of *C. acutus*, since in the present experiment, the weight gain was constant.

Hernández-Hurtado *et al.* (2012) evaluated diets with different proportions of fish and beef liver in the early-stage of *C. acutus*. These authors indicate that the treatment with a higher percentage of beef liver obtained a growth of approximately 211 g in 5 months. Thus, the inclusion of beef liver was positive for the offspring, suggesting that the fat content allows the crocodiles to grow and survive as well as to withstand the effects of

heat stress. On the contrary, Barrios-Quiroz and Casas-Andreu (2010) reported that diets with chicken and beef liver generate lower growth rates and consider that the inclusion percentage of chicken and beef liver can be a determining variable. Brien (2015) observed that the fish-based diet generates higher growth in length, and red meat increases weight. However, Pérez *et al.* (2009) reported that, although there is a high effectiveness in fish diets it is not recommended to supply said diet for a period longer than three months. In addition to the differences between one diet and another, the food proportion must be considered according to the weight of the individuals. The typical juvenile crocodilian will consume a proportion of food between 15 and 20% of its body weight per week, at a constant temperature of 32 °C, and once they reach the sub-adult stage, they only need to consume 8-10% per week (Blessing *et al.*, 2014). Different diets and factors that influence the growth of these animals have been reported. However, it is necessary to generate knowledge about the formulation of diets for the early stages of *C. acutus*.

CONCLUSIONS

Based on the results of the present study, it can be concluded that under the experimental conditions, there are no significant differences in stocking density in the interval from 12 to 24 ind m^{-2} and it is recommended to grow juveniles of *C. acutus* at a density of 24 ind m^{-2} to optimize the infrastructure's profitability. It is essential to conduct more research on the stocking density in juveniles depending on their weight and length, environmental and management factors, and the transition phase to decrease the stocking density according to their growth.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Provision of urban amenities and public works analysis in the City of Chihuahua, Mexico

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ABSTRACT

Objective: To identify the basic geostatistical areas (AGEBS) that until 2019 were classified as priority attention zones, in order to analyze the lack of amenities and to assess indicators for monitoring sustainable development in the urban area of the municipality of Chihuahua.

Design/Methodology/Approach: An analytical-synthetic methodology was used. Bibliographical and statistical techniques were applied to study the levels that are reflected at the national and municipal scales, as well as the indicators of socially underdeveloped areas, in order to make proposals for their improvement.

Results: Based on a diagnosis of the marginalization levels in the City of Chihuahua, Chih., 3% of the city population lives in areas with scarce or non-existent amenities, generating low development in its inhabitants.

Study Limitations/Implications: The distances between the different types of amenities in the city were determined, as well as the access to essential amenities (*i.e.*, education and health). These amenities are located at inaccessible distances.

Findings/Conclusions: We would like to propose a compact and connected city model where amenities are nearby. This proposal includes the densification of the main sub-centers of the city, as well as the optimization of the required resources and the necessary infrastructure for the provision of services and urban equipment. The ultimate objective is to prevent the ongoing and disproportionate growth of the city.

Keywords: geostatistics, urban amenities, services, sustainable development.

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INTRODUCTION

In first-world cities, the provision of urban amenities has been increasingly implemented, including those aimed at providing health care to the citizens. Urban development implies compliance with planning strategies; consequently, a city achieves, to a greater or lesser extent, specific goals, such as the adequate distribution of urban amenities and infrastructure which enables citizens to develop (Mauricio and Bass, 2015).

Image by wonderland woo at Pixabay

The second chapter of the Ley General de Asentamientos Humanos, Ordenamiento Territorial y Desarrollo Urbano highlights that the construction of infrastructure works and amenities for regional, urban and rural development should promote access for all to the services, benefits, and prosperity offered by the cities. These efforts should be promoted in coordination with the state and municipal governments and the territorial demarcations and should include the participation of the social and private sectors (Cámara de Diputados del H. Congreso de la Unión, 2016).

The socioeconomic differences in the urban space become evident over time and they entail disadvantages for the most vulnerable groups, who find themselves in a very precarious habitat, as a result of the scarce provision of urban infrastructure and the low or null presence of urban services. The situation is aggravated by the economic crisis that Latin American countries face, which makes it impossible for the governments of the large metropolis to respond to the housing demand and to provide urban services in the poorest areas. All this articulation exacerbates the disadvantages of these zones and works as a social exclusion mechanism against the most disadvantaged groups (Aguilar and López, 2016).

Mexico ranked among the Latin America countries with the worst cases of territorial inequality. According to the Latin American Center for Rural Development, from 2005 to 2010, poverty was reduced in 60% of its municipalities; however, in the rest of the country the poverty levels were considerable (Tourliere, 2018).

Among the states with numerous settlements with a very low marginalization level, Chihuahua, Baja California, and Jalisco stand out with 456 (13.1% of the total of localities), 304 (8.7%), and 289 (8.3%) localities, respectively (Consejo Nacional de Población, 2010).

The objective of this study is to identify and analyze the basic geostatistical areas that need priority attention, detect the lack of amenities, and assess indicators for sustainable development in the urban area of the city of Chihuahua. This essential information can help to detect the urban amenities needs, prioritizing the outskirts, which lack educational, health, social assistance, and other types of services. These findings show that the lack of amenities in the said study areas is a reality.

MATERIALS AND METHODS

The research was carried out in the city of Chihuahua. Different sources of information were used to achieve a more comprehensive understanding of the subject. Based on the various sources of information that present social underdevelopment indicators, the municipal and the national levels were identified. These findings allowed us to determine the level of underdevelopment that exists in the city of Chihuahua. Tools such as ArcGis were used to map and analyze the necessary data.

In the case of data collection from priority attention zones, information from the Consejo Nacional de Evaluación de la Política de Desarrollo Social (CONEVAL, 2010) was consulted. CONEVAL handles social development data from urban and rural areas at all levels (municipal, state, and national). The following data were collected: development indexes, poverty indicators, marginalization level, etc.

In addition to the data from the municipality of Chihuahua obtained from the Instituto Nacional de Estadística y Geografía (INEGI, 2016), this research was supported by the Instituto Municipal de Planeación (IMPLAN Chihuahua, 2016), which has a very extensive database regarding the amenities of the city of Chihuahua.

RESULTS AND DISCUSSION

In 2010, the city of Chihuahua had 819,543 inhabitants (Figure 1), out of which, 25,129 people (3% of the total population of the city) lived in priority attention zones.

Potable water

Regarding domestic potable water supply per five-year periods, an important increase (94.7 to 98.0%) can be seen in a 20-year period (Table 1). However, the sustainability of such infrastructure (Figure 2) is problematic: the network is old, which results in a 10-20% leakage, mainly in old areas of the city such as the urban center. Major works have been carried out to divide the network into sectors, seeking to control the leaks that have occurred.

The needs are accentuated in the so-called priority attention polygons where 3.1% of the total population of the city lives. They are settled in areas that are generally characterized by natural risks, land irregularity, and limited-service provision feasibility.

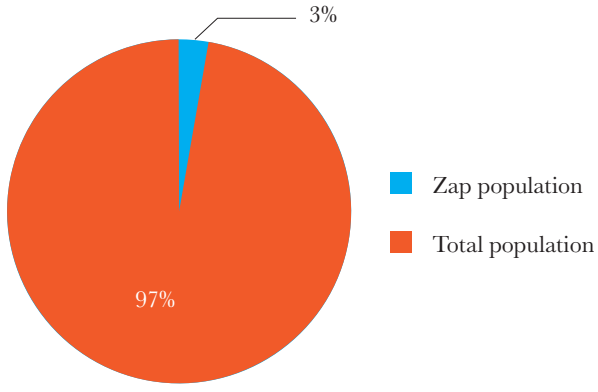

Figure 1. Population in priority attention zones (ZAP) and population in the urban area of the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

Table 1. Houses with potable water per five-year periods in the city of Chihuahua, Chihuahua, México (2010).

Source	Period	Households inhabited individuals	Houses with water	%
Population and Housing Count 1995	1995	155,359	147,082.00	94.67
XII General Population and Housing Census 2000	2000	173,640	167,544.00	96.49
II Population and Housing Count 2005	2005	208,235	191,727.00	92.07
Census of population and housing 2010	2010	237,106	222,833.00	93.98
Intercensal Survey 2015	2015	264,300	259,014.00	98.00

Source: Quintana (2019).

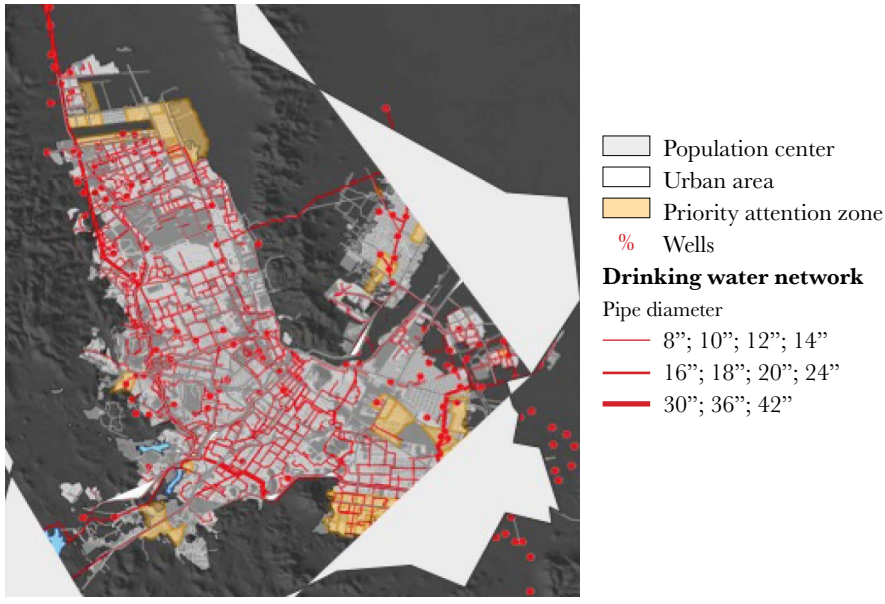

Figure 2. Potable water infrastructure of the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

Sewerage system

The sewerage system advances are even more significant: coverage increased from 92 to 98% in 10 years (Table 2). There are 1,362 houses in the city that still do not have the service; most of them are located within the already defined priority attention polygons (Figure 3).

Electrical grid

From 2005 to date, the electrical grid coverage had an equally notable advance (from 94 to 96%) (Table 3). These services need to be provided in the south and north of the city, near the Sacramento River (Figure 4). There was a remarkable setback in terms of service coverage during the year 2005 with respect to previous periods.

Street lighting

Eighty-six percent of the city has total or partial street lighting coverage. Only 14% of the city does not have consolidated services (Figure 5). These areas require land regularization to receive the said essential service. There are areas that lack any kind of public lighting infrastructure; these areas are considered priority attention zones (Figure 6).

Table 2. Houses with sewerage system per five-year periods in the city of Chihuahua, Chihuahua, México (2010).

Source	Period	Inhabited private homes	Houses with drainage	%
Population and Housing Count 1995	1995	155,359.00	144,139	92.78
XII General Population and Housing Census 2000	2000	173,640.00	165,957	95.58
II Population and Housing Count 2005	2005	208,235.00	194,219	93.27
Census of Population and housing 2010	2010	237,106.00	225,866	95.26
Intercensal Survey 2015	2015	264,300.00	262,978	99.50

Source: Quintana (2019).

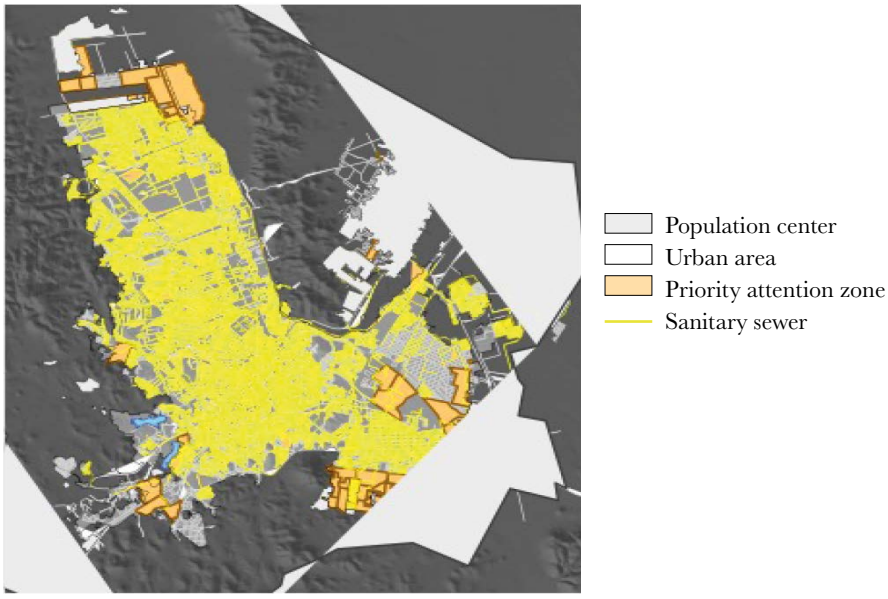

Figure 3. Sewerage system coverage in the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

Table 3. Electrical grid domestic coverage per five-year periods in the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

Source	Period	Inhabited private homes	Homes with electricity	%
Population and Housing Count 1995	1995	155,359	152,764	98.33
XII General Population and Housing Census 2000	2000	173,640	170,350	98.11
II Population and Housing Count 2005	2005	208,235	194,848	93.57
Census of population and housing 2010	2010	237,106	227,587	95.99
Intercensal Survey 2015	2015	264,300	253,728	96.00

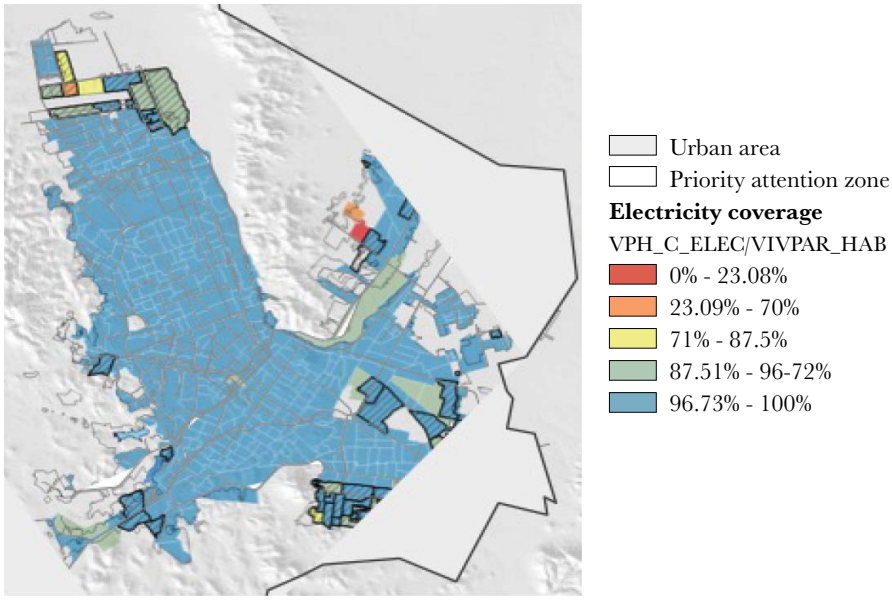

Figure 4. Electrical grid coverage in the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

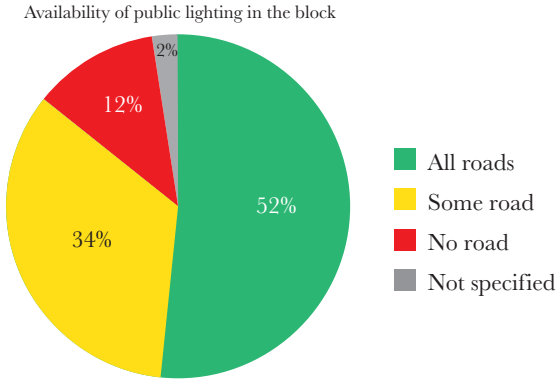

Figure 5. Street lighting availability in the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

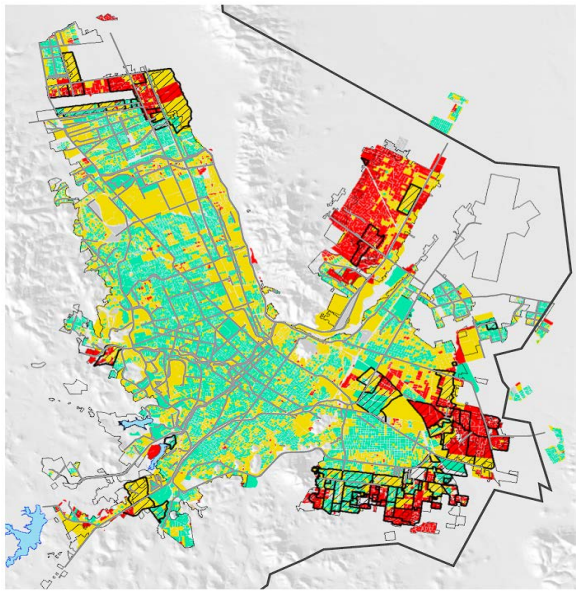

Figure 6. Street lighting coverage in the city of Chihuahua, Chihuahua, México (2010). Source: Quintana (2019).

According to data from INEGI (2016), the street lighting coverage in the urban area is optimal (86% of the blocks have total or partial coverage) and, according to municipal information, 74,857 lights have been installed in roads and public spaces. The remaining 14% is made up of irregular origin areas and suburban farms that do not have consolidated services and require specific land regularization programs that facilitate access to the service. Several of the deficient areas are included within the priority attention polygons defined by the Secretaría de Desarrollo Agrario, Territorial y Urbano (SEDATU, 2016).

CONCLUSIONS

Urban amenities provide the material basis for the basic services that the population requires. In close link with housing, infrastructure, and land, they allow a socio-spatial distribution, provide an internal structure to the city, and enable territorial planning. The

city-wide coverage in the various amenity headings is acceptable, taking into consideration the 4,970 consolidated modules of the different subsystems at all levels. However, some settlements are still devoid of services as a result from their distance to the consolidated urban area or their irregular origin. A detailed analysis of the current conditioning factors is necessary to supply and consolidate the various types of urban amenities. This analysis must be based on the physical, population, and social conditions of deprived areas and the sociodemographic dynamics that determine the temporality of their situation as reserve areas. Likewise, priority coverage mechanisms must be implemented in the following zones: Low-income settlements of low urban quality, Areas lacking social urban amenities, Areas with dispersed amenities (that is to say, that have no order), Areas far from primary amenities, Settlement areas with priority attention polygons, Short-term growth reserve zones, Zones without urban center area, urban sub-center, district center, or metropolitan vision coverage.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Prediction of weaning weight of grazing beef by machine learning

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ABSTRACT

Objective: To develop and validate models using the variables available at calving to predict the weaning weight (WW) of grazing beef calves.

Design/Methodology/Approach: The WW was modelled using machine learning (ML) algorithms and ordinary least squares (OLS). The model included three variable availability scenarios and the best fit was identified using the coefficient of determination (r^2), the mean squared error, and the bias.

Results: ML algorithms achieved a better fit than OLS in all scenarios. ML had a 0.70, 0.67, and 0.78 r^2 when the following modelling variables were available: B) dam age at calving and parity, calf sex and weight, weaning age, and calving date; I) in addition to the previous variables, dams' weight at calving, type of calving, calf and cow racial purity; and A) in addition to the all the previous variables, type of service, cow and sire tags and sire breed.

Study Limitations/Implications: The ML and OLS models were representative of a specific database. Modelling based on regional or national data should be studied. Using the lowest number of variables in this study, ML in scenario B provided an acceptable fitting for the prediction modelling of the WW of grazing beef calves.

Findings/Conclusions: ML performed better than OLS, without causing an overfitting, based on the suitability of the WW predictions regarding a database that was not used to train the model.

Keywords: Alfalfa, artificial intelligence, regression.

Image by Reinhard Borrmann at Pixabay

INTRODUCTION

Beef production will amount to 75 Mt in 2030 (a 5.8% increase), in response to the growing demand for animal products (OECD/FAO, 2021). Although grazing animal production pollutes the environment (Steinfeld *et al.*, 2006) and there are proposals for human feeding based on meatless meals, beef production has a significant sociocultural aspect and it is also an option in arid ecosystems where foraging of the primary production is the main strategy. In the short term, improving the efficiency of the beef production plans has been visualized as a way to address climate change (Chang *et al.*, 2021).

Weaning weight (WW) is used to evaluate beef production cows. WW is influenced by genetic effects (Koots *et al.*, 1994), as well as the maternal ability and environmental factors (Kennedy and Henderson, 1975). The role of WW is not limited to genetic improvement and production planning and projection; WW is also a parameter that defines the cows' contribution to the profitability of the commercial operation (Harris and Newman, 1994). Studies on milk yield, early weaning, and other cow-calf production aspects are still under study (Mulliniks *et al.*, 2020) and are needed to identify optimization parameters (Thompson *et al.*, 2020; Greenwood, 2021).

The relation of WW with other production variables defines the nature of production records and, therefore, enough data must be collected. Weaning age, calf sex, dam age at calving, and other variables are used to standardize WW; however, local or temporal conditions also impact its modelling (Harris and Newman, 1994). Achieving the target weaning weight is fundamental for grazing production, because pasture supply is restricted. Consequently, WW prediction models based on specific changes to predictor variables (such as weaning age) are important, once other effects have been adjusted. Once the production projection has been determined, the plan can be modified to suit the environmental resources available and their uncertainty. Coupling animal production plans with environmental limiting factors is fundamental to adapt to certain conditions (such as climate change) and to promote sustainability (Taylor *et al.*, 2020; Greenwood, 2021).

Statistical modelling traditionally uses linear or non-linear regression, likely including polynomial expressions with one or more explanatory variables. The best fitting for these models is achieved with the minimization of the error variance or the maximization of a likelihood function. Bayesian methods are another alternative, particularly regarding the meta-analysis of the data or in those cases in which statistics assumptions are not fulfilled (McElreath, 2020). Recently, as a result of advances in computing power, machine learning (ML) algorithms have proven to be relevant for predictive modelling and data exploration. Both ML models and models solved through ordinary least squares (OLS) have their advantages, but they also have limitations. Therefore, comparing methodologies is important to select the best tool; at the same time, a simple model capable of providing a faithful representation of reality must be established. Interpretability is still a pending task in ML and, overall, they are a black box model: a solution is achieved, but exactly how it was achieved is unknown.

In this study, WW predictive models were trained and validated based on the variables available at the calving. Variables that became available after the calving were not used for

predictive purposes. The following hypothesis was set forth: a ML algorithm would predict WW better than OLS regression. A database of Limousin beef cows and their grazing calves was used to achieve the objective of this study.

MATERIALS AND METHODS

A beef herd grazing mixed pasture was studied at Centro de Enseñanza, Investigación y Extensión en Producción Animal en Altiplano, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México (UNAM). The site is located at 20° 36' 13.88" N and 99° 55' 02.91" W, at an altitude of 1,913 m. The weather is temperate, with a 512 mm average annual rainfall and a 17.5 °C average temperature, with frost from October to February, warm summers, and mild winters.

Cows and their calves grazed on a paddock divided with an electric fence and with center-pivot irrigation. The pasture was established in 2004 with a mixture of species: alfalfa (*Medicago sativa*), cocksfoot grass (*Dactylis glomerata*), fescue (*Festuca* sp.), and perennial ryegrass (*Lolium perenne*); alfalfa was dominant by 50%. Average grazing and rest periods were 2.7 and 37.5 d, respectively. The cows were sporadically fed with good quality hay when handled on yards. At the beginning and during the weaning, the calves were supplied variable amounts of hay and concentrated feed. Cow feeding was exclusively on grazing. The productive model included year-round-calving. Weaning groups were established and the calves were kept apart from the grazing group; however, heifers were returned to the grazing group a few days later, until mating and becoming pregnant. Once a positive pregnancy diagnosis was obtained, they remained in the grazing group until they gave birth and considered cows and so forth.

This study included the 2004-2010 records of an 88-Limousin cow herd, with 159 births (up to 5 calvings per cow). The Limousin calves were the result of artificial insemination (AI) and natural mating (NM); additionally, eleven crossbred calves were born from artificial insemination. The response variable was the weaning weight (WW) of calves. The following predictor variables were recorded: cow and sire tags (representing ancestry), age and weight of dams at calving, type of calving, dam parity, type of service and sire breed, calf sex, calf weight and calnving date, weaning age, and racial purity of the calf and the cow. Weaning age is a variable defined after calving, but it was included as a WW predictor variable, since it determines weaning management.

The R language was used to develop the codes (R Core Team, 2013). Eighty-percent of the records were randomly chosen and OLS and ML models were developed, combined with three modelling variable availability scenarios: basic (B), intermediate (I), and wide (A), according to Table 1. In order to prove the hypothesis, the ML model should have a better performance than OLS in all these scenarios.

The OLS models were developed with a stepwise procedure in the R software, using the lm, stepAIC, and VIF functions. The stepAIC function of the MASS package chooses the best model using the Akaike information criterion. The VIF function of the car package determines the variance inflation factor (VIF); a VIF=10 threshold was used to eliminate variables from the model and to avoid multicollinearity (Fox and Weisberg, 2018). Using the Pratt index, the calc.yhat function of the yhat package determined the importance of

Table 1. Predictor variable used for machine learning or ordinary least squares modelling with three variable availability scenarios: Basic (B), Intermediate (I), and Wide (A).

Predictor variable	Abbreviation	B	I	A
Cow tag	cow			x
Sire tag	sire_tag			x
Sire breed	sire_br			x
Dam age at calving (months)	dam_age_cal	x	x	x
Dam weight at calving (kg)	dam_ weight_cal		x	x
Type of calving [1]	type_calving		x	x
Type of service [2]	type_service			x
Calf sex	calf_sex	x	x	x
Calf weight (kg)	calf_weight	x	x	x
Calving date (month)	calving_date	x	x	x
Weaning age (days)	weaning_age	x	x	x
Race purity of the calf (%)	purity_calf		x	x
Race purity of the cow (%)	purity_cow		x	x
Dam parity	parity	x	x	x

[1]Normal or difficult calving. [2]Normal mating (NM) or artificial insemination (AI).

the explanatory variables in the variance portioning. The models were validated with the remaining 20% of the records. The goodness of fit between observed and predicted values was measured using the coefficient of determination (r^2); the square root of the mean squared error (RMSE) was calculated using the RMSE function of the Metrics package; and the bias was measured following Bland and Altman (2010) with the blandr package.

The same records selected for the OLS training were used to build the ML models. A stack of models based on ML algorithms was generated with the AutoML function of the H20 package v.2.32.14 (Hall *et al.*, 2019). The ML approach takes into consideration several algorithm realizations: deep learning (DL), feedforward artificial neural network (DL), general linear models (GLMs), gradient-boosting machine (GBM), extreme gradient boosting (XGBoost), default distributed random forest (DRF), and extremely randomized trees (XRT). The AutoML function trains individual models, as well as two model assembles: the first assemble is developed from all the algorithms used in the generated models; the second assemble only takes into consideration the best model of each class or family of algorithms. Often, both assembles achieve better predictions than individual algorithms. The deviance was used as a goodness of fit statistic in order to sort the models within the ML model stack, as well as a criterion to stop the model optimization. The best model assemble or the best individual model were used to predict WW in the records reserved for validation (20%). The h2o.explain function of the H2O package was used to determine the importance of the variables of the individual models; however, it cannot be applied to a model assemble (Hall *et al.*, 2019). The same goodness of fit measurements was used to compare the OLS and ML models; the best modelling method would have the highest r^2, the lowest RMSE, and the lowest bias. In order to interpret the contribution of

each ML model variable, its SHAP (Shapley Additive exPlanations) values were estimated, using the h2o.explain function.

RESULTS AND DISCUSSION

The training data base was comprised of 127 records (118 Limousin and 9 Angus-Limousin calves). The validation database included 32 records (29 Limousin and one of each Angus, Belgian Blue, and Blonde D'Aquitaine crosses). Both databases had similar average values for the calf quantitative variables (Table 2). Both databases showed a 3% occurrence of difficult calving. The percentage of IA services was 34 and 40 for training and validation data, respectively. The only major correlation between the predictor variables was recorded between parity and dam_age_cal (r=0.82); the correlations for all the other variables were lower than r=0.23, except for purity_calf and purity_cow, which had a r=0.26 correlation.

ML obtained a better validation than OLS in all scenarios (Table 3). All the goodness of fit measurements favored ML, although bias should be chosen before the coefficient of determination as a goodness of fit criterion (Bland and Altman, 2010). The ML of scenario A obtained the best validation, according to the goodness of fit measurements; likewise, the OLS performed better in this scenario than the OLS of other scenarios. In scenario A, the highest OLS error was also detected in the graphic representation of the observed versus the model-estimated WW values (Figure 1a and Figure 1b). The estimated data showed less dispersion in the ML model, both during the training and the validation phases (Figure 1c and Figure 1d); a similar phenomenon was recorded in the other scenarios (data not shown).

In all three scenarios, the best representation with the ML always was the model assemble; additionally, the best individual models always were of the XGBoost type —a decision tree type algorithm. In scenario A, the deviance of all the model assembles was 472.87 and the deviance for the best individual model was 494.21. In scenario I, the assemble for the best family was 649.53 and the deviance for the best individual model was

Table 2. Average ($\bar{y}$) and standard deviation (s) of the variables in the weaning weight (WW) model training and validation databases.

Variable		Training				Validation			
		Female		Male		Female		Male	
		$\bar{y}$	s	$\bar{y}$	s	$\bar{y}$	s	$\bar{y}$	s
dam_ weight_cal[1]	(kg)	637	57.2	654	54.9	627	76.3	676	52.0
Dam _wean_we[2]	(kg)	654	48.7	602	50.6	509	49.2	615	52.3
dam_age_cal	(months)	58	26.9	64	29.2	65	36.2	65	26.6
calving_weight	(kg)	37	3.6	39	4.1	36	3.2	39	3.9
weaning weight	(kg)	241	34.6	244	46.2	230	42.9	242	50.9
weaning age	(days)	201	20.9	198	18.8	205	22.4	194	25.6
GDP[3]	(kg)	1.02	0.18	1.03	0.21	0.96	0.26	1.05	0.21
n		62		65		17		15	

[1]Weaing weight, [2]Dam_wean_we: dam weight at weaning, [3]GDP: daily weight gain of the calf; these three variables were not used in the modelling.

Table 3. Goodness of fit statistics between predicted and observed weaning weight (WW) values, using the training database, with internal and external validation: root of the mean square error (RMSE), residual standard error (RSE), coefficient of determination (r^2), bias, and interval of confidence (IC). The models used were machine learning (ML) algorithms and multiple regression least squares (OLS). The scenarios refer to the availability of explanatory variables for the modelling: Basic (B), Intermediate (I), and Wide (A).

		RMSE	r^2	Bias	IC	
Scenario B						
ML	Training	13.88	0.93	7.51	5.49	9.53
ML	Validation	23.20	0.70	−0.98	−10.32	8.37
OLS	Training	34.26	0.32	0.00	−5.92	5.92
OLS	Validation	32.88	0.39	−4.90	−18.01	8.20
Scenario I						
ML	Training	17.39	0.82	0.27	−2.73	3.28
ML	Validation	25.49	0.67	−9.36	−18.92	0.19
OLS	Training	33.53	0.35	0.00	−5.79	5.79
OLS	Validation	32.54	0.41	−5.89	−18.79	7.01
Scenario A						
ML	Training	5.20	0.99	3.97	3.38	4.56
ML	Validation	21.75	0.78	−0.50	−8.46	7.46
OLS	Training	32.61	0.35	0.00	−5.75	5.75
OLS	Validation	36.28	0.36	−5.67	−18.79	7.46

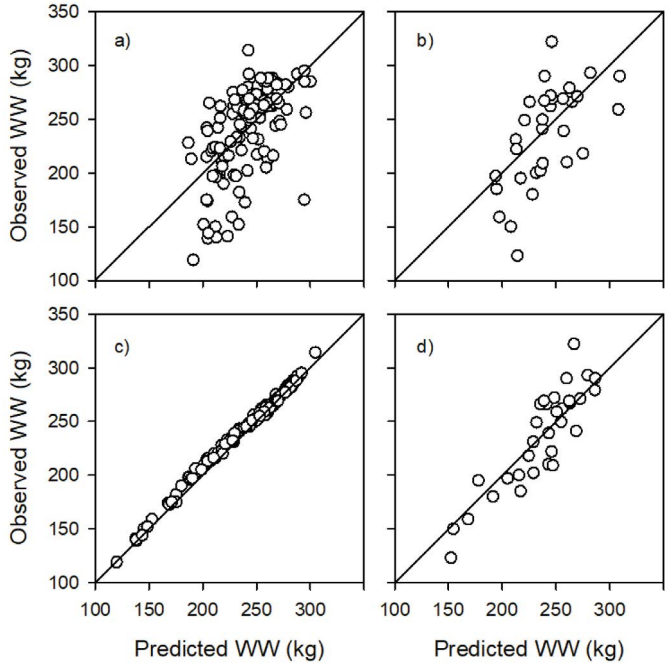

Figure 1. Ratio of the recorded and predicted WW values in scenario A, according to the fit of a multiple regression model with ordinary least squares (OLS) for the training (a) and validation (b) databases. Figures c and d belong to the machine learning (ML) model. The diagonal line stands for the 1:1 ratio.

678.30. In scenario B, the assemble for the best family was 538.06 and the deviance for the best individual model was 670.14. The lowest deviance values indicate a better model.

The most important variables for all ML and OLS models were: weaning_age, calf_ weight, dam parity, and dam_age_cal (Table 4). Racial purity variables were important for ML in scenarios I and A. Ancestry variables were only important for ML in scenario A. By itself, calf sex was not significant in any model. In the ML model, the importance of breeding bulls was significant; this phenomenon is discussed later on.

Scenario A was better than I for ML, because the ancestry variables were taken into account; r2 improved by 0.11 and both the bias and the interval of confidence were lower (Table 3). In the ML of scenario A, the sires with more progeny were important, particularly Ambition, whose offspring were light; meanwhile, Vet Mosco's offspring were also light, but it did not have the same importance (Table 5). The importance of breeding bulls for ML was closely linked to this database. Consequently, the WW dependence on the variables of scenario I was analyzed. Scenario I is an overall model with greater potential application, although it had a greater bias.

Management decisions are based on the weaning age variable and the dependency of WW on this variable showed a sigmoid shape in various ML models; however, a GLM model (such as OLS) had a linear and proportional dependency (Figure 2a). Therefore, there must be a window of opportunity where weaning age (≈200 to 225 d) had a significant influence and then, other factors determined WW. In the case of ML, Figure 2 shows similar dependency relationships between other variables of importance for the models, which were different in the case of the GLM. The vertical bars show the frequency of the

Table 4. Importance of the explanatory variables included in the machine learning (ML) or ordinary least squares (OLS) models in three explanatory variable availability scenarios, according to Table 1. The importance of the category variables is associated with a specific variable value.

Predictor variable	ML			OLS		
	B	I	A	B	I	A
dam_age_cal	0.15	0.12	0.02	0.08	0.06	0.07
dam_ weight_cal			0.08			
calving_weight	0.28	0.17	0.10	0.06	0.07	0.08
calving_date	0.20	0.10	0.04			
weaning_age	0.25	0.39	0.18	0.38	0.38	0.34
purity_calf		0.07	0.01			
purity_cow		0.03	0.03			
parity	0.11	0.10	2.17E-03	0.48	0.40	0.40
calf_sex: Female			0.02			
type_service: NM			4.59E-05		0.09	0.11
calf_sex: Male[1]						
Sire: AMBITION			0.48			
Sire: VET_MOSCO			0.02			
Sire: ROBLE			0.01			

[1]The breedings bulls were only important in the case of male calves. B: Basic, I: Intermediate, A: Wide.

Table 5. Weaning weight adjusted to 205 d (kg) of female (H) and male (M) descendants of the breeding bulls included in Table 4. Number of calves (n), average ($\bar{y}$), and standard deviation (s) for the complete database under study. Other breeding sires are not included.

Sire	Race	F			M		
		n	$\bar{y}\bar{y}$	s	n	$\bar{y}\bar{y}$	s
Ambition	Limousin	11	138.2	25.9	19	147.4	23.3
Vet Mosco	Limousin	13	151.1	31.4	14	145.9	35.8
Memin	Angus	3	155.6	26.5	6	153.2	19.8
Turcio	Limousin	7	154.2	21.3	8	156.5	18.8
Sucha	Limousin	16	169.6	21.2	13	157.3	32.1
Roble	Limousin	6	174.6	32.8	3	152.4	51.2
Highlander	Limousin	4	162.5	27.9	6	179.6	15.4
Hato		79	161.6	28.9	80	154.8	30.9

observations, together with the dependency graph, they point out how the WW prediction per model changes according to the accumulated evidence. Consequently, ML did not have a strong dependency on the increase of dam_age_cal (dam age at calving), because few older cows were recorded (Figure 2c).

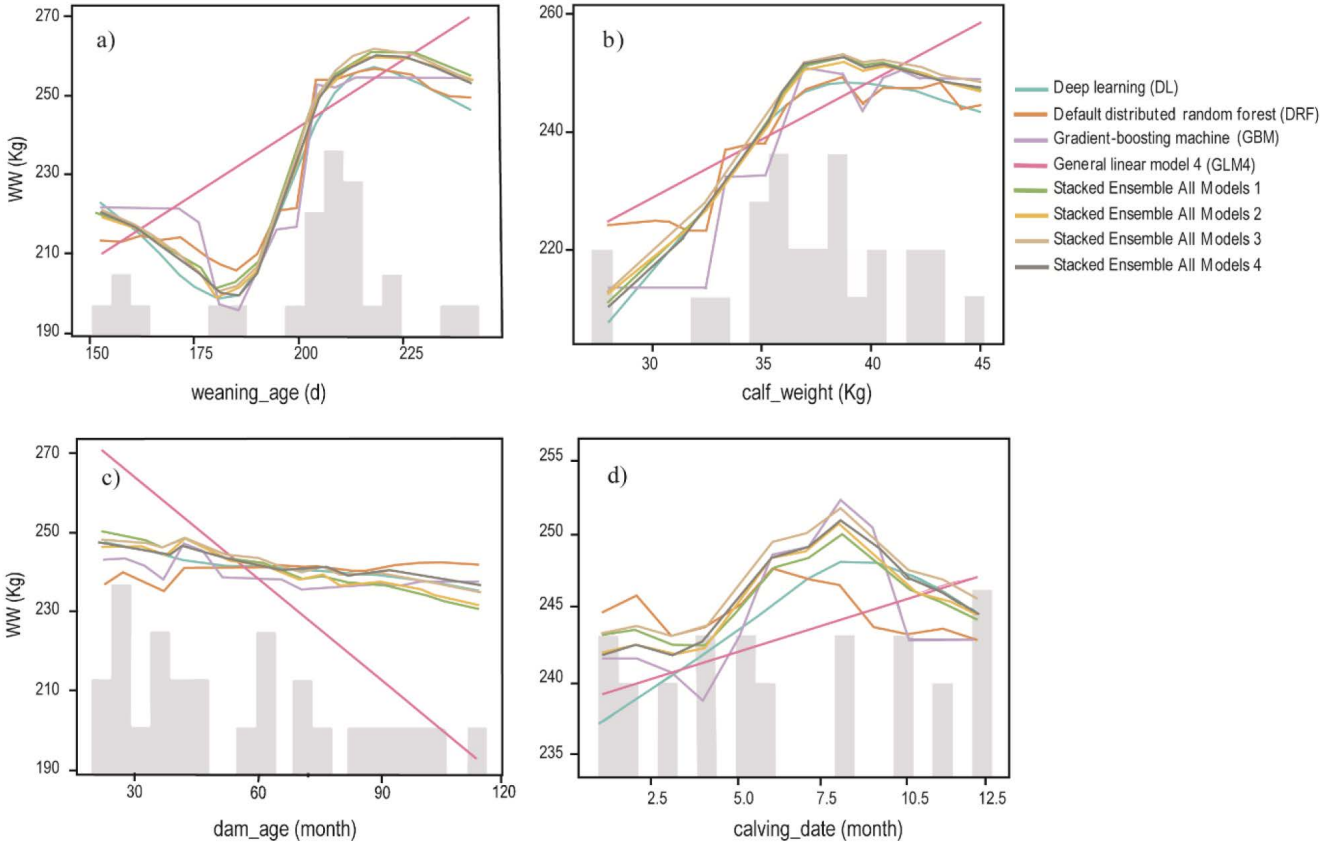

Figure 2. Partial dependency in scenario I for weaning weight (WW) according to: a) weaning age, b) calf weight, c) dam age at calving, and d) calving date. All the other variables remained fixed, assuming a lack of correlation with other explanatory variables. The bar graph points out the frequency of the data in the model validation database.

WW depended on calving_date during the summer. The uniform data frequency throughout the year was remarkable and therefore, ML algorithms do not simply depend on a greater number of data (Figure 2d). A potential increase in food quality and quantity during the summer suggested a greater milk yield and, consequently, a greater WW. Greater attention should be paid to these variables along with the changes in the weight of the dam during lactation. Nevertheless, measuring them in commercial operations is a difficult task. The ML models presented can be part of a reproductive planning and pasture budgeting strategy contributing to the optimization of the production plan, based on several important variables: seasonal variation of the production, longevity of the cows, and use of chosen breeding bulls.

CONCLUSION

The ML model assemble predicted the WW with a lower error and bias. It is an alternative tool to the traditional OLS, regardless of the number of variables available to train the model, even when only production variables that are essential for any cattle-raising operation are available. The best machine learning algorithm was XGBoost.

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AGRO PRODUCTIVIDAD

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Bat community structure in the Tabasco Plain wetlands

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ABSTRACT

Objective: To describe the diversity of bat communities in two types of wetlands in the coastal region of the Tabasco Plain.

Methodology: Sampling was carried out at two different times of the year (dry and wet seasons) for three consecutive years, considering two types of vegetation (mangrove and popal-tular). The samples were collected during 3 effective days (6 h periods with 30 min monitoring intervals) per station, using mist nets.

Results: A total of 510 individuals belonging to 22 species of six families were recorded; the phyllostomid bats were the most diverse and abundant. The *Artibeus jamaicensis*, *Noctilio leporinus*, and *Glossophaga soricina* species were the most representative. The vegetation with the greatest diversity was the mangrove with 18 species, while 12 species were found in the popal-tular areas. The diversity of order 1 indicates that the mangrove has 0.78 more diversity than the popal-tular. Seven food guilds were present, including the dominant frugivorous animals. Only three species fall within a protection category, according to NOM-059-SEMARNAT-2010; they comprise 12% of the protected species in the state of Tabasco, Mexico.

Implications: In order to determine their diversity and abundance —and ultimately to develop base information—, communities in the wetlands must be evaluated.

Conclusions: The mangroves host the greatest diversity and abundance of bats to which they provide shelter and food. Therefore, they are considered crucial for their conservation and, overall, they are important habitats for this group.

Keywords: Abundance, diversity, chiropteran, wetlands.

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INTRODUCTION

Wetlands are important ecosystems. Their functions include stabilizing the coasts —they are a protection barrier against natural phenomena—, being a natural water filter —they eliminate pollutants—, and accumulating nutrients through sediment deposition —they become areas with great biological productivity (López- Portillo *et al.*, 2010). They are of vital importance for many species, as they represent a source of food and

Image by Ben Mayr at Pixabay

natural shelters. They provide spawning and development sites for fish and insects, and they serve as a nesting area for various migratory birds (Blanco, 1999; Gatto *et al*., 2005; Villagran-Mella, 2006). Therefore, the conservation of these ecosystems is fundamental for the maintenance of biodiversity.

Meanwhile, these biotic systems are threatened by human activities: land-use changes and climate variations are the main factors behind the deterioration and fragmentation of these areas (Mitsch and Hernández, 2013). This situation reduces wildlife abundance in these environments, where ecosystem services can also be compromised and decrease in quality (Soberón, 2010; Badii *et al*., 2015). In wetlands, bats are insect population controllers (Gómez-Naranjo, 2017). Emballonuridae, Mormoopidae, Vespertilionidae, and Molossidae are included among the most abundant families (Ceballos and Olivia, 2005). Establishing the vertebrates' abundance and diversity is of vital importance to determine the habitat's conservation degree (Tellería, 2013). Given the scarce information about chiropteran in the flooded environments of southeastern Mexico, data about the structure of the bat community in different wetlands of the Tabasco Plain must be obtained.

MATERIALS AND METHODS

The study area is located in the Gulf Coastal Plain and the Grijalva sub-basin sections, Tabasco, Mexico (Figure 1). It has an area of 8,475.77 km^2 and it includes the municipalities of Centla, Centro, Jalpa de Méndez, Macuspana, Nacajuca, and Paraíso.

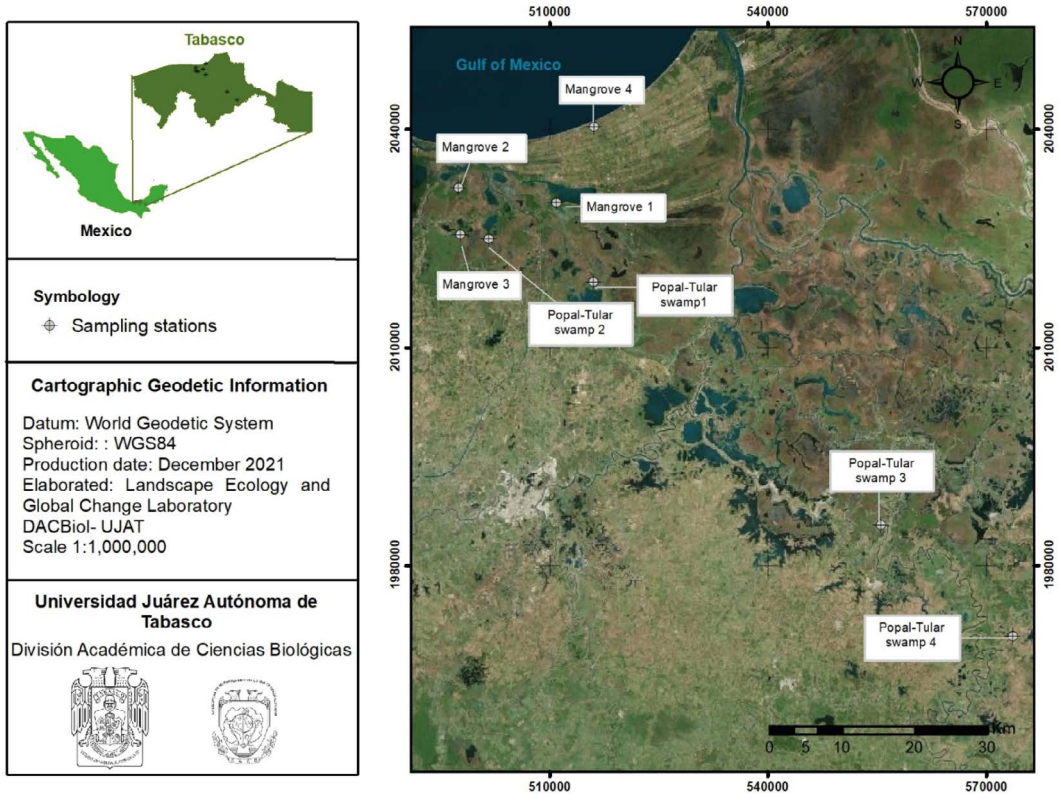

Figure 1. Delimited study area and location of sampling stations in the flooded area of the Tabasco Plain.

Only climatic group A is included in this the zone, represented by three types: Aw (in just one part of the eastern region of the territory), Am (in the east-west strip) (Galindo *et al.*, 2006). It has a mean annual temperature of 27 °C, with an average annual rainfall of 2,550 mm (INEGI, 2016). In Tabasco, the year can be divided into three climatic seasons: a) dry, from March to May; b) wet, from June to September; and c) North winds (nortes), from October to February (Moguel and Molina-Enríquez, 2000).

In this study, two types of vegetation (mangrove and popal-tular) were selected in each type of wetland, at four stations (Figure 1). Those sampling areas that met the selected types of vegetation (mangrove and popal-tular), that had a minimum area of 100 ha per vegetation fragment, that were easily accessible, and that guaranteed the safety of the work team were considered viable. The samples were collected during 3 effective sampling days per station in the dry and wet seasons. Data collected for three consecutive years were used.

During the sampling, four 12-m long × 2 m wide mist nets were installed, which remained open from 6:00 p.m. to 12:00 a.m. and were checked at 30-min intervals. The captured individuals were identified according to the field guide for bats (Medellín *et al.*, 2008), using the nomenclature developed by Ramírez Pulido *et al.* (2014). After they were identified, the bats were released at the capture point.

For data analysis, the Chao 1 estimator was used to determine the probable number of species observed. Specific abundance was determined as the total number of chiropteran species recorded. The species accumulation curve was used to determine the increase in species (observed abundance) during the seasonal sampling for each type of vegetation. The greater the sampling effort, the greater the number of species collected (Jiménez and Hortal, 2003), until the abundance reaches a maximum and stabilizes at an asymptote (Escalante, 2003). Diversity was analyzed with order 1 (Shannon index exponential). Consequently, all species are considered in the diversity value and proportionally weighted according to their abundance in the community (Hill, 1973; Jost, 2006, 2007; Tuomisto, 2010a, 2010b, 2011; Moreno *et al.*, 2011). These parameters were estimated with the EstimateS 9.0 software (Colwell, 2013).

Based on the existing bibliography on feeding habits, seven types of feeding guilds (frugivorous, omnivorous, insectivorous, carnivorous, nectarivorous, hematophagous, and piscivorous) were taken into consideration (Ceballos and Navarro, 1991; Ceballos and Oliva, 2005; Giannini and Kalko, 2004; Kalko and Hadley, 2001).

The conservation status of the identified species was established following NOM-059-SEMARNAT-2010 (SEMARNAT, 2010). The four categories used in the standard were considered: Probably Extinct in the Wild (E), Endangered (P), Threatened (A), and Subject to Special Protection (Pr).

RESULTS AND DISCUSSION

We captured 510 individuals belonging to 22 species from six families. The Phyllostomidae family has the greatest diversity (14 species) and abundance (420 individuals), followed by Vespertilionidae (4 species and 7 individuals), and Noctilionidae (1 species and 66 individuals). Only one species each has been recorded for the Molossidae, Emballonuridae and Morpoopidae families. The most abundant species is

Artibeus jamaicensis (273 individuals), followed by *Noctilio leporinus* (66) and *Glossophaga soricina* (43).

The mangrove was more diverse (18 species) and more abundant (417 individuals) than the popal-tular, where 93 individuals of 12 species were captured. Of the eight sampling stations, mangrove 4 and mangrove 1 have the greatest diversity (12 and 10 species, respectively) and the greatest abundance (268 and 81 individuals, respectively).

Regarding the sampling years, the greatest diversity was obtained in 2012 (13 species), while in 2010 and 2011 only 12 species were found. Regarding abundance, we captured 235 individuals in 2010, 127 in 2011, and 147 in 2012 (Table 1).

There was a greater abundance in the wet season (335 individuals of 16 species) than in the dry season (175 individuals of 15 species). The highest number of species (11) was recorded during the 2012 rains, followed by the 2010 rains (10). The highest abundance of individuals was recorded in the 2010 rains (171 individuals), followed by the 2012 rains (92 individuals).

The mangrove 1 and mangrove 4 sampling stations showed the greatest diversity by season (7 species) during the 2012 rains, followed by mangrove 4 in the 2011 rains (6 species). The highest abundance was recorded in mangrove 4 during the 2010 and 2011 rains (86 and 42 individuals respectively), followed by mangrove 1 in the 2011 rains (42 individuals) (Figure 2).

The species accumulation indicates that the observed diversity consisted of 22 species, equivalent to 81.48% of the species expected for the study area. However, according to the Chao1 index, 27 species should have been found. The diversity of order 1 indicates that the mangrove (5.49) has +0.78 more diversity than the popal-tular (4.71). That is to say, the popal-tular has 85.79% of the diversity of the mangrove. According to the sampling year, the greatest diversity was found in the mangrove for the years 2012 and 2011. The popal-tular had the greatest diversity in 2010 and the lowest in 2012 (Figure 3).

Bat communities include seven food guilds: frugivorous have the most diverse presence with ten species (all belonging to the Phyllostomidae family), followed by insectivorous with seven species. The remaining guilds (omnivorous, carnivorous, nectarivorous, hematophagous, and piscivorous) only have one species each. According to abundance,

Table 1. Richness and abundance of each sampling station per year.

Sampling station	2010		2011		2012	
	Richness	Abundance	Richness	Abundance	Richness	Abundance
mangrove 1	5	19	2	15	7	47
mangrove 2	4	21	4	16	1	2
mangrove 3	2	14	1	2	4	13
mangrove 4	7	107	6	89	9	72
popal-tular swamp 1	4	9	1	1	1	3
popal-tular swamp 2	4	17	2	2	2	3
popal-tular swamp 3	5	35	0	0	2	5
popal-tular swamp 4	3	13	2	2	3	3
Total	12	235	12	127	13	148

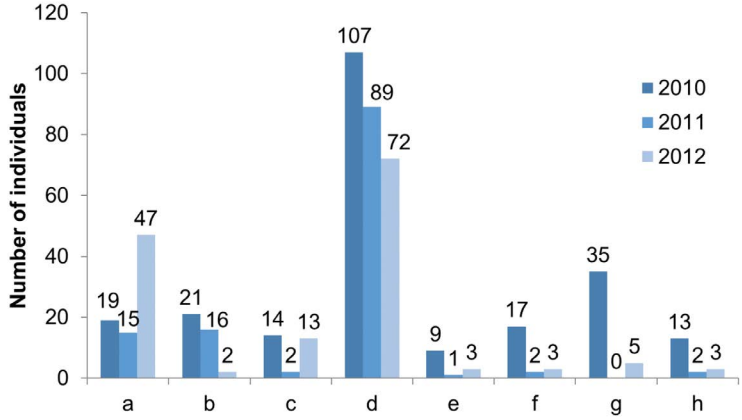

Figure 2. Abundance in sampling stations per year. a) mangrove 1, b) mangrove 2, c) mangrove 3, d) mangrove 4, e) popal-tular 1, f) popal-tular 2, g) popal-tular 3, h) popal-tular 4.

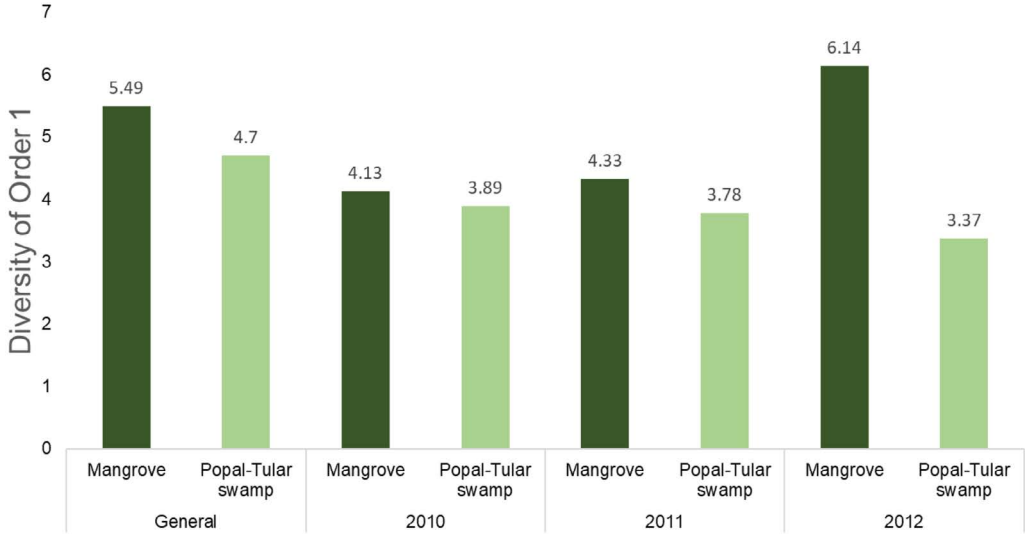

Figure 3. Vegetation diversity per sampling year.

frugivorous are the dominant species with 364 individuals (291 in mangroves and 73 in popal-tular), followed by piscivorous, with 66 individuals (55 in mangroves and 11 in popal-tular), and nectarivorous with 43 individuals. By number of species, frugivorous were the most abundant in both types of vegetation (9 and 5 species, respectively), followed by insectivorous with four species in both mangrove and popal-tular. Meanwhile, omnivorous and hematophagous bats were only present in the mangrove area.

Regarding the species protected by NOM-059-SEMARNAT-2010 (SEMARNAT, 2010), 21 individuals of three species are reported. *Rhynchonycteris naso* and *Myotis carteri* are "Subject to Special Protection (Pr)", while *Trachops cirrhosus* is " Threatened (A)". Both *M. carteri* and *T. cirrhosus* were reported in both seasons, while *R. naso* was only found in dry seasons and in the mangrove.

The diversity of bats obtained in the present study is similar to that reported by Sánchez-Hernández *et al.* (2005), Moreno-Bejarano and Álvarez-León (2003), Andrade

et al. (2008), and Gordillo-Chávez *et al.* (2015), all of whom conducted their research in wetlands. The mangrove had the greatest diversity of chiropteran, because of its larger vegetation structures, which offer better shelter and food conditions. Other researchers have shown that the diversity of species in bat communities tends to increase in more complex habitats, since they provide bats with more options for food, shelter, and perch sites, as well as protection against predators (Castro-Luna *et al.*, 2007; Bobrowiec and Gribel, 2010; García-García and Santos Moreno, 2014; García-Morales *et al.*, 2014).

Frugivorous bats showed the greatest diversity and abundance in both types of vegetation. Most of the species that make up the guild —such as *Artibeus jamaicensis*, *Artibeus lituratus*, or *Carollia perspicillata*— are versatile in terms of food and shelter selection (Galindo-González, 2004; Ceballos and Oliva, 2005; Estrada-Villegas *et al.*, 2010). In this sense, wetlands have a high natural productivity, offering food and protection resources for frugivorous bats, which mainly depend on the availability of food. The presence of frugivorous bats benefits these types of environments because these bats disperse seeds (Galindo-González, 1998; Olea-Wagner *et al.*, 2007).

The second most diverse guild were the insectivorous bats. In this regard, it can be inferred that the type of sampling used did not match the foraging habits of the species belonging to this guild. García-Morales (2021) points out that insectivorous species are the most diverse in wetlands. Such is the case of *Molossus rufus*, *Pteronotus davyi*, or *R. naso*, which feed on the surface of water bodies or in clear spaces in the vegetation, in addition to having a more developed echolocation system that allows them to detect nets more easily (Kalko and Hadley, 2001; Andrade *et al.*, 2008). On the one hand, research carried out in wetlands near the study area include few or no records of insectivorous bats (Sánchez-Hernández, 2005 and Gordillo-Chávez *et al.*, 2015, Plasencia-Vázquez *et al.*, 2020). On the other hand, these species are more abundant in the wetlands of other countries —such as Colombia (Moreno-Bejarano *et al.*, 2003) or Brazil (Andrade *et al.*, 2008)— and are not under any category of risk. This situation would reaffirm the protection status assigned to species recorded in this study, such as *M. carteri*, *R. naso*, and *T. cirrhosus*, which are considered typical of mangroves. The protected species reported in this study are equivalent to 12% of the total chiropteran species reported for Tabasco, Mexico (Hidalgo-Mihart *et al.*, 2015; Valdez-Leal *et al.*, 2019).

CONCLUSIONS

The wetlands of the Tabasco Plain house 26.82% of the bat species distributed in Tabasco, Mexico. The Phyllostomidae family is the most diverse and abundant in the study area. The most abundant species within the study were *A. jamaicensis* and *G. soricina*, which rank as the most common species in most studies of neotropical bats. Based on seasonality, the greatest diversity in the mangrove was recorded during the dry season, while the greatest diversity in the popal-tular was recorded during the wet season. The greatest diversity was recorded in 2012 and 2010 for the mangrove and the popal-tular areas, respectively. The wetlands are home to bat species from seven different food guilds; frugivorous bats have the largest number and the most abundant species. Only three species of bats (*R. naso*, *M. carteri*, and *T. cirrhosis*) were recorded under some category of protection; these

were the first species recorded in the wetland areas in the state of Tabasco. The greatest diversity and abundance of bats were recorded in the mangroves. Consequently, this type of vegetation is considered crucial for the conservation of this group of mammals.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Cow milk production cost in a semi-specialized system in the mountainous region of Veracruz, Mexico

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ABSTRACT

Objective: To analyze cow milk production cost in farm production units (UPPs), in a semi-specialized system, in the mountainous region of Veracruz, Mexico.

Design/Methodology/Approach: A questionnaire was applied to milk producers; additionally, the production units were visited.

Results: The main elements of the variable cost of milk production included: feeding, animal health, and fuel (86% of the total). The workforce accounted for 35 to 60% of the fixed costs. The production cost per liter fluctuated between USD$0.26 and USD$0.352 and the selling price ranged from USD$0.28 to USD$0.30; consequently, the profit margin is low. The profit per liter of milk fluctuated between USD$0.02 and USD$-0.04. The improvement in milk quality can increase profitability.

Study Limitations/Implications: The analysis focuses in the last year of operations and only takes into account six production units; therefore, the conclusions are only valid in that context.

Findings/Conclusions: Some UPPs have a positive profit; however, the combination of production factors must be reviewed. Additionally, in order to guarantee that more producers obtain a profit, some adjustments must be made.

Key words: Economic analysis, dairy cattle, milk quality, profitability.

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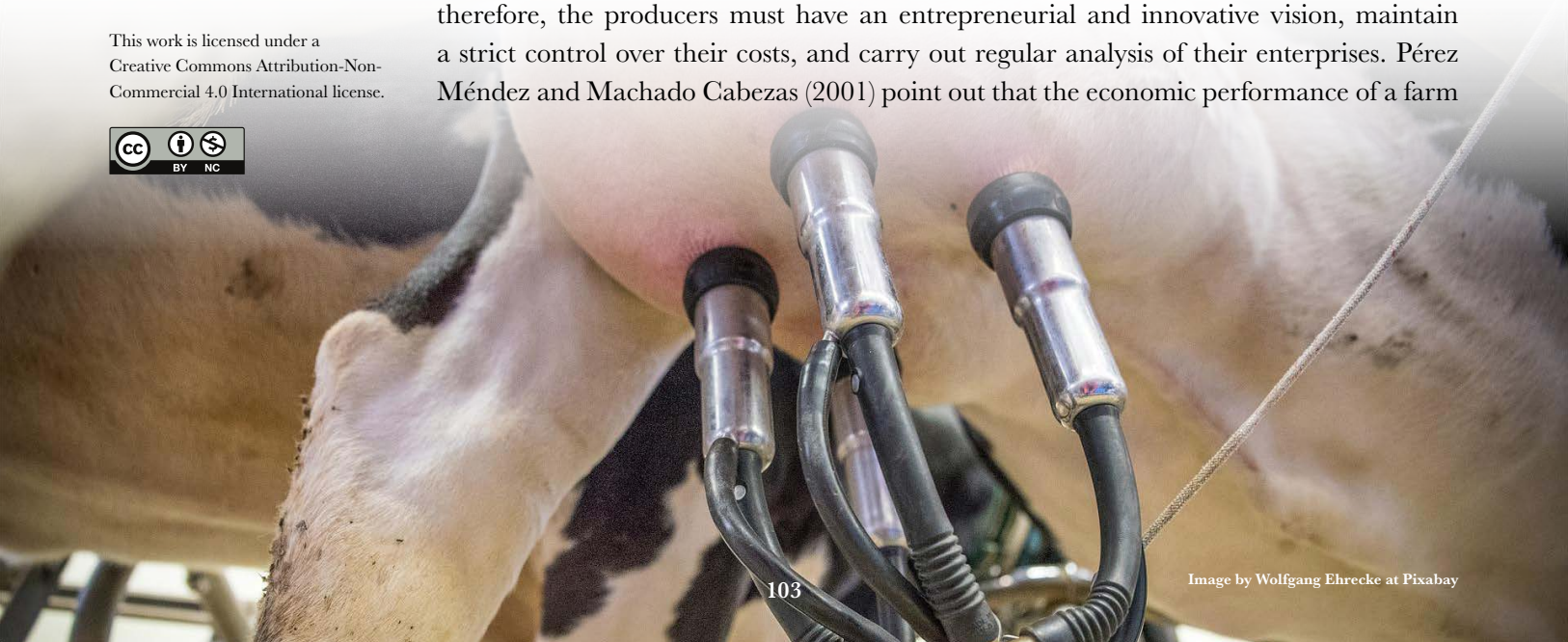
INTRODUCTION

Agricultural businesses have the same complexity than any other economic sector; therefore, the producers must have an entrepreneurial and innovative vision, maintain a strict control over their costs, and carry out regular analysis of their enterprises. Pérez Méndez and Machado Cabezas (2001) point out that the economic performance of a farm



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depends on the ability of the managers to guide the farm production unit (UPP) towards the optimization of its profits, using economic techniques that can help them during the decision-making process. Profits must be planned, it is not just something that producers can expect to obtain at the end of the year (Makeham and Malcom, 1986).

Additionally, during the last years, the livestock sector has changed at an unprecedented pace. As a result of the innovative technologies and the structural changes in the sector, livestock production has experienced a significative increase (FAO, 2019). Nevertheless, millions of people in rural areas still use traditional cattle production systems, which are their livelihood and guarantee the food security of their families (FAO, 2021). In Mexico, milk production is carried out in different ecological regions and producers utilize different production systems (Loera and Banda, 2017). In Veracruz, the semi-specialized system is mainly used in the mountainous region (Pérez *et al.*, 2004). However, the number of studies about the semi-specialized system is very small; therefore, the objective of this study was to evaluate the economic situation of farm production units (UPPs) that carry out their production activities using the semi-specialized system and to offer recommendations aimed to achieve a higher economic efficiency.

MATERIALS AND METHODS

The work field stage of this study was carried out from January 2021 to May 2021, in Xico, Ixhuacán de los Reyes, and Jilotepec, in the mountainous region of Veracruz, Mexico. A survey was exclusively carried out with cattle farmers who use a semi-specialized dairy system. The producers took part in the survey voluntarily. The milk production cost was calculated using the FIRA (Trust Funds for Rural Development) methodology proposed by Trejo-González and Floriuk-González (2010).

The six farm production units (UPPs) that were studied developed their livestock activities with a milk production semi-specialized system, using *Bos taurus* genotypes (Holstein and Brown Swiss). All the UPPs use mechanical milking, twice a day. Animals graze mainly on rye grass (*Lolium hybridum*), kikuyo grass (*Pennisetum clandestinum*), and white clover (*Trifolium repens*); they also have unlimited access to water and mineral salts. Cattle is fed twice a day (during the morning and the afternoon), in a field rotation system. During the milking, they also receive a concentrate supplement —18% protein: 1 kg per every three liters of milk produced by the cow—, divided into two portions (morning and afternoon). The six UPPs developed a health program that includes de-worming, vitamins, and vaccination (bovine rabies, clostridial disease, and pasteurellosis). The six UPPs use artificial insemination, with reproductive status diagnosis.

A convenience selection process was used to choose the cattle farmers that took part in the study. For this purpose, the profile of the research subject was defined. Cattle farmers who own semi-specialized milk production enterprises were chosen. Additionally, they should be enrolled in the programs developed by the Secretaría de Agricultura y Desarrollo Rural (SADER) (national level) and the Secretaría de Desarrollo Agropecuario, Rural y Pesca (SEDARPA) (state level). Producers must also have production and economic records and they should be willing to share their information and take part in the study.

The producers that met the selection criteria and agreed to take part in the research were subjected to a survey that covered the following points: their production units, the identification data of the enterprises, the available resources, the production volume, the technologies they use, the list of their assets, and their cost and sales strategies. During the visits to the production units, we checked the facilities, the animals, and the logbooks. All the field data for each production unit were input into a Microsoft Excel spreadsheet. The data were subjected to a descriptive statistical analysis. All the values were converted to US dollars.

RESULTS AND DISCUSSION

Characteristics of the chosen UPPs

Just like other UPPs, milk producers have a limited control of the technical-administrative information (Parra-Cortés and Magaña-Magaña, 2019); consequently, only six enterprises with records agreed to take part in the study. The average size of the properties is 18.33±7.45 ha (8-30 ha), with a herd of 63.17±38.31 heads (37-139 heads), and an animal stock average of 4.07±3.38 AU ha^{-1} (2.1-10.7 AU ha^{-1}). Most of the herds have similar characteristics.

Technology use and productive indicators

Overall, there is a high use of technology. All the UPPs carry out health (vaccination, de-worming, and other) and mineral supplementation practices. Cows receive concentrate supplement, stubble, and fodder. All UPPs carry out only artificial insemination. The differences in size, management, and use of technology in the UPPs determines differences in the production; consequently, calving rate fluctuates between 60 and 85%, the production per cow varies from 6 to 16 kg d^{-1}, and milk production per lactation per cow ranges from 3,000 to 7,560 kg. The average calving rate of the UPPs in the study was 74.16±11.58%. The average milk production per lactation was 4,785±1,511.21 kg. In fact, only UPP1 had a milk production per lactation of 7,560 kg. Five UPPs sell calves five days after they are born, with an average weight of 38.5 kg; however, one UPP sells 200-kg breeding bulls, at twice the price per meat kg.

Income

In this production system, the income comes from selling different products and each product contributes a different rate of the said income. Milk production accounts for the highest percentage of the income and, to a lesser degree, fattened male calves and heifers, as well as cull cows, also contribute to the income. The selling price per unit fluctuated between USD$0.28 and USD$0.30 per liter of milk. The annual amount of milk sold per UPP ranged from 40,000 to 219,000 L, accounting for 77.33-97.44% of their total income. The total annual average of income per UPP was USD$29,830.51±19,085.78 (USD$13,532.53-$66,043.37). The average income of milk sales was USD$27,224.10±18,750.85 (USD$12,144.58-$62,269.88) (Table 1). Osorio (2001) pointed out that a low production level is characterized by a negative economic margin per liter; consequently, producers lose money and must sell other products.

Table 1. Income and sales rate of milk, calves, cull cows, and breeding bulls of six farm production units in the mountainous region of Veracruz, Mexico.

Farm	Total income (US$)	Income from milk sales (US$)	Income from milk sales (%)	Income from calves sales, (US$)	Income from calves sales (%)	Income from culling cows, (US$)	Income from culling cows (%)
1	33,850.60	32,983.13	97.44	867.47	2.56	-	-
2	24,053.01	22,361.45	92.97	650.60	2.70	1,040.96	4.33
3	16,881.93	13,055.42	77.33	2,342.17	13.87	1,484.34	8.79
4	24,621.59	20,530.12	83.38	3,513.25	14.27	578.22	2.35
5	66,043.37	62,269.88	94.29	650.60	0.99	3,122.89	4.72
6	13,532.53	12,144.58	89.74	867.47	6.41	520.48	3.85

Structure of cost production

In average, the total cost was USD$31,550.26±22,691.54, resulting from the addition of variable costs (USD$23,664±17,614.31) and fixed costs (USD$7,886.18±5,312.34) (Table 2). Out of the variable costs, the headings in which the UPPs had the highest average expenditurewere:feeding(USD$15,964.28±12,378.96),health(USD$2,144.59±1,901.29), fuel (USD$2,006.10±938.03), mineral supplement (USD$1,318.38±1,370.46), technical support (USD$1,028.12±141.87), insemination (USD$734.94±557.41), grassland maintenance (USD$630.52±563.89), and NLIS (National Livestock Identification System) ear tags (USD$56.87±29.13). The average values for fixed costs were: regular workforce (USD$5,833.90±4,445.63); opportunity costs (USD$1,444.25±765.74); depreciation (USD$318.87±184.94); and management (USD$289.16).

Variable costs accounted for 63.20 and 83.26% (73.81%±7.54) of the total cost, while fixed costs ranged from 16.74 to 36.8% (26.20%±7.54). These results do not match those reported by Sánchez-Medina *et al.* (2018), who conducted research in 24 family farms in the State of Mexico and recorded variable costs that accounted for a 90.7% average. The main elements of variable production costs were feeding, health, and fuel. These components accounted for 86% of the total cost. The average values were: feeding (67.46%), health (9.06%), fuel (8.48%), mineral supplement (4.64%), technical support (4.34%), artificial insemination (3.11%), grassland maintenance (2.66%), and NLIS ear tags (0.24%). According to Moran (2009) more than half of the costs of small dairy enterprises are related to feeding; consequently, Moran recommends growing forage instead of buying it. Additionally, Moran suggests using the milk sales income minus the feeding cost as a profitability indicator, because it is simple and easy to measure. The average percentages of each fixed cost heading were: regular workforce (73.98%), opportunity costs (18.31%), depreciation (4.04%), and management (3.67%). Given that fixed costs are not impacted in the short term by the production volume and are independent of the production activity of the UPP, they must always be kept at a minimum (Novaes *et al.*, 2001).

Livestock products are the sole source of financial resources for the production system. Three UPPs surpassed the break-even point and entered the profit stage. The net margin fluctuated between −19.15 (UPP6) and 11.28 (UPP5).

Table 2. Income and production costs of six farm production units in the mountainous region of Veracruz (US$).

Item	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
Feeding	21,227.23	9,700.96	4,915.66	12,243.37	38,664.82	9,033.64
Drugs and vaccines	2,438.55	1,132.53	608.67	1,903.61	5,783.13	1,001.06
Fuel	2,313.25	1,610.60	1,132.53	1,610.60	3,759.04	1,610.60
Mineral supplement	667.90	699.57	554.12	6,07.52	3,759.04	911.28
Technical asistence	1,204.82	963.86	963.86	867.47	1,204.82	963.86
A.I.	722.89	578.31	265.06	530.12	1,831.33	481.93
Pasture management	867.47	307.23	307.23	307.23	1,686.75	307.23
NLIS eartags	28.92	49.16	31.81	52.05	106.99	72.29
Total, variable costs	29,471.03	15,042.22	8,778.94	17,514.45	56,795.92	14,381.89
Variable costs, %	79.18	66.80	63.20	74.57	75.82	83.26
Labor	6,265.06	5,397.59	3,759.04	4,096.39	14,216.87	1,268.43
Opportunity cost	952.53	1,546.80	819.28	1,343.33	2,912.00	1,091.57
Depreciation	243.37	243.37	243.37	243.37	696.39	243.37
Administration	289.16	289.16	289.16	289.16	289.16	289.16
Total, fixed costs	7,750.12	7,476.92	5,110.84	5,972.24	18,114.41	2,892.53
Fixed costs, %	20.82	33.20	36.80	25.43	24.18	16.74
Total Costs	37,221.15	22,519.14	13,889.79	23,486.70	74,910.34	17,274.42
Total Income	33,850.60	24,053.01	16,881.93	24,621.59	66,043.37	13,532.53
Gross Margin, USD$	−3,371	1,534	2,992	1,135	−8,867	−3,742
Gross Margin, %	−9.96	6.38	17.72	4.61	−13.43	−27.65

Milk production cost

The unit cost of production is an excellent indicator of competitiveness (Muñoz-Luna and Rouco Yañez, 1997; Lobos *et al.*, 2001). The sold milk volume fluctuated between 40,000 L (UPP 6) and 219,000 L (UPP 5), the cost production ranged from USD$0.268 (UPP2) to USD$0.386 (UPP6), and the selling price varied from USD$0.29 (UPP2) to USD$0.315 (UPP3 and UPP6); therefore, the production cost in UPP2, UPP3, and UPP5 was lower than the selling price, unlike UPP1, UPP4, and UPP6. The production cost varies vastly between UPPs. It is the result of the decisions that each producer makes regarding the investment and the management of available resources. The cost per liter does not depend on a higher milk production, but on an efficient management and the reduction of variable costs (particularly, feeding).

Holmann (1998) pointed out that the most intensive milk production system does not generate an increase that is proportional to the investment levels required to achieve profitability. This situation must be evaluated in the livestock production context and under low economic resources conditions. Strategies and mechanisms must be identified to allow producers to achieve a better combination of production factors, aiming to create a financial fluctuation that will provide them cash throughout the year.

Vázquez-Selem *et al.* (2020) evaluated the economic efficiency of a dual-purpose system (SDP) and a dairy family enterprise with a semi-specialized system in Veracruz.

They pointed out that there is direct correlation between technology implementation and the financial profitability and the economic efficiency that the producers can achieve. Consequently, mechanisms and policies aimed at the technological upgrading of the milk production systems must be developed. Meanwhile, as part of their analysis about family milk production in the Valle del Mezquital, Espejel-García *et al.* (2016) interviewed 66 selected milk producers and identified five innovations that improved production: silage feeding, artificial insemination, mechanical milking, quality analysis, and integration into a collective tank.

Identification of improvement points

Overall, the improvement points that were identified have a direct relationship with milk quality and they impact the final price of milk. According to the survey results, the main problems that the UPPs face are sub-clinical mastitis (66%) and the presence of solids in the milk (50%). All the producers in this study sell their milk to Liconsa, Nestlé, or to a cheesemaker. The enterprises award quality bonuses to producers who comply with low levels of somatic cells and reductase; who do not use antibiotics; whose product has good protein and fat content; whose certificate of herd free of brucellosis and tuberculosis is in force; who produce up to 3,000 L; and who deliver the milk to the enterprise in an ongoing and permanent basis. For their part, cheesemakers do not buy milk based on its quality and they handle the payment according to the time of the year (USD$0.22-USD$0.31).

CONCLUSIONS

Feeding is the main concept that determines milk production cost in units that use semi-specialized systems, in the mountainous region of Veracruz. This aspect can be used as a good predictor for milk production cost, based on the current market prices in the study region.

In the case of producers who sell their product below its actual production cost, most of their income comes from selling milk and their variable costs account for 80% of the total cost. Consequently, they should carry out adjustments. Improving milk quality would help to obtain a higher sale price. However, producers must reduce the number of somatic cells and reductase, guarantee the continuity of the cooling chain, and make sure that there are no antibiotic residues in their milk production.

Keeping records and economic and production indicators will allow the UPPs to plan their improvement activities, making them more effective, optimizing their workforce, and looking for less expensive feeding alternatives. This type of study must be carried out periodically in order to determine profitability changes in the UPPs and to provide a wider and brief scope for the decision-making process. Finally, the transformation of UPPs into appropriate legal entities would help them to commercialize their products and would facilitate their access to new markets and diverse financial entities.

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AGRO PRODUCTIVIDAD

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Insects: An alternative for sustainable production in Mexico

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ABSTRACT

Objective: To analyze the sociocultural, economic and environmental aspects of insects in Mexico.

Design/Methodology/Approach: A bibliographic review was conducted from October 2021 to January 2022, searching for literature available in databases from Google Academic, Sciencedirect, SpringerLink, Google Patent, EBSCO, Semantic Scholar and the content available through the remote access of the CONRICyT. The bibliographic systematization of the articles consulted was developed using the Excel 2016 software and the Mendeley Desktop version 1.19.4 software.

Results: Entomology presents high ecological, economic and social value, directed towards the horizons of food security, care for the environment, and as an alternative for productive diversification. The economic importance that edible insects represent for Mexico stood out, visualizing commercial alternatives for small-scale producers.

Study Limitations/Implications: The results only present data referring to Mexico.

Findings/Conclusions: The importance of sustainability that insects in Mexico present was made evident. Practices to raise awareness are suggested, which mitigate neophobia and strengthen the adoption and consumption of this resource in the different social strata of the Mexican society.

Keywords: Mystical, playful, medicinal, environmental, edible.

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INTRODUCTION

Facing the constant increase of the human population, food insecurity is becoming a challenge of global nature (Van Huis and Oonincx, 2017); therefore, there is an inquiry about the search for food as an alternative for sustainable consumption and production (Batat and Peter, 2020). Within this context, the phylum Arthropoda (particularly the class Insecta), the largest group of the animal kingdom, is considered an ideal candidate as

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option for food rich in proteins, fats and minerals, and friendly with the environment, which can contribute to mitigate problems of hunger and malnutrition (Puzari, 2021).

The consumption and use of insects is an ancestral activity represented approximately by 3,071 ethnic groups, who search for, harvest, prepare, store and trade this resource in a sustainable way, allowing the conservation of 90% of the natural germplasm (Ramos-Elorduy, 2009). Although the origin of entomophagy (consumption of insects) is unknown, it is believed that the first experiences emerged from the guest-host relationship in which humans hosted parasitic organisms (fleas and lice), which they acquired in the transition from nomad to sedentary living, projecting entomophagy to approximately 10,000 years ago (López de la Cruz *et al.*, 2015).

Insects are part of the human diet in different places of the planet, particularly in countries of Asia, Africa and Latin America. This resource is rich in nutrients and considered a delicacy for its consumers, particularly in Japan, Australia and Europe (Raheem *et al.*, 2019). In fact, entomophagy is practiced in every country, particularly in human groups of low income, by consuming eggs, larvae, pupae and adult organisms (Feng *et al.*, 2018).

In addition to the nutritional benefits, insects also present a series of economic and ecological advantages, since they carry out functions such as pest control, pollination and nutrient recycling. Their production is low-cost and reduces environmental problems such as agricultural pressure, aquaculture and animal breeding, by requiring less reproductive time, less amount of soil, water and food (Barton *et al.*, 2020).

In Mexico, the consumption of insects constitutes part of the culture and identity of different ethnic groups; they are natural resources that society has known how to exploit, characterizing gastronomy from various communities, particularly in rural, peasant and indigenous zones (López de la Cruz *et al.*, 2015).

Comparatively to other means of subsistence from animal protein (pork meat and beef), which cause great environmental problems, insects are a means of protein purveyance based on a sustainable model; therefore, the Food and Agriculture Organization of the United Nations (FAO) recommends the consumption and production of these organisms (Iseppi *et al.*, 2021). In parallel, the intake of arthropods that could become pests reduces the use of chemical contaminants that harm the environment. Therefore, eliminating pests by consuming them can be a practical and promising path (Van Huis and Oonincx, 2017).

Regarding food conversion, to produce 1 kg of beef, 10 kg of feed are required; for 1 kg of pork, 5 kg of feed; and for 1 kg of chicken, 2.5 kg of feed; this is all of low environmental sustainability (Fleta-Zaragozano, 2018). In turn, only 1.7 kg of feed is necessary to produce 1 kg of insects (Saara-Maria *et al.*, 2019). Under the same context, the water footprint represented by the production of insects per ton (4,341 m^3) is relatively low, compared to beef (154,115 m^3) and pork meat (5,988 m^3) (Van Huis and Oonincx, 2017).

It has been shown that greenhouse gas emissions from the production of insects is low, compared to emissions from beef production; for example, the emission of methane gas in insect breeding ranges between 0.00 and 0.16 g kg^{-1} of mass per day, compared to the emission of cattle which in average produces 0.239 g kg^{-1} of corporal mass per day (Anankware *et al.*, 2015).

Because of the aforementioned, this review had the objective of analyzing the sociocultural, economic and environmental aspects of insects in Mexico.

MATERIALS AND METHODS

A bibliographic search based on scientific literature was applied for the development of this study. The review was centered on the search for cultural (medicinal, mystical, playful, aesthetic and decorative), nutritional, environmental (pollination, biodegradation, biological pest control) importance, forms of consumption, price of sale and perspectives of consumption in Mexico. The articles available in databases in Google Academic, Sciencedirect, SpringerLink, Google Patent, EBSCO, and Semantic Scholar were identified, as well as the content available through the remote access of the CONRICyT. To filter the information, keywords were used such as: entomophagy, entomophagy and sustainable development, importance of insects in Mexico, food security and edible insects, entomologic environmental services, among others (all terms in Spanish). To order, classify and generate the references of the articles consulted, the Excel 2016 software and the Mendeley Desktop version 1.19.4 software were used. This review began in the first week of October 2021 and concluded in January 2022.

RESULTS AND DISCUSSION

Cultural value of insects in Mexico

Since immemorial times, insects have been part of the cultural identity of different ethnic groups, constituting part of their diet, medicine, art, with religious and mystical value; at the same time, they have strengthened the biocultural diversity of various social groups that have given them a value and respect for natural resources (Ramos Elorduy *et al.*, 2006; Ramos Elorduy and Viejo Montesinos, 2007; Costa Neto, 2015) (Tables 1, 2, 3 and 4).

Nutritional value of the insects

The dietary habit and preference for the consumption of insects in each region is linked to the historical background and geographical origin, in addition to their abundance, easy harvest and nutritional value (Ramos-Elorduy *et al.*, 1997), coevolving depending on lifestyle, tradition and educational level. This phenomenon explains how a certain food resource is considered for a certain group a primitive food, while the same resource in a different social stratum is valued as gourmet food and of high economic value. In addition to the cultural value that the entomological group denotes for Mexico, recently nutritional characteristics have been described that could contribute to mitigate the problems of hunger and malnutrition, particularly in rural zones where currently 11,238,031 households experience these problems (Ramírez-Sánchez *et al.*, 2021). However, the rural areas are those that show the highest consumption of insects, compensating the nutritional requirements that the conventional diet contributes; this thanks to the nutritional levels offered by this resource, such as described by Carmona-López *et al.* (2021) and different researchers who have enlisted a diversity of orders, families, genera and species of edible insects.

Table 1. Medicinal value of some entomological groups in Mexico.

Entomological group	Part used	Disease that heals
Melipona fasciata Latreille	Honey	Flu, cough, conjunctivitis
Apis mellifera	Honey and stinger	Flu, cough, rheumatism
Polybia occidentalis	Honey	Flu, cough
Polybia sp.	Honey	Flu, cough
Taeniopoda eques	Insect legs	Mouth ulcer
Cicadidae	Whole consumption	Dyslalia
Armadillidiidae	Whole consumption	Fever
Gryllus sp.	Insect legs	Developmental dysphasia and fever
Agriotes sp.	Whole consumption	Blisters on the hands
Neuroptera	Whole consumption	Stye
Apidae	Insect bite	Rheumatism and bad air
Scarabaeidae	Whole consumption	Wart removal
Oniscidea	Sofrito (spread)	Ear pain and deafness
Lepidoptera	Toasted in the comal	Speaking difficulties
Hymenoptera	Insect bite	Sloth of the hand
Zopherus jourdani	Necklace	Insomnia and crying of children
Ulomoides dermestoides	Living consumption	Cancer and diabetes

Table 2. Magical, mystical, and religious use of some entomological groups in Mexico.

Entomological group	Way of use	Action that causes
Automeris sp.	Mystical	Nahuales
Apidae	Mystical	Used in mystical prayers
Musca domestica	Larval stage	Make enemies sick
Oligochaeta	Adult phase	Make enemies sick
Araneae	Whole consumption	Black and white magic
Geometridae	Mystical	Short height in children
Arachnis aulaea	Mystical	Double hair disease (rash)
Araneae	Mystical	Herpes labialis
Pachylia syces	Nahual	Sterilization and cleft lip
Formicidae	Symbolic	Sign of omen
Hesperiidae	Symbolic	Family visit
Cicadidae	Song	Weather events
Apidae	Honey	Bath with petals (sweetness)
Odonata	Whole consumption	Attract love partner
Odonata	Whole consumption	Lucky attraction
Theraphosidae	Insect legs	Damage an enemy
Phasmida	Whole consumption	Love sign
Euschistus sulcacitus	Shredded	Illnesses of the heart and sorceries
Gryllus assimilis	In powder	Poisoning

Table 3. Value of ludic use of some entomological groups in Mexico.

Entomological group	Use	Part used	Way of use
Hymenoptera	Children's game	Indirect use	Children's song
Coleoptera	Children's game	Direct use	Capture and confinement
Eucheira socialis	Textile use	Capullo	Dresses for dolls
Lepidoptera	Festivity	Indirect use	Outfit
Schausiana trojesa	Children's game	Direct use	Collection and jokes
Formicidae	Children's fun	Direct use	Collection and classification
Musca domestica	Children's fun	Direct use	Observation and mutilation
Phasmida	Fun	Direct use	Indicates the location of the sun
Leptophobia aripa	Fun	Direct use	Capture and observation
Oniscidea	Children's toy	Direct use	Projectile
Oligochaeta			They collect and mutilate

Table 4. Value of aesthetic and decorative use of some insects in Mexico.

Entomological group	Use	Way of use
Coleoptera	Collection and light	Gifts in the form of a flashlight
Sceliphron sp.	Honeycomb preservation	Scenic beauty of housing
Eucheira socialis	Use of silk	Purse making
Alaus lusciosus	Artisanal use	Living necklaces and headdresses
Pyrophorus noctilucus	Ornamental use	Live brooches attached to a pin

Ecological importance of insects

The ecological importance of insects is in function of environmental services that they offer. These emerge from numerous interactions between animals, plants and the biophysical surroundings where they are found (Rojas Rodríguez *et al.*, 2019). Some of these benefits are the following:

Pollination: Insects carry out an important role in the reproduction of various flower species, developing very specific adaptive vectors that allow the plant-pollinator coexistence (Ku-Ruiz and Sosenski, 2021). Presently, around 100,000 species of pollinators are recognized, of which 98% correspond to the Insecta class (Stefanescu *et al.*, 2018). A value higher than 90% of 250,000 species of angiosperms require pollinating organisms for their production, including 75% of the one hundred species of agricultural cultivation that make up most of the cereals, foods recognized globally.

Biodegradation: The degradation of organic wastes is regulated by the role that it plays in the entomological community (Figueredo-Matheus and Albarracín-Balaguera, 2021). In such a process, organisms such as ants, flies, termites, beetles, among others, degrade the plant matter forming small fractions that allow the final decomposition by soil microorganisms (Smetana *et al.*, 2019). Likewise, close to 4,000 species of dung beetles contribute to the disintegration of manure from different vertebrates, avoiding the loss

of approximately 80% of atmospheric nitrogen which contributes to global warming and controlling the emission of bad odors (Chowdhury *et al.*, 2017). On the other hand, because of the COVID-19 sanitary crisis, a massive amount of waste has been generated (products based on polyethylene and polystyrene) that are economically unviable for their recycling, the same as various plastic wastes that affect the environment; a strategy of sustainable innovation that attempts to reduce this impact includes actions where insects (particularly moths and beetles) contribute to the degradation of such material based on the microbiological action of their digestive tract, mitigating the ecological impact on the planet (Rodríguez-Carreón *et al.*, 2021).

Biological pest control: Pest control in agricultural production is fundamental to obtain quality yields and to offer a better price for the sale of products; however, in most of the cases, this activity is carried out through chemical products that deteriorate the environment and alter the microbiological activity of the soil. Recently, a trend for the biological control of insects has been generated as an alternative for sustainable production, enlisting various parasite and predator organisms that keep the impact of harmful insects stable. Among some of these orders of predator insects of pests, there are the following: Neuroptera (crisopas, ants), Odonata (dragon flies), Coleoptera (beetles), Hemiptera (bedbugs), Diptera (flies), and Himenoptera (ants, bees and wasps), exceeding by far the number of beneficial insects in comparison to the number of harmful species (Chowdhury *et al.*, 2017).

Commercialization of insects in Mexico

From the 549 species of edible insects recorded in Mexico (Ramos-Elorduy *et al.*, 2008), only 95 (18.84% of the total species) are traded in different life stages (eggs, larvae, pupae and adults). This commerce is carried out in higher proportion during the rainy season, taking into account the phenology and seasonality of the organisms (polyvoltine and univoltine). However, several species are preserved (dry, in brine or frozen) and are sold according to the demand in different seasons of the year (Ramos-Elorduy *et al.*, 2006). For the sale of such a resource, insects acquire various presentations: dry, frozen, roasted, fried, boiled, wrapped, alive, by liter, by weight, by measure, by taco, in gorditas, quesadillas, ice-creams, turnovers, pizzas, soups, mole, tamales, sandwiches, among others (Pino-Moreno *et al.*, 2017). For their part, prices vary according to the directed market, showing exorbitant prices in international trade in cities like Tokyo, Paris, New York, Los Angeles, among others (Fleta-Zaragozano, 2018). However, the prices in Mexico vary in function of the form of sale (by insect, kilogram or dish), seller (harvester or intermediary), and the product's presentation, acquiring prices from $ 0.50 per insect to $ 3,040 per kg (Table 5).

Perspectives of consumption of insects in Mexico

Despite the benefits offered by the consumption of insects, there are still psychological (neophobia-fear-disgust), cultural and religious factors, which limit the acceptance of these products as an entomophagy practice (Toti *et al.*, 2020); this is particularly in young people and inhabitants of rural zones where young people avoid their consumption (Orkusz *et al.*, 2020). On the other hand, the external market integrated by tourism and visitors

Table 5. Average price for the sale of some edible insects in Mexico.

Entomological group	Average Price (MXN)		
	Collector	Intermediary	Saucer
Acentrocneme hesperiaris	$ 190 kg	$ 3 149 kg	$ 210
Liometopum apiculatum Mayr	$ 550 kg	$ 3 040 kg	$ 611
Myrmecocystus mexicanus	$ 1 an insect		
Hypopta agavis	$ 75 kg	$ 475 kg	$ 240
Helix aspersa	$ 14 kg		
Sphenarium sp.	$ 150 kg; $ 5 an insect	$ 1 204 kg	
Thasus gigas	$ 400 kg; $ 0,50 an insect	$15 a bag	
Atta mexicana S	$ 270 kg	$ 800 kg	$ 35 a glass of sauce
Atta cephalotes L.			
Arsenura armida armida Cramer	$ 46 kg		
Phasus triangularis H.E.	$ 3 an insect		
Aeschna sp. o *Anax* sp.	$ 150 kg		$ 25 (50 g)
Euleucophaeus tolucensis	$ 350 kg		$ 10 (30 g)

Source: Pino-Moreno *et al.* (2017); Pino-Moreno *et al.* (2020).

from different countries have given a high price to the consumption of this resource, attributing them nutritional, medicinal and aphrodisiac properties, and as an alternative for sustainable diversification with environmental advantages, exhibiting added value and increasing economic profit for sellers (Van Huis and Oonincx, 2017). In addition to this, the value of an emotional aspect has been derived, based on recreational actions such as adventure, wildness and the audacity to consume these products, generating new challenges and opportunities in the sale for local commerce (Tuccillo *et al.*, 2020).

CONCLUSIONS

Sociocultural, economic and environmental aspects of insects in Mexico were analyzed. This resource represents good horizons on the path to food security, caring for the environment, and as an alternative for productive diversification. The economic importance that insect trade represents in Mexico stands out, showing opportunities for small-scale producers of marginalized zones and tourist areas in Mexico. This study suggests awareness-raising practices to mitigate neophobia as a limitation in the adoption and consumption of this product by certain social strata in Mexico.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Zoonotic parasite frequency in homebound and feral dogs in Texcoco, State of Mexico, Mexico

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ABSTRACT

Objective: To describe and compare the frequency in which different parasites infect homebound and feral dogs, in the localities of the municipality of Texcoco, State of Mexico, Mexico.

Design/Methodology/Approach: In order to determine the presence of ectoparasites and gastrointestinal parasites, a sampling was carried out from August 2019 to July 2020, in localities of Texcoco, State of Mexico, Mexico. A total of 500 samplings of faeces from homebound and feral dogs were gathered.

Results: The general parasitosis samples had a 39% frequency (95% IC: 34.8-43.34%). Out of 325 samples obtained from homebound dogs, 134 (41.2%) tested positive (95% IC: 36.0-46.6%). Meanwhile, 175 samples were taken from feral dogs and 61 samples (34.8%) had at least one egg (95% IC: 28.1-42.1%). More than one type of parasite was found in 110 samples. The presence of parasites reached 48.8% in females (95% IC: 43.3-54.4%), while the percentage in males reached 66.4% (95% IC: 59.5-72.80%).

Study Limitations/Implications: The main limitation of this cross-sectional study is that data was gathered during a certain period (neutering/spaying campaigns). Therefore, the results may vary, if the same population is analyzed in another period.

Findings/Conclusions: The *Ancylostoma* sp. + *Toxocara* sp. association had the highest Relative Risk and Cross-Product Ratio in 5-60-month-old homebound male dogs. Regarding the age group, 0-4-month-old animals had the highest parasitosis frequencies.

New studies on this subject must be carried out to achieve a more exhaustive evaluation of the health status of homebound dogs, focusing on issues such as vaccination status, the interval between de-worming treatments, and the presence of parasites. Feral and semi-homebound dogs must also be included in the studies.

Keywords: Zoonosis, dogs, public health, epidemiology.

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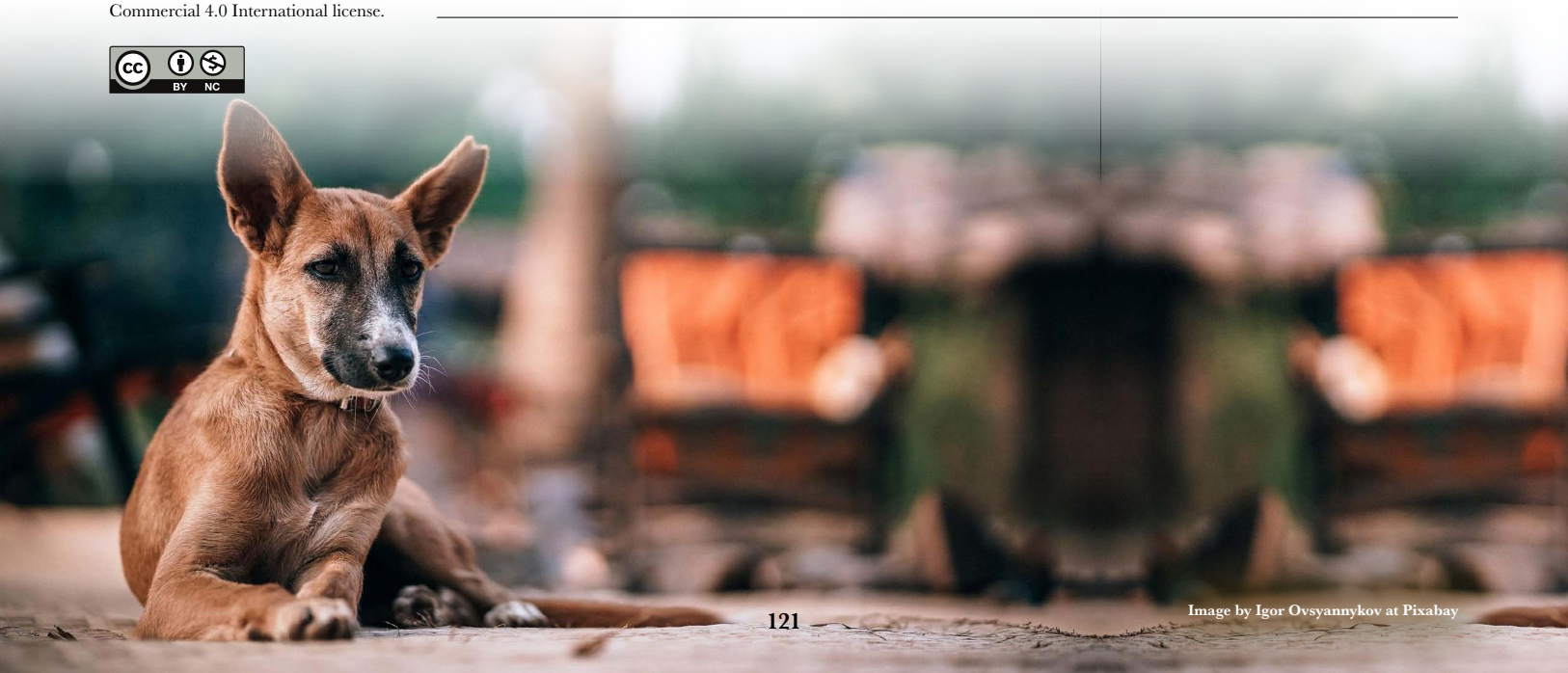

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INTRODUCTION

There are about 700 million dogs living in the world, 75% of which live in the streets (Anderson and Shwiff, 2015). In Mexico, there are approximately 16 million dogs and 10 million of them are stray dogs. In Mexico City, there are about 5 million dogs and 3 million of them are stray dogs. Each year, more than 100 thousand dogs fall into this condition. There are no records about the health of these dogs (Acevedo-Ramírez and Peralta-Abarca, 2010).

The inappropriate management of this dog population is a serious public health and animal welfare issue (Martínez-Barbosa *et al.*, 2008). Dog populations are constantly exposed to pathogens (mostly zoonotic) that cause diseases (particularly, parasitosis) (Acevedo Ramírez and Peralta Abarca, 2010; Kisiel *et al.*, 2016).

Giardiasis, dipilidiosis, toxocariosis, and ancylotomiasis are some of the parasitic zoonoses that dogs share with humans. Toxocariosis and ancylotomiasis manifest as visceral/ocular and cutaneous *Larvae migrans*, respectively (Macpherson, 2013; Rodríguez-Caballero *et al.*, 2017). The most vulnerable population are children and teenagers (6-16 years old) (Walsh, 2012; Cociancic *et al.*, 2018).

The objective of this study is to describe and compare the frequency in which different parasites infect homebound and feral dogs, in localities of Texcoco, State of Mexico.

MATERIALS AND METHODS

The work was carried out from August 2019 to July 2020, in Texcoco, State of Mexico, Mexico (latitude: 19° 30'-42"-N; longitude: 98° 52' 58" W; at 2257 m.a.s.l.). Temperature fluctuates from 6 to 16 °C. The region has an annual rainfall of 500-1,200 mm. A total of 500 samples of faeces were collected from 325 homebound and 175 feral dogs, who were neutered or spayed during the neutering/spaying campaigns carried out by the regional Centros de Bienestar Animal. While the animals were under general anesthesia, a 10 g sample of faeces was taken directly from their rectum, using latex gloves. The samples were then preserved in 4% formalin or 70% alcohol. All the samples were cooled and sent to the Laboratorio de Diagnóstico Parasitológico, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México, where a fecal flotation study was carried out. The samples were divided into three groups:

A) Dogs with and without owner (homebound and feral dogs);
B) Age groups, divided as follows: 1st, 0-4 months; 2nd, 5-8 months; 3rd, 9-12 months; 4th, 13-60 months; 5th, older than 60 months; and
C) Sex.

All the information about the animals —including the contact information of the owner or person in charge of the dog and the result of each analysis— was recorded and stored in a Microsoft Excel 2007™ database. Subsequently, the information was analyzed using the EpiInfo 7™ software. Frequencies with a 95% confidence interval (95% IC) were obtained. Relative Risks (RR) and Cross-Product Ratio (RPC) were calculated. A Fisher's exact test

was carried out using the *Ancylostoma* sp. + *Toxocara* sp. association in each age and sex group, level of ownership, and the frequency of each group.

RESULTS AND DISCUSSION

The overall level for the frequencies that tested positive for parasites was 39% (95% IC: 34.8-43.34%). Out of the 325 homebound dog samples, 134 samples (41.2%) had at least one parasite egg (95% IC: 36.0-46.6%). Meanwhile, out of the 175 samples from feral dogs, 61 samples (34.8%) had parasite eggs (95% IC: 28.1-42.1%). Table 1 shows the frequency of the parasitosis.

Regarding mixed infections, the results were the following: ninety-nine samples had two types of parasites; seven samples had three types of parasites; and one sample showed five types of parasites (Table 2).

Three-hundred and nine samples were taken from female dogs. There was at least one parasite in 151 samples (48.8%) (95% IC: 43.3-54.4%). Out of the 191 samples taken from male dogs, 127 samples (66.4%) tested positive (95% IC: 59.5- 72.80%). Table 3 shows the frequency of the various parasites.

The *Ancylostoma* sp. + *Toxocara* sp. association obtained the highest RR and RPC in 5-60-month-old homebound male dogs (Table 4). The *Ancylostoma* sp. and *Toxocara* sp. parasites also had the highest association frequency and were found in La Purificación Tepetitla, San Juan Tezontla, and El Xolache (Table 5).

Zoonotic gastrointestinal parasites were detected in homebound and feral dogs in several localities of Texcoco, State of Mexico. Eggs of *Toxocara* sp. (13.6%) and *Ancylostoma* sp. (14.8%) were the most frequently found parasites. These results match the findings of Eguía-Aguilar *et al.* (2005), who recorded 13.33% of *Toxocara* sp. and 62.5% of *Ancylostoma* sp. in Mexico City. Meanwhile, Ponce-Macotela *et al.* (2005) recorded 10-18% of *Toxacara canis* and 22-65% of *Ancylostoma caninum* in the same city.

The larvae of *Ancylostoma* sp. can survive in the environment for several months and can penetrate human epidermis by direct contact. Consequently, they have a great zoonotic importance. Likewise, this disease has been associated with *Uncinaria* sp., which was also found in homebound dogs in this study. Meanwhile, *Toxocara* sp. is one of the most common dog parasites. It is mostly found among males, especially those younger than 36 months old (Overgaauw and van Knapen, 2013). Its impact on dogs of that age range was also detected in this study.

Toxocara sp. can spread to humans through accidental ingestion of embryonated eggs, soil and water, or contaminated vegetables. It can survive for months and even years in optimal conditions (Mizgajska-Wiktor *et al.*, 2017). Unfortunately, if it is not addressed, this disease is particularly frequent among children from low-income populations, both in the tropic and the subtropic regions (*e.g.*, Mexico), as well as in industrialized countries (Macpherson, 2013). There are other routes of infection; for instance, a person may eat meat from paratenic hosts (poultry, pigs, and ruminants) infected with larvae, particularly if the meat is not well done (Cociancic *et al.*, 2018).

The presence of the *Ancylostoma* sp. + *Toxocara* sp. association in the animal samples gathered in human populations is a potential public health risk, as a consequence of the

Table 1. Frequency of zoonotic parasites in homebound and feral dogs in Texcoco, State of Mexico, Mexico.

Result	Domiciliated n=325			Nondomiciliated n=175		
	Frequency	%	CI 95%	Frequency	%	CI 95%
Ctenocephalides sp.	47	14.4	11.0-18.7	77	44	36.5-51.6
Ancylostoma sp.	39	12.0	8.9-15.9	35	20	14.3-26.7
Toxocara sp.	23	7.0	4.7-10.4	45	25.7	19.4-32.8
Cystoisospora sp.	2	0.6	0.1-2.2	5	2.8	0.9-6.5
Dipylidium caninum	0	0.0	0	3	1.71	0.3-4.9
Uncinaria sp.	2	0.6	0.1-2.2	0	0.0	0

IC 95%: 95% Confidence Interval.

Table 2. Multiparasite infections in homebound and feral dogs in Texcoco, State of Mexico, Mexico.

	Frequency
2 parasites	
Ctenocephalides + *Toxocara*	40
Ancylostoma + *Ctenocephalides*	27
Ancylostoma + *Toxocara*	13
Ancylostoma + *Cystoisospora*	3
Ancylostoma + *Dipylidium*	3
Dipylidium + *Ctenocephalides*	3
Cystoisospora + *Ctenocephalides*	2
Cystoisospora + *Toxocara*	2
Dipylidium + *Toxocara*	2
Ancylostoma + *Uncinaria*	1
Cystoisospora + *Dipylidium*	1
Ctenocephalides + *Uncinaria*	1
Toxocara + *Uncinaria*	1
3 parasites	
Ancylostoma + *Cystoisospora* + *Dipylidium*	1
Ancylostoma + *Cystoisospora* + *Ctenocephalides*	1
Cystoisospora + *Dipylidium* + *Ctenocephalides*	1
Cystoisospora + *Dipylidium* + *Toxocara*	1
Dipylidium + *Ctenocephalides* + *Toxocara*	2
Ctenocephalides + *Toxocara* + *Uncinaria*	1
4 parasites	
Ancylostoma + *Cystoisospora* + *Dipylidium* + *Ctenocephalides*	1
Ancylostoma + *Cystoisospora* + *Dipylidium* + *Toxocara*	1
Cystoisospora + *Dipylidium* + *Ctenocephalides* + *Toxocara*	1
5 parasites	
Ancylostoma + *Cystoisospora* + *Dipylidium* + *Ctenocephalides* + *Toxocara*	1

Table 3. Frequency of zoonotic parasites in female and male dogs in Texcoco, State of Mexico, Mexico.

Parásito	Hembras (n=309)	Machos (n=191)	RPC IC 95%	Prueba exacta de Fischer's
	Frecuencia % IC 95 %	Frecuencia % IC 95 %		
Ctenocephalides sp.	63 20.4 16-25.2	61 31.94 25.4-39.1	1.57 0.76-3.23	p>0.05
Ancylostoma sp.	48 15.5 12-20.0	26 13.61 9.1-19.3	0.34 0.04-2.7	p>0.05
Toxocara sp.	33 10.7 7.7-15	35 18.32 13.1-24.6	0.88 0.24-3.22	p>0.05
Cystoisospora sp.	4 1.3 0.5-3.2	3 1.57 0.3-4.5	-	p>0.05
Dipylidium caninum	2 0.6 0.2-2.3	1 0.52 0.01-2.8	-	-
Uncinaria sp.	1 0.3 0.1-1.8	1 0.52 0.01-2.8	-	p>0.05

RPC: Cross-Product Ratio; IC 95%: 95% Confidence Interval.

Table 4. *Ancylostoma* sp. + *Toxocara* sp. association frequency divided by age, sex, and level of ownership of dogs in Texcoco, State of Mexico, Mexico.

	Association *Ancylostoma* sp. + *Toxocara* sp.				
Age group (months)	**RR**	**CI 95%**	**OR**	**CI 95%**	**Fischer's Exact Test**
0 - 4	0.89	(0.49-1.60)	0.79	(0.22-2.8)	P>0.05
5 - 8	1.24	(0.92-1.67)	**3.29**	(0.9-12.03)	**P<0.05**
9 -12	1.06	(0.87-1.28)	**2.8**	(0.23-33.87)	P>0.05
13 - 60	1.08	(0.95-1.22)	**6.95**	(0.92-52.02)	**P<0.05**
More than 60	0.95	(0.91-1.00)	0	(0)	P>0.05
Sex					
Male	1.2	(0.92-1.57)	**2.27**	(0.89-5.75)	**P<0.05**
Female	0.99	(0.89-1.10)	0.96	(0.35-2.64)	P>0.05
Domiciliated					
Yes	1.11	(0.96-1.27)	**2.87**	(1.06-7.8)	**P<0.05**
No	0.91	(0.75-1.10)	0.67	(0.27-1.66)	P>0.05

RR: Relative Risk; RPC: Cross-Product Ratio; IC 95%: 95% Confidence Interval.

Table 5. *Ancylostoma* sp. + *Toxocara* sp. association frequency of dogs in the main localities of Texcoco, State of Mexico, Mexico.

Place	*Ancylostoma* spp.	*Toxocara* spp.	Relative Risks	Odds ratio
	Frequency % CI 95%	Frequency % CI 95%	RR IC95%	OR IC95%
Boyeros	1 1.4% 0.03-7.3	4 5.9% 1.6-14.3	0.80 0.65-.099	-
Centro	4 5.4% 1.4-13.2	2 2.9% 0.3-10.2	0.95 0.89-1.01	-
ISSSTE	6 8.1% 3.03-16.8	2 2.9% 0.3-10.2	0.33 0.06-1.65	-
La Purificación Tepetitla	7 9.5% 3.8-18.5	8 11.8% 5.2-21.8	1.58 0.83-3.03	**7.35** 1.26-42.6
San Juan Tezontla	7 9.5% 3.8-18.5	4 5.9% 1.6-14.4	1.5 0.73-3.04	**4.5** 0.33-60.1
San Simón	3 4.1% 0.8-11.3	1 1.5% 0.04-7.9	0.9 0.73-1.1	-
Tequexquinahuac	4 23.53% 9.56-27.26	1 7.14% 1.27-31.47	1.1 0.73-1.84	**3.25** 1.16-64.6
UACh	12 16.2% 8.6-26.6	6 8.8% 3.3-18.2	1.02 0.65-1.59	1.11 0.17-6.97
Xolache	5 6.8% 2.2-15.0	18 26.5% 16.5-38.5	1.29 0.62-3.67	**2.33** 0.35-15.1

F: absolute frequency; CI95%: Confidence Interval 95%. RR: Relative Risk; RPC: Cross-Product Ratio.

close coexistence between homebound dogs and humans. This risk is particularly high among children, who are the most vulnerable to parasitic infections.

In this study, the *Ancylostoma* sp. + *Toxocara* sp. association had a >2 Cross-Product Ratio in the 2, 3, and 4 groups (5-60-month-old) of homebound male dogs. This situation suggests a lack of preventive medicine among this population stratum, which increases the risk of the owners' families to get parasites (Rinaldi *et al.*, 2008; Šlapeta *et al.*, 2015). Cases of interaction between stray animals (mainly cats and dogs) and humans in urban districts, parks, cattle-raising areas, and even in preschool playgrounds have been reported. Therefore, we suggest determining the risk and the exposition factors based on the knowledge about the natural history of the disease.

New studies must be carried out to achieve a more exhaustive evaluation of the health status of homebound dogs, focusing on issues such as vaccination status, the interval between de-worming treatments, and the presence of parasites. Feral, free-roaming, and

homebound dogs must also be included in the last two population groups, as well as those dogs that are part of the trap-neuter-return programs (CER). The studies must include tests for intermediate and paratenic species (Kwan Nigel *et al.*, 2019). The use of geographic information systems can be useful to manage this type of dog population, allowing preventive medicine interventions aimed particularly at preventing and controlling zoonotic infections (Rinaldi *et al.*, 2008; Šlapeta *et al.*, 2015; Taetzsch *et al.*, 2018).

CONCLUSIONS

New studies must be carried out to achieve a more exhaustive evaluation of the health status of homebound dogs, focusing on issues such as vaccination status, the interval between de-worming treatments, and the presence of parasites. Feral and semi-homebound dogs must also be included in the last two. A surgical neutering/spaying campaign must be carried out, along with an anti-rabies vaccination campaign and other preventive medicine interventions aimed particularly at preventing and controlling zoonotic parasite infections.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Development of an application for the differentiation of the genus of Baird's sparrow (*Centronyx bairdii*) based on an artificial neural network

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ABSTRACT

Objective: To develop a computer application with the possibility of being used in the field with high reliability to differentiate the sex of sparrows of the species *Centronyx bairdii*.

Design/Methodology/Approximation: A previously developed neural network was used to predict the sex of *C. bairdii* individuals. This algorithm was installed in an application developed using the MATLAB GUIDE environment for using graphic user interfaces.

Results: The computer application developed allows the introduction of morphometric data of individuals and predicts their sex with a confidence level of 92.3%.

Study Limitations/Implications: To install and run the application it is necessary to have a Windows version 7 operating system or later versions and the Matlab Ver. 7.5.0 software.

Findings/Conclusions: Through the computational application generated, it is possible to determine the genus of the species *Centronyx bairdii* with an accuracy of 92.3%. This is a useful tool for sexing birds of this species in the field.

Keywords: Baird sparrow, sexing, monomorphic birds.

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INTRODUCTION

Baird's sparrow (*Centronyx bairdii*) is a grassland bird native to the south of Canada and north of the United States, which during winter migrates towards various regions of the Chihuahuan Desert such as Arizona, New Mexico and Texas in the USA, and Chihuahua, Sonora, Durango and Coahuila in Mexico (AOS, 1998; CEC, 2013). Its populations have

shown a constant decrease during recent decades (Sauer *et al.*, 2017) and at the same time the need for its conservation requires greater research efforts (Berlanga *et al.*, 2010). An important physical characteristic of this species is that it has monomorphic plumage and its sex cannot be determined through its color or other observable characteristics (Figure 1). Determining the sex is a basic component to establish the proportion of males and females (PMF) in a population, as fundamental variable for demographic studies. The PMF represents an opportunity to understand the competence during mating, mating systems, and parental care of the chicks (Murray, 1984; McNamara *et al.*, 2000).

Sierra (2018) mentions that the most conventional techniques to determine the sex of monomorphic bird species are: a) exploratory dissection; b) use of bioacoustics; and the most recent, c) use of techniques based on DNA analysis. The latter implies elevated costs, in addition to being invasive for birds through the collection of blood or feathers.

In this regard, in the scope of classification, the use of artificial neural networks (ANN) constitutes a very powerful tool that has been used in other fields with satisfactory results. However, these networks have not been used very frequently in ornithology and they have been used primarily to distinguish the song between species (Lopes, 2011), and to a lesser extent to differentiate the genus of birds (Jennings *et al.*, 2008).

Recently, Pereda-Solís *et al.* (2020) developed an artificial neural network to determine the sex of *C. bairdii* with a confidence level of 92%. This ANN used as inputs the morphometric measurements of weight, wing chord, tail length, culmen, beak width, and beak depth. Because of this, the interest for translating this predictive capacity and for easing sexing of individuals of this species in the field emerges. Thus, the objective of this study was to develop a computer application with a high reliability to differentiate the sex of sparrows of the species *Centronyx bairdii*.

MATERIALS AND METHODS

Artificial Neural Network

Neural networks are defined as a computational system that imitates the computational capacities of biological systems (Hornik *et al.*, 1989). For this study the ANN developed by

Figure 1. Baird sparrow.

Pereda-Solís *et al.* (2020) was used, which generally consists of a multilayer perceptron type ANN with 4, 2 and 2 neurons in the hidden layers. It presents a confidence level of 92.3% which means that the model can distinguish between a male and a female sparrow with a level of accuracy higher than 92% (Figure 2).

Development of the application

To develop the application, a Dell Precision model T5500 computer was used, equipped with an Intel® Xeon E5603 processor at 1.60 GHz of 64 bits, Gallium 0.4 AMD CEDAR graphics card, with 3.8 GB of memory and a hard drive of 70.6 GB with operating system Windows 7. Programming was carried out through the GUIDE utility (Graphical User Interface Development Environment) which is available in the MATLAB version 7.5.0 software (MathWorks, 2017). This environment of visual programming allows designing graphic interfaces and executing software, as well as being a tool of great usefulness when a continuous data input or the active interaction with the user are required. In turn, GUIDE allows creating windows and dialogues in a simple way that contain basic components, such as labels, text fields, buttons and containers, among other elements.

RESULTS AND DISCUSSION

The interface was designed in MATLAB language and an auto-executable file (.EXE) was generated in a portable computer to favor its transport to the field. Through the introduction of the longitudinal data (mm) of wing, tail, culmen, beak depth and width, and weight of the individual (g), it is possible to obtain a high reliability in the sex of the bird as a result. This application, in addition to indicating on the screen the sex of the individual (Figure 3A), generates a file that can be edited in any spreadsheet (format .XLS) with all the morphometric data introduced by the user, as well as the solution generated (1=male, 0=female; Figure 3B).

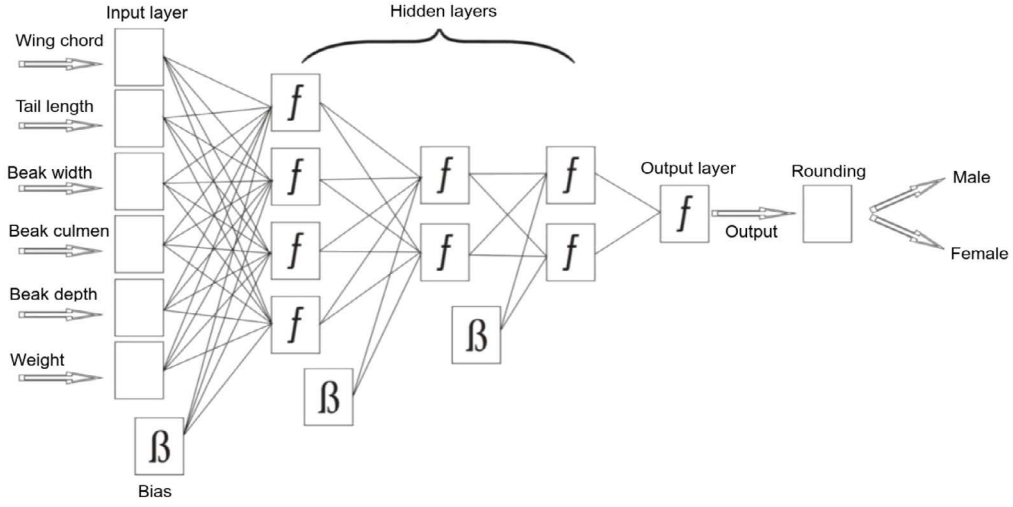
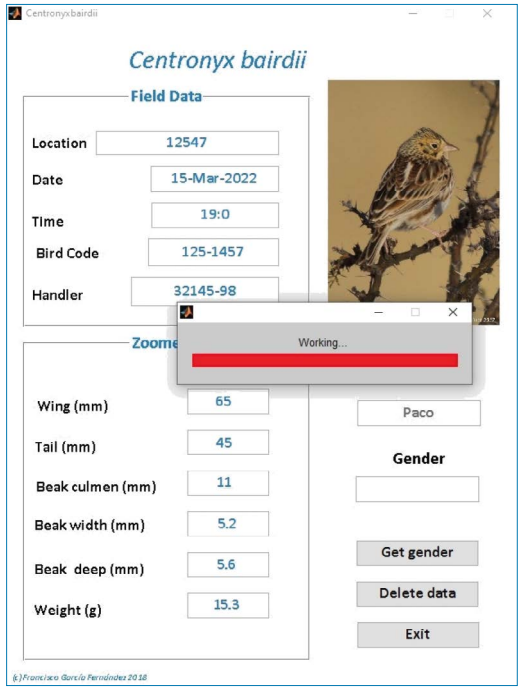


Figure 2. Scheme of neural network used to determine the sex of the Baird sparrow through morphometric data (Pereda-Solís *et al.*, 2020).

A



B

Bird code	Wing	Tail	Beak culmen	Beak width	Beak depep	Weight	Gender
262124874	68	48	11.1	5.6	5.8	18.3	1
262124875	66	45	10.8	5.2	5.8	17.4	0
262124876	69	47	11.8	5.6	5.6	18.2	1
262124877	67	45	11.4	6.1	5.6	15.9	0
262124878	70	50	11	5.7	5.9	17	0
262124880	67	49	11.2	8.8	5.5	16.8	1
262124881	67	48	10.9	5.7	6.3	16.3	0
262124881	67	48	10.9	5.7	6.3	16.3	0
262124882	69	48	11.6	6.2	5.1	17.1	0
262124883	67	50	11.5	5.5	5.9	16.4	0
262124852	67	49	12	5.6	5.5	16.8	0
262124853	69	45	11.7	5.4	5.6	16	0
262124857	68	46	11.8	5.9	6.5	18.8	1
262124858	66	47	11.4	5.4	5.7	17	0
262124859	67	46	11.2	5.4	6.2	17.1	0
262124860	69	48	11.6	5.5	6	18.3	1
262124861	67	44	12	6.5	6	17.1	1
262124862	66	44	11.4	6	5.7	15.9	0

Figure 3. Application screen (A) and results file (B).

CONCLUSIONS

A computer application was developed from an ANN, which through capturing morphometric data of sparrows of the species *Centronyx bairdii* can determine the genus with an accuracy of 92.3%. This application is a non-invasive, useful, fast and economic method for sexing birds of this species in the field.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Economic impact of porcine epidemic diarrhea in Mexico

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ABSTRACT

Objective: The number of pre- and post- outbreak weaned piglets was evaluated, as well as return to productive normality, cost of weaned piglets, and economic impact (implications) of Porcine Epidemic Diarrhea (PED).

Design/Methodology/Approximation: The data were obtained from 24,597 farrows of weaned piglets from Mexican pork farms under conditions of technification. A mixed effects design was used with the time variable as class variable to determine the return to productive normality. The costs were determined with the general cost formula with emphasis on the number of weaned piglets (NWP). The economic impact was estimated using data from the Input-Product Matrix in Mexico.

Results: The average NWP before the outbreak was 9.75 per sow and birth, and from weeks 1 to 6 post-outbreak it was 2.43, 2.07, 2.87, 4.42, 6.22 and 8.07, respectively, with a weekly production cost of $114, $134, $97, $64, $46, $36 and $33 USD. The farms returned to normality in terms of NWP during week 7 post-outbreak.

Study Limitations/Implications: For every $77 thousand USD that cease to be invested in the demand, the amount that will cease to be generated is $96 thousand USD; therefore, an effect in the offer would be equivalent to a loss of 12,675 USD.

Conclusions: The statistical model allowed establishing the return time to normality of the farms being studied. Likewise, the methodology of costs with emphasis in the weaned piglet allowed to determine the cost of the piglet from the farms affected regardless of the physiological state of the other sows in production.

Keywords: sow performance, economic performance, productivity, livestock.

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INTRODUCTION

Outbreaks of Porcine Epidemic Diarrhea (PED) disease decrease, firstly, the number of weaned piglets in the farms and, as consequence, there are less finalized pigs, less kilograms of meat in the market, a decrease in the pork meat offer, and a negative economic effect both in the farm and in the markets. Despite the measures for control and prevention that have been applied, the disease continues affecting pork producers.

Image by Siggy Nowak at Pixabay

PED was identified in Europe in 1971 (Lee, 2015) and the first strains were isolated in 1976 (Pensaert and Bouck, 1978) as *Alphacoronavirus*. During the decade of the 1970s and 1980s, the disease was reported in Europe, although without paying closer attention since its consequences were not significant (Pensaert and Bouck, 1978). Two devastating outbreaks of the disease took place in 2010 in Asia and 2013 in North America (Stevenson *et al.*, 2013). The outbreaks continued since then and extended to Canada and Mexico (Stevenson *et al.*, 2013; Perri *et al.*, 2014; Trujillo-Ortega *et al.*, 2016).

PED is a transmittable disease that causes acute diarrhea, vomit, dehydration and high mortality in newborn piglets (Bertasio *et al.*, 2016; Li *et al.*, 2016). The losses range from 1 to 3% as a result from the disease, causing approximate losses of 1 billion dollars both for producers and for consumers (Paarlberg, 2014).

Weng (2016) has estimated the cost of interventions to face the PED disease for production systems under conditions of technification; however, there are still few studies in the matter and the methodologies to attain data vary in their countable and financial structure.

Porcine meat production in Mexico has been classified in many ways: for its zootechnics aims, technification level, geopolitical regionalization, economic contribution, among others. The classification based on technification level has been used by the official sectors as reference to explain the dynamics and production of pork meat in Mexico. Thus, three strata are defined: 1) backyard system that contains between 20 and 30% of the stock, with low or "null" technification and 15 to 20% of production; 2) semi-technified system with 20 to 30% of the stock, and from 25 to 30% of the volume where the technological level is variable; and 3) the technified system that produces more than 50% of the volume of pork meat in Mexico (FIRA, 1997; Bobadilla Soto *et al.*, 2010). The recent dynamics and level of specialization of pork meat production places the Northeastern, Center-West and Peninsula Regions as those of greatest specialization, dynamics and technological consolidation, economic and volume of national production (Rebollar *et al.*, 2014; Rebollar *et al.*, 2016). These systems include different measures for prevention and control, as well as biosafety protocols; however, the disease has emerged in all types of productive systems.

In this study the productive effects of the PED disease are described in farms specialized in breeding-finalization of pork meat under conditions of technification, in different states of the Republic. The objective of the study was to evaluate the productive and economic effects of the Porcine Epidemic Diarrhea (PED) in specialized and technified farms for pork meat production located in the regions with highest specialization in Mexico.

MATERIALS AND METHODS

The study was conducted during 2013 and 2014 in pork meat production farms in different regions in Mexico specialized in breeding and finalization, including states such as: Sonora, Veracruz, Puebla, Jalisco and Guanajuato. The productive information of 24,597 farrows at weaning (equivalent to 3% of the national stock under conditions of technification) was analyzed, which showed their first outbreak of PED.

Information referred to the number of weaned piglets was used, classified into: a) pre-outbreak or week "zero", which averaged productive information of 26 previous weeks;

and b) post-outbreak, where the production of each week after was recorded, until week 26 after the outbreak (Goede and Morrison, 2016).

To statistically determine the return to productive stability, a mixed effects design was used with the time variable as class variable (Park *et al.*, 2009), which allowed establishing the statistical comparisons between each week after the outbreak. The best structure of covariance was determined and an adjusted Tukey's test was used to determine the significance (Kraemer, 1956).

In the cost analysis the methodology by Muñoz and Rouco (1995) for one weaned piglet was used, which emphasizes the variations of variable costs per weaned piglet. The mathematical expressions are the following:

$$TC = F + V$$

where: TC=cost of weaned piglet; F=fixed costs; and V=variable costs.

The fixed costs were formed by:

$$F = L + S + Co + R + A + Fi + CO + Ot$$

where: L=labor costs; S=supply costs; Co=energy and fuel costs; R=repair and maintenance; A=amortization of fixed assets; CO=opportunity costs; and Ot=other lower costs.

The variable costs were established by the items:

$$V = \left(AR + AM + AV + AMV + AL + M + T + CO / \left(TOTCER * W\right)\right) * z$$

where: AR=amortization costs of breeders; AM=diet of the sows; AMV=boar diet; AV=amortization of the boar; AL=diet of piglets; M=medicines; T=transport; CO=opportunity costs; $TOTCER$=total number of sows in the farm; W=weighting factor by virtue of all the variable costs referring to the production unit of a commercial piglet; and z=number of weaned piglets.

The depreciation of breeding animals was calculated as follows:

$$AR = \left(PH - \left(PD - \left(1 - MORR\right)\right)\right) / \left(PARM / PAR\right) - REP$$

where: PH=purchasing price of the sow; PD=discard price of the sow; $MORR$=mortality of breeders expressed in percentage; $PARM$=average number of births of the sows; PAR=number of births per sow and year; and REP=replacements of breeders.

The average of births per reproducing farrow can be calculated in any moment of the production, notwithstanding the physiological stage in which sows are found.

$$PARM = \sum(CER * n) / TOTCER$$

where: CER=number of sows; and n=number of birth. $PAR = 365 / \left((114{,}5 + LAC + INT) * (1 - NAB + VAC / CUB)\right)$; LAC=duration of lactation; INT=weaning-fertile mounting interval; NAB=total number of abortions; VAC=number of empty sows; CUB=number of mounts carried out. In turn, INT is formed by the sum of the intervals between weaning and first mounting (INT1); percentage of first repetitions*21 (INT2); percentage of second repetitions*42 (INT3); percentage of third repetitions*63 (INT4); and percentage of acyclical repetitions mean days of appearance.

$REP = PAR/PARM$ and the weighting factor is:

$$w = PAR * VIV * (1 - MOR) * (1 - MORT)$$

where: PAR=number of births per sow and year; VIV=piglets born living by birth; MOR=mortality in lactation; $MORT$=mortality in weaning-commercial piglet transition expressed in percentage points.

The monetary units are expressed in United States Dollars (USD) with an exchange rate Mexican Peso:US Dollar of 1:12.97, with date of June 30, 2014, according to the Bank of Mexico. The economic implications measured as the economic impacts were estimated with the information contained in the values from Leontif's inverse matrix of Mexico's Input Product Matrix (Sosa *et al.*, 2017) and their multipliers (Sosa, 2016).

RESULTS AND DISCUSSION

Number of weaned piglets

The average of weaned piglets before the disease was 9.75 piglets per sow and birth. The number of weaned piglets was severely affected (Table 1), with the highest productive losses standing out in the first three weeks post-outbreak.

Table 1. Number and cost per weaned piglet.

Week	Number	Cost (US$)
0	9.75	30.47
1	2.43	114.50
2	2.07	133.94
3	2.87	97.31
4	4.42	64.09
5	6.22	46.29
6	8.07	36.28
7	8.72	33.77

Source: Prepared by the authors with field data.

The potential impact of the disease in mortality stopped at the sixth week post-infection ($P<0.05$).

This reduction in production in farms with PED was similar to the one reported by Perri *et al.* (2014) and Weng *et al.* (2016). The prevalence of the disease can range between 30 and 40% and with higher occurrence in small-scale farms (Van Reeth and Pensaert, 1994), indicating that it is possible to relate technical and biosafety controls, as well as the size of the farms with the impact and the prevalence but particularly in the duration of the disease. In the United States, by June 2014 a high impact of the disease had been reported in farms of the Midwest, region where the specialized farms in pork production with largest stock are found (Hill *et al.*, 2014). Since the PED outbreaks analyzed in this study are primary outbreaks, the mortalities in some cases were 100% in piglets less than one week old, basically due to the piglets not having any protection (Geiger and Connor, 2013).

If the farm is in excellent conditions of management and biosafety, the total losses of piglets can be reduced to only 4 weeks, although the mortality can be prolonged until week eight in farms whose management is not adequate, showing mortalities of 100% from week two to eight (Engele and Whittington, 2014).

One of the procedures to determine the state of the disease is not only the return to productive stability; the moment when the diagnosis sampling of the disease is negative must be considered (Linhares *et al.*, 2014). In the case of PED, it has been reported that the virus stays endemic in the farm for a very variable time after the outbreak, although the production stabilizes due to the maternal immunity that is generated (Goede *et al.*, 2015). Weng *et al.* (2016) report a stabilization period of eight weeks, and Goede and Morrison (2016) of six weeks with intervals that range from the fourth to the eighth week.

Costs of the weaned piglet

The economic impact of the disease at the farm level is reflected in the increase of the cost per weaned piglet. Table 1 presents the costs per weaned piglet and week. The highest cost was recorded in the first three weeks, with a maximum cost of US$114 in week 2 post-outbreak. The cost before the outbreak was US$30 and in week 7, that is, in productive stabilization, of US$33.77. In general terms, there were less weaned piglets after the disease and more expensive piglets for the farms. Although it was statistically shown that since week seven post-outbreak, there was no difference in the number of weaned piglets per sow, the cost of the weaned piglet was US$3.3 more expensive.

Rogers (2018) reported average costs of US$29.36, 37.97 and 30.32 US before, during and after the outbreak, with losses that range from US$25.62 to US%292 in the weeks with 100% mortality.

The loss of piglets due to the disease, using as unit of reference one thousand producing sows, was 1,533 piglets, figure similar to the 1,688 reported in other studies (Goede and Morrison, 2016) using this same reference.

The production cost of a piglet in a farm from their birth to their finalization is impacted by the number of births that the sow has per year and in its productive life. The change

in these factors will generate the difference in the number of piglets weaned and sold per sow per year. Considering this information, the total cost from birth to finalization can reach values of US$8.86 to $71.80 and the productivity can be reduced from 25 to 80%. Furthermore, the producers must include the cost not only of the losses of productive life of the farm but also the expenses generated by the interventions (Weng *et al.*, 2016). In this sense, the loss of piglets will represent great losses for the producers. For a farm with 700 reproducing sows, the loss from the effect of PED will result in losses of $166 dollars per sow. In this study, the estimated cost per sow amounted to $142.20 dollars.

IMPLICATIONS

The demand multiplier (Sosa *et al.*, 2017) of the economic branch of "Porcine farm" was 2.2419 and of the offer 1.1644. In the case of the demand this implied that for each US$77,101.00 invested in the porcine farm (purchase of food, fuel, supply inputs, etc.), US$95,751.73 were promoted in the other sectors related. Thus, considering an average cost of US$192.76 per fattened pig (110 kg of live weight), a stock of 1,000 sows and 9.75 fattened pigs per sow and birth, the total invested in this operation would add up to US$1,879,405.49, which would promote a total of US$2,334,033.68 to the rest of the economic sectors related.

The offer multiplier, in its part, was 1.16; that is, for each US$77,101.00, an amount of US$12,675.40 is promoted in the economic sectors related, and therefore, the lack of this economic activity would reflect its negative impact with the amount mentioned.

PED is a disease with an impact in the supply chain and the pork meat product. The total number of pigs sacrificed in 2014 in the United States of America was 4.64% less than in 2013 (Schulz and Tonsor, 2015), producing changes in the prices of the product in the short term (Marsch, 1999) and price-production asynchrony (Martínez-Castañeda and Lorga, 2016).

If a decrease of 1, 2 and 3% in the production from the effect of PED is considered for the economic impact of the disease, the amounts of US$2,310,827.27, US$2,287,485.58 and US$2,264,143.89 respectively, would cease to be generated for every 1.000 sows at birth (Table 2).

Table 2. Economic impact due to PED*.

	Percentage variation			
	0	**−1**	**−2**	**−3**
Invested (USD)	$1 879 410.00	$1 860 615.90	$1 841 821.80	$1 823 027.70
Balance	0	−$18 794.10	−37 588.20	−56 382.30
Impulse to other sectors (USD)	$2 334 168.96	$2 310 827.27	$2 287 485.58	$2 264 143.89
Difference	0	−$23 341.69	−$46 683.38	−$70 025.07

*=1.000 sow, $192.76 pig production cost; 9.75 Total number of pigs sold by sow and farrow. Source: Elaborated with field data.

CONCLUSIONS

In the regions studied, where pork farming is carried out in technified systems, the effect of PED had a duration of six weeks, reaching productive statistical stability since week seven. The number of weaned piglets during the disease outbreak was 2.43, 2.07, 2.87, 4.42, 6.22 and 8.07 in weeks one to six post-outbreak. The costs per weaned piglet in the weeks since the outbreak were US$114.50, US$133.94, US$97.31, US$64.09, US$46.29, and US$36.28 from week one to six post-outbreak. For every US$77 thousand that ceases to be invested in the demand, slightly less than US$95,751.73 and US$12,675 would cease to be generated in the offer.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Perception of ranchers about the predator attack insurance in the Calakmul region, Campeche, Mexico

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ABSTRACT

Objective: To evaluate the operation of the Fondo de Aseguramiento Ganadero and its effectiveness regarding predator attacks, through the perception of ranchers who operate in the area of influence of the Calakmul Biosphere Reserve.

Design/Methodology/Approach: The communities were visited in order to contact and ask the permission of the ejido authorities, as well as to inform ranchers about the activities. The streets of the communities were randomly covered by our team and a survey was carried out with all the available producers. The snowball method was used to identify producers who have been impacted by predator attacks.

Results: Seventy surveys were carried out with ranchers of 18 communities from the northern, central, and southern regions of the area of influence of the Calakmul Biosphere Reserve (RBC), from October 2019 to January 2020. All the interviewed ranchers have been impacted by predator attacks; however, only 27% of them have reported the attacks to the Seguro de Ataques por Depredadores (Predator Attacks Insurance, SAD) and have obtained a compensation for their losses. Eighty-eight percent of the ranchers have received an immediate answer from the technician in charge of the insurance. Fifty-six percent of the ranchers mentioned that SAD has beneficial effects, 28% said they are not aware of its potential benefits, and 13% think that SAD does not have beneficial effects.

Study Limitations/Implications: Although producers who have requested the insurance were identified, many other producers who have been impacted by predator attacks have not reported them. In many cases, the producers hunt the predator. Hunting these predators is illegal; therefore, producers decided not to provide the required information.

Key words: jaguar, carnivore, protected area, preservation.

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INTRODUCTION

The first species that disappear are those that can be found in areas with high human population and in which directly threatened species live —*i.e.*, wolves or felines (Hoogesteijn, *et al.*, 2016). In Mexico, the illegal hunting of jaguar takes place in both protected and unprotected areas (Núñez, 2020). In many rural and wild areas, where livestock is the main economic activity, actual or alleged livestock predators are hunted or poisoned (Rosas-Rosas and Valdez, 2010). Núñez-Pérez *et al.* (2020) have suggested that retaliatory killing is one of the main causes of the death and decline of wild felines.

Predation has an irregular spatial and temporal distribution. Additionally, it is more frequent near or inside forests, as well as in places with low biomass of natural preys, as a result of either hunting or habitat destruction (Hoogesteijn *et al.*, 2016).

Among other factors, the economic impact of predator attacks depends on the type of livestock management, the economic level of the producer, and the type of livestock that the predators attack. For some rural producers, the impact of a predator attack can devastate the economy of the family, while for more technified producers —who own extensive properties and, therefore, a higher number of cattle— predation losses are not a catastrophic event (Peña-Mondragón *et al.*, 2016).

Losses caused by a deficient livestock management (health, starvation, accidents) are usually higher than predation losses (Hoogesteijn *et al.*, 2014). However, cattle owners are usually less tolerant to predator attacks than to other kind of losses, such as sickness or rustling; consequently, ranchers decide to eliminate the predator (Hoogesteijn *et al.*, 2014).

In order to intervene in the conflict between wild carnivores and ranchers, Mexico implemented the Seguro de Ataque por Depredadores (SAD). This program "protects the death and/or forced slaughter of breeding, dual purpose, milking, and working cattle, as well as breeding goats and sheep, horses and pigs, when their deaths are caused by predator attacks" (CNOG, 2021).

Although it came into force in 2006, SAD has had varied regional results. However, its effectiveness in reducing the death of wild predators has not been evaluated. Additionally, there is a lack of information about what ranchers think about this strategy. This situation limits the scope and effectiveness of this strategy.

Among other factors, the overall perception of people towards a species or a subject is measured by their values, attitudes, personality, age, gender, education, employment, religion, socio-economic status, and cultural heritage (Lazos and Paré, 2000). These factors are in constant flux, because they depend on the context and experiences in which they were created (Durand, 2008).

Consequently, the objective of this work was to evaluate the operation and effectiveness of the livestock insurance fund, offered in case of a predator attack against livestock. This evaluation should take into account the perception of the ranchers of the Calakmul region, Campeche, Mexico, where there are constant reports about wild predator attacks against cattle. This work suggests changes for the local implementation of the SAD.

MATERIALS AND METHODS

Study area

The Calakmul Biosphere Reserve (RBC) is located within the Yucatan Peninsula, in southern Campeche, and it has an area of 723,185.12 ha (INEGI, 2019). It is part of the Gran Region of Calakmul (Figure 1), which includes the Maya Biosphere Reserve in Guatemala and the preservation area of the Rio Bravo Dos Milpas in Belize. The RBC has a warm and subhumid climate (Aw) and a 24.6 °C annual mean temperature. Its highest m.a.s.l. is located in the Champerico hill (390 m); the minimum m.a.s.l. varies from 100 to 150 m. The predominant types of vegetation are medium semi-evergreen forest, medium semi-deciduous forest, and semi-deciduos lowland forest (Martínez and Galindo, 2002). Several productive activities are carried out in the area of influence of the RBC, such as agriculture, beekeeping, timber harvesting and non-timber forest harvesting, tourism, and livestock raising. Livestock raising leads to the coexistence between producers, wild carnivores (in particular, jaguars), and their habitat.

Information gathering

A structured interview was used to open the conversation with the inhabitants. An interview with the ejido representatives and livestock associations leaders was carried out in order to confirm the existence of problems between wild life and the inhabitants (Rodríguez-Calderón *et al.*, 2018).

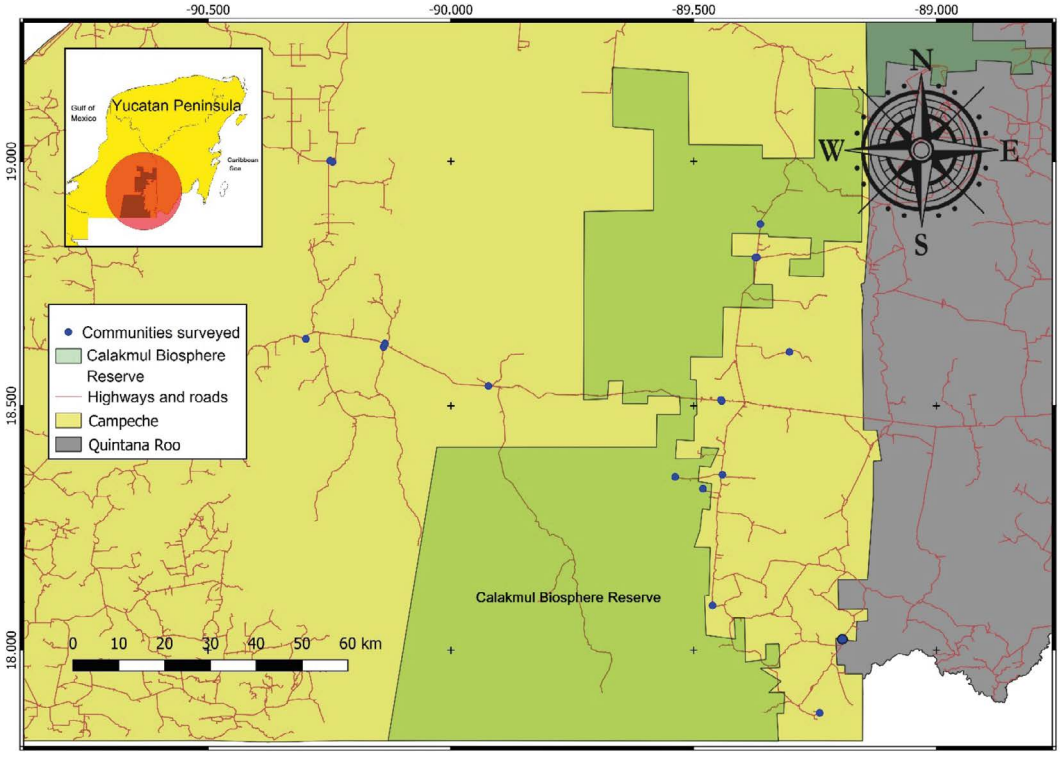

Figure 1. Location of the communities (blue circles) where the study was carried out. Calakmul Biosphere Reserve, Campeche, México.

Study area selection

Literature research was carried out in order to gather information about the conflict between producers and wild predators. The aim was to conduct surveys in communities located within the area of influence of the Calakmul region, in order to identify aspects related to the SAD. Subsequently, the communities were visited with the authorization of the ejido and municipal authorities, with the aim of informing them about the rancher-focused surveys. In order to identify producers in the communities under study, data from Sistema Nacional de Identificación Individual del Ganado (SIINIGA) and the data provided by the RBC —which has been gathering predation reports for years (Simá-Pantí, TBP)— were analyzed.

Based on the data provided by the producers, informants who have livestock in their property were selected from each community. Several factors were taken into account: age, time of residence in the community, awareness about the livestock activity processes, and natural resources.

A total of 70 surveys were conducted with ranchers of 18 communities from the area of influence of the RBC. Communities were divided in three groups: northern, central, and southern areas. In order to conduct the surveys with ranchers, a snowball method was used. This method consists of locating some individuals, who, on their turn, lead to others, and so forth, until enough samples are gathered. Categories included aspects such as awareness about the SAD, telephone numbers to report incidents, best known diffusion methods, perception about the benefits, how to report incidents, how long it takes for the technician to arrive, assistance provided by the technician, money paid for the predated animals, where and when more talks were given, and finally, what actions they would take if the SAD disappeared.

Data analysis

After the surveys concluded, all the gathered data was input and analyzed in a systematic way, using an Excel® sheet. Those who had been impacted by predation and those who have reported predation incidents to the SAD were identified. The data was analyzed per region, in order to understand how the service was provided to the Calakmul region.

A qualitative analysis was conducted. This methodology has been tested in several socioenvironmental studies (Hernández *et al*., 2006). Based on the producer answers, a percentage of representativeness was obtained for each question of interest (Rodríguez-Calderón *et al*., 2018). The properties of the interviewees were georeferenced with the help of the *ejido* commissioners, using the maps developed by the National Institute of Statistics and Geography (INEGI, 2019) for the National Agrarian Registry (RAR). If the common use properties of the *ejidos* were georeferenced, only a single point was taken into account.

RESULTS AND DISCUSSION

Based on the information obtained from the surveys, awareness and perception about the SAD were identified per region. The surveys were carried out as follows: 15 surveys in 6 communities of the northern region (1 woman and 14 men); 34 surveys in 7 communities of the central region (3 women and 29 men); and 23 surveys in 5 communities of the

southern region (3 women and 20 men) (Table 1). Out of the 70 ranchers, 56% (n=39) came from other states (Chiapas, Michoacan, Oaxaca, Quintana Roo, Tabasco, and Veracruz) and 44% (n=31) are from Campeche.

Regions Communities Women Men Total surveys

Most of the ranchers attended junior high school (n=36), followed by those who have no schooling (31%), incomplete primary school (17%), primary school (9%), high school (6%) and incomplete junior high school (1%).

Awareness about the predator attack insurance

Most of the ranchers (70%) from the communities located in the northern, central, and southern regions of the area of influence of the RBC are aware about the predator attack insurance. The central region (Xpujil and Constitución) had more (2) livestock associations than the other regions. In the northern communities, the diffusion methods included three-page leaflets and posters (Figure 2). Meanwhile, the central communities mentioned that there are others diffusion methods, such as talks with fellow producers, SINIIGA, RBC, and NGOs (for example, Pronatura Península de Yucatán (PPY) and the World Wildlife Fund (WWF)). The southern communities also mentioned talks from various institutions. In the northern communities, the less known diffusion methods included talks and other type of advertisement, while in the central communities, radio spots were mentioned. In the southern communities, radio spots and posters were also mentioned as the less known

Table 1. Communities where the surveys were conducted.

Regions	Communities	Women	Men	Total surveys
North	Akimpech	0	1	1
	Nueva Vida	0	3	3
	Nuevo Becal	1	3	4
	Pablo García	0	2	2
	Refugio	0	4	4
	Chilam Balam	0	1	1
Central	Centenario	0	1	1
	Nuevo Conhuas	3	7	10
	Constitución	0	14	14
	Heriberto Jara	0	2	2
	La Guadalupe	0	2	2
	López Mateos	0	3	3
South	Valentín Gómez Farías	0	2	2
	Centauro del Norte	0	5	5
	Justo Sierra Méndez	1	1	2
	Manuel Castilla Brito	0	1	1
	Once de Mayo	1	9	10
	Santa Rosa	1	2	3
		7	63	70

Figure 2. The interviewees mentioned that the information about the predator attack insurance was received from different methods, including talks, leaflets, and posters. Figure 2a shows the FAG and the RBC personnel giving in-person talks to a community in Calakmul. Figures 2b and 2c show examples of the posters used to spread information about the predator attack insurance.

methods. Most of the ranchers said that they are unaware of the SAD's telephone numbers. Sixty-eight percent of the central communities is unaware of how the SAD operates. Only 12 producers from the central communities mentioned that they know how SAD operates; this figure is almost the same in the southern region (n=12). Ranchers are not satisfied with the payment given for breeding males. Fifty-six percent of the ranchers mentioned that SAD has beneficial effects, 28% said they are not aware of its potential benefits, and 13% think that SAD does not have beneficial effects.

Talks about the predator attack insurance (SAD)

Sixty-four percent of the ranchers mentioned that they had never attended talks about the SAD. None of the ranchers from the northern region mentioned attending talks in 2012, 2014, and 2019. The ranchers from the central region did not attend any talk in 2012, 2015, and 2019.

Ranchers who were assisted by the SAD

Only 27% of the interviewed ranchers have reported attacks to the SAD and have obtained a compensation for their losses; the remaining 73% did not comply with the policies, because several reports were filed after the 72-h deadline; therefore, they were not provided with an advisory number and, consequently, never obtained a response. Eighty-eight percent of the ranchers that were assisted by the SAD mentioned that its response to predator attacks was immediate; 6% mentioned that the response was not immediate, while the remaining 6% mentioned that the response time was variable. Thirty-five percent of the ranchers have reported the incidents to the RBC and they mentioned that making a call was an important factor to obtain the SAD's support. All the ranchers interviewed in this study mentioned that their livestock have been attacked

by predators; however, only 27% have reported the incident to the SAD and have received the compensation for their losses. Eighty-eight percent of the ranchers mentioned that they had received an immediate response from the SAD technician. Fifty-three percent of the ranchers said that the SAD technician had a good attitude, while 47% said that it was excellent.

Ninety-one percent of the area of distribution of the jaguar is outside the protected natural areas; therefore, programs must be developed to reduce the conflict between jaguars and humans (predation), in order to guarantee a reduction of retaliatory killings.

The results obtained in this study show that most of the ranchers (70%) have been aware about the existence of the SAD for several years. Fifty-four percent are not aware of how the mechanisms and the procedures to obtain the SAD's assistance in the field work.

SAD fulfills its assistance policy function sending an adjustor to the field; the adjustor works with the concerned party and/or beneficiary in a timely and proper manner. Additionally, thanks to the support of the RBC/CONANP technical personnel, most of the complaints generated during a year can be solved. However, this is an informal support: there is no formal agreement regarding this activity. If a formal agreement were in place, a more effective assistance could be offered in case of predator attacks. Therefore, ranchers perceive that the SAD is only a temporary palliative. Nevertheless, it is also a strategic plan to reduce their anger and the subsequent retaliatory killings of carnivores —particularly jaguars, which are included among the endangered species (NOM-59-SEMARNAT-2010; SEMARNAT, 2010).

The RBC head office and several NGOs have supported ranchers in the Calakmul region to carry out preventive measures against predator attacks. They have also trained producers in order to improve their livestock herds and to obtain a higher production. This training included grazing management, grass silage, electrical fences, and how to gather information in the field.

The RBC head office also plays a fundamental role in the management of the jaguar-rancher conflict through a biological monitoring. This activity includes the monitoring carried out by groups trained by the RBC. Additionally, it collaborates with NGOs to provide several financial support strategies for the communities, in order to implement mitigation measures (such as electrical fences), reducing the predation risk.

Thirty percent of livestock losses in Calakmul result from diseases (Figure 3). This is a very common problem among rural communities, as a consequence of the lack of technical training and appropriate management programs (Iftikhar *et al.*, 2009). Just like in other areas (Iftikhar *et al.*, 2009), if time and resources are invested in order to improve livestock health management and to reduce deaths caused by diseases, productivity would improve and, at the same time, the proportional impact of predation would be reduced. Extensive management makes it difficult to accurately identify the species of predators, as well as to make an appropriate evaluation of the causes of death. Although the interviewees hold jaguars and cougars (*Puma concolor*) accountable for most of the attacks, it is important to bear in mind that, according to the SAD's regional data, the number of cases that received a compensation for jaguar or cougar attacks is lower than those received for wild dog attacks (CNOG, 2021).

Figure 3. Sheep in a typical safeguard stable. Animals are in a severe malnutrition state. Diseases account for a high percentage of the deaths in herds located in the Calakmul region, Campeche, Mexico.

Most of the attacks took place at night, which matches the findings of Zarco-González *et al.* (2012) and other studies (Figure 4). This is important because, a very useful measure to reduce losses in small herds is to protect the animals at night, just like some of the interviewees mentioned in this study.

A sense of justice and injustice can be clearly identified in the perception that ranchers have about the SAD. This is not only the result of the costs and benefits of livestock raising, but also of the management of jaguars and their livestock. The effective and friendly assistance helps the SAD to build a better link with the livestock sector and the community. Most of the ranchers acknowledged the inherent right to life, of the survival of carnivores, and the importance of their survival for future generations (their children). Even more important, we discovered alternative narratives that are currently been distributed by the conservationists of Calakmul. For instance, even those ranchers who have been impacted by predator attacks and the subsequent losses, reaffirmed the right of wild carnivores to life.

Figure 4. Cougar captured by a tramp camera, while killing a sheep in a livestock plot, in the Centauro del Norte ejido in the Calakmul region, Campeche, Mexico. Source: Animal Karma/WWF Mexico.

Additionally, people shared the same perception about procedural justice and they clearly distinguished among justice criteria. For them, the payment or compensation provided by the SAD is a temporary and effective element of justice that takes into account the justice of not killing wild carnivores.

CONCLUSIONS

Ranchers from the Calakmul region are aware of the SAD. They have been assisted and, in several cases, have benefited by some strategies established in the area by the RBC or the NGOs which actively work in the region. The SAD is an effective tool to reduce the anger of the producers towards wild carnivores. Sometimes it allows local technicians to dig deeper in order to implement some non-predatory strategies, such as the establishment of electrical fences.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Goat kid meat in the formulation of Vienna-type sausage

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ABSTRACT

Objective: To evaluate the substitution of pork meat with goat kid meat in the formulation of Vienna-type sausage.

Design/methodology/approach: A randomized complete block design was used with three treatments to substitute pork meat with goat kid meat: control sausage with 100% pork meat (SC1), sausage with 50% of pork meat and 50% of goat kid meat (SC2), and sausage with 100% of goat kid meat (SC3). The physicochemical variables (cooking loss (CL), pH, color, water holding capacity (WHC), proximate composition), textural profile and sensory characteristics were measurement to evaluate the treatments.

Results: The CL of sausages elaborated with goat kid mead did not have difference ($P>0.05$). The pH and WHC increased ($P<0.05$) for SC3, but their luminosity decreased ($P<0.05$) and the yellowness increased ($P<0.05$). Redness was similar ($P>0.05$) between sausages. The moisture, fat, protein, carbohydrate and ash contents improved ($P<0.05$) for SC2. Hardness, cohesiveness, chewiness, gumminess and resilience increased ($P<0.05$) for SC2 and SC3. The sensory evaluation showed that the three treatments were accepted by the consumers.

Limitations on study/implications: 100% of goat kid meat in the formulation did not improve the physicochemical variables due to increased CL, WHC, b*, carbohydrates and hardness, and decreased L*.

Findings/conclusions: The goat kid meat can be used at 50% for the formulation of Vienna-type sausages.

Keywords: composition, color, sensory, texture.

Image by 1195798 at Pixabay

INTRODUCTION

One of the main causes of meat deterioration is the oxidative process, which can happen during the conversion of muscle to meat, in meat processing or during storage (Cunha *et al.*, 2018). Likewise, meat products can have problems due to biochemical, sensorial and microbiological deterioration of the meat. Thus, the need to preserve foods could be through different methods such as freezing, refrigeration, dehydration and transformation of the meat into meat products (Teixeira *et al.*, 2020). Some examples of transformed meat products are chorizo, ham and sausage. In this sense, the Vienna-type sausage is a cured product prepared with lean meat and popular due to its color, flavor and taste (Wimontham and Rojanakorn, 2016).

Presently, methods are used not only to conserve the meat but also to satisfy the consumer in terms of health, flavor and texture, and even to reformulate transformed meat products with different additives or substituting the meat with another type of meat. In this sense, goat meat could be used to elaborate Vienna-type sausage in combination with pork meat. This is because goat meat has an average composition (g 100 g^{-1}) of 75.84 water, 20.60 protein, 2.31 lipids, 1.11 ash and 109.00 Kcal, and it stands out because it has double the amount of protein and a fourth less fat than beef and pork meat (USDA, 2021).

In recent studies different formulations of sausages with goat meat have been evaluated. For example, Frankfurt-type with different types of fat (Bratcher *et al.*, 2011), varied concentrations of pork fat (Leite *et al.*, 2015), goat meat and beef (Malekian *et al.*, 2016), sodium reduced (Da Silva-Araujo *et al.*, 2021), and other studies related with Vienna-type sausage (Vivar-Vera *et al.*, 2018; Diego-Zarate *et al.*, 2021; Sriwattana *et al.*, 2021). However, few studies have used goat kid meat in the elaboration of Vienna-type sausages, which could be an alternative for consumers due to the nutritional value of the meat of this species, which could improve the quality in a meat product.

In this study the substitution, partial or complete, of pork meat for goat meat in the formulation of Vienna-type sausages was evaluated through the physicochemical analysis (pH, cooking loss, color, water holding, and proximate composition), instrumental texture profile, and sensory acceptance.

MATERIALS AND METHODS

Experimental design

The experimental arrangement was based on a completely random block design, where pork meat was substituted in two levels by goat meat in the formulation of Vienna-type sausage. The treatments were defined as: control sausage 100% pork meat (SC1); sausage with 50% pork meat and 50% goat meat (SC2); and sausage with 100% goat meat (SC3). Each treatment was replicated twice with 1.3 kg each.

Elaboration process of the sausage and sampling

The process of elaboration and formulation of the sausage (Table 1) was carried out according to the method by Wimontham and Rojanakorn (2016). A total of 18 Eppendorf tubes of 50 mL per treatment (with replica; n=36 tubes) were used to pack the meat paste and evaluate the variables. From these tubes, seven were used for the physicochemical

Table 1. Formulation of the Vienna-type sausage to substitute pork meat.

Ingredients (%)	Treatments[1]		
	SC1	SC2	SC3
Pork meat	52.83	26.41	0.00
Goat meat	0.00	26.41	52.83
Pork back fat	19.44	19.44	19.44
Ice	20.93	20.93	20.93
NaCl	1.75	1.75	1.75
Sodium tripolyphosphate	0.10	0.10	0.10
Sodium ascorbate	0.07	0.07	0.07
Sausage condiment	0.50	0.50	0.50
Starch	4.39	4.39	4.39
$NaNO_2$	0.015	0.015	0.015
Total	100.00	100.00	100.00

[1] SC1: sausage control with 100% of pork meat; SC2: sausage with 50% of pork meat and 50% of goat meat; SC3: sausage with 100% of goat meat.

tests (cooking loss, pH, water holding and color), seven tubes for texture, and four tubes for sensory evaluation.

Cooking loss (CL), pH and water holding capacity (WHC)

The CL was determined with the weight of the meat paste packed before and after its cooking. The pH was measured with a potentiometer (HANNA; HI99163, Woonsoket, RI, USA) inserting the puncture electrode into the sample. The WHC was evaluated through the compression method (Méndez-Zamora *et al.*, 2015).

Color determination and proximate analysis

The color variables were measured with a colorimeter (SADT®, Chin Spec®, Color Difference Meter, Colorimeter-SC20, Beijing, China), and values were recorded of the color space CIE L*a*b*, luminosity (L*), red coordinates (a*), yellow coordinates (b*), chroma and hue angle. The total color change (TCC) and the coloring index (CI) were calculated with the equation by Ledesma *et al.* (2016) and Silva-Vazquez *et al.* (2018). In the proximate analysis (AOAC, 2016) the following were analyzed: moisture, proteins, fats, ash and carbohydrates (obtained from difference). The latter are estimated on dry basis.

Texture analysis and sensory evaluation

The instrumental texture profile analysis (TPA) was conducted according to the method established by Méndez-Zamora *et al.* (2015). The following variables were measured: hardness (N), adhesiveness (g s), elasticity (mm), cohesiveness (dimensionless), gumminess (g), chewiness (g mm) and resilience (dimensionless) in a texturometer (TA.XT. Plus, Stable Micro SystemsSerrey, England). The sausages were standardized at 2.4 cm diameter and 2.0 cm length. The trial was carried out at a preliminary speed of 2 mm s^{-1}, trial speed

and post-trial speed of 5 mm s^{-1}, compressing 60% of the sample in two cycles with time between cycles of 0.5 s. The sensory evaluation was carried out through an acceptability trial by attributes (Meilgaard *et al.*, 2006). A total of 20 semi-trained consumers conducted the test when they received the sausage samples (three pieces of 0.3 cm thickness and 2.54 cm diameter) in plastic containers with a random three-digit number. Each consumer evaluated the redness, softness, juiciness, flavor and general acceptability, using a hedonistic scale of 5 points: 1=I dislike it very much, 2=I dislike it, 3=I neither like it nor dislike it, 4=I like it, 5=I like it very much. The test was done in a laboratory of sensory tests, in individual cabins with chair, sink, light and access to the sample.

Data analysis

The analysis of variables was conducted with Minitab® (2013), using the instruction of the general linear model to obtain the variance analysis and to evaluate H_0 (equality of treatments) of each variable. H_0 was rejected when $P<0.05$. For the case of physicochemical variables and texture, seven repetitions per replica per treatment were considered (n=14), and in the sensory analysis the evaluator was considered as a block. When H_0 was rejected, the means comparison of the treatments was carried out with Tukey's statistical test ($P<0.05$). The means comparison in carbohydrates was done with Fisher's LSD test ($P<0.05$). The data arrangement for the analysis was based on a completely random block design. In the sensory evaluation, Friedman's non-parametric test was used, considering the evaluator as block effect in the Minitab® (2013) procedures.

RESULTS AND DISCUSSION

Cooking loss, pH and water holding capacity

Cooking loss (CL) obtained in the Vienna-type sausages (SC) elaborated with goat kid meat did not present a significant difference ($P>0.05$) between treatments (Figure 1). SC3 presented a CL of 0.67%, followed by SC1 with 0.64% and SC2 with 0.53%. Opposite results were found in other studies; for example, in pork meat sausages a CL of 15.54% was found (Nuñez De González *et al.*, 2008), in Vienna-type pork sausages 2.35% (Wimontham and Rojanakorn, 2016); meanwhile, goat sausages subjected to freezing presented 9.78% of CL (Da Silva-Araujo *et al.*, 2021). The temperature, cooking time of the ingredients, and amount of fat in meat products affects the cooking loss (Choi *et al.*, 2010), which is why meat from a single species has better yield after cooking instead of combining meat from different species, although goat kid meat in the elaboration of sausage had a lower yield after cooking. The pH values obtained in the Vienna-type sausages experimented on with goat kid meat are showin in Figure 1. The pH values presented a significant difference ($P<0.05$) between treatments. SC3 obtained the highest pH with 6.14 and SC1 the lowest pH with 5.96.

Similar results from those of SC3 were found in the study by Leite *et al.* (2015), where goat sausages with 10% pork fat presented a pH of 6.10, while goat sausages with 30% pork fat had pH of 6.16. However, the results obtained by Wimontham and Rojanakorn (2016) in Vienna-type sausages made of pork meat were the opposite, the pH was 6.61. Lonergan

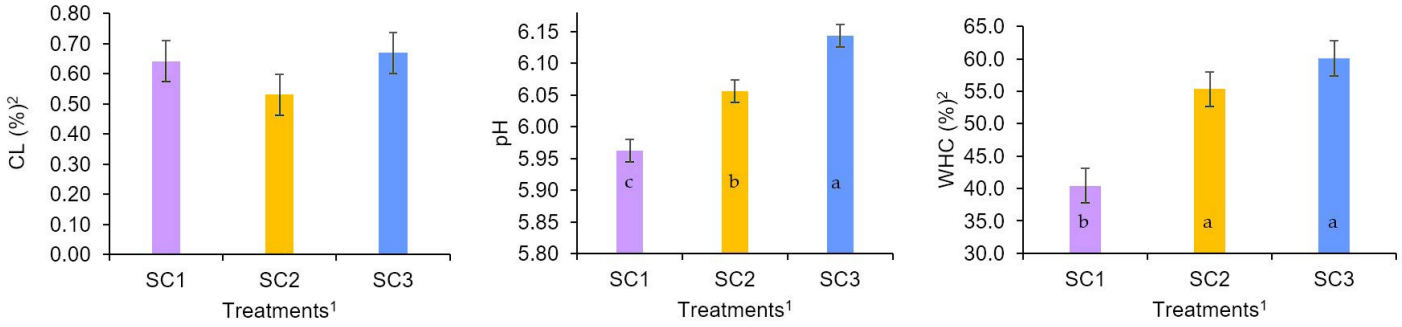

Figure 1. Cooking loss behavior (CL), pH and water holding capacity (WHC) of Vienna-type sausages elaborated with goat kid meat.
[1] SC1: control sausage 100% pork meat; SC2: sausage with 50 % pork meat and 50% goat meat; SC3: sausage with 100% goat meat.
a-c Means in bars with different letter are statistically different (Tukey, P<0.05).

et al. (2007) reported that the average pH of the pork meat canal is 5.71, while Teixeira *et al.* (2011) reported a pH of goat kid meat of 5.8-5.9. In this study, the pH increased when the pork meat was substituted by 50 and 100% with goat kid meat.

The WHC of the treatments presented a difference (P<0.05) between Vienna-type sausages elaborated with goat kid meat. SC3 obtained the highest WHC (60.11%) and SC1 the lowest WHC (40.44%) as shown in Figure 1. Similar results to SC3 were found in the study by Méndez-Zamora *et al.* (2015), where they studied Frankfurter sausages made of pork and bovine meat, while frozen goat meat sausages presented a WHC of 82% in another study (Da Silva-Araujo *et al.*, 2021).

Colorimetry

Figure 2 shows the results of luminisity (L*) obtained between sausages (CS) treated with goat kid meat, where a significant difference was found (P<0.05). SC1 obtained the highest L* (78.40) and SC3 the lowest L* (75.27). In previous studies lower values of L* were found than those obtained in pork meat Vienna-type sausages, of 70.72 (Wimontham and Rojanakorn, 2016); and L* was 63.63 in pork sausages (Nuñez De González *et al.*,

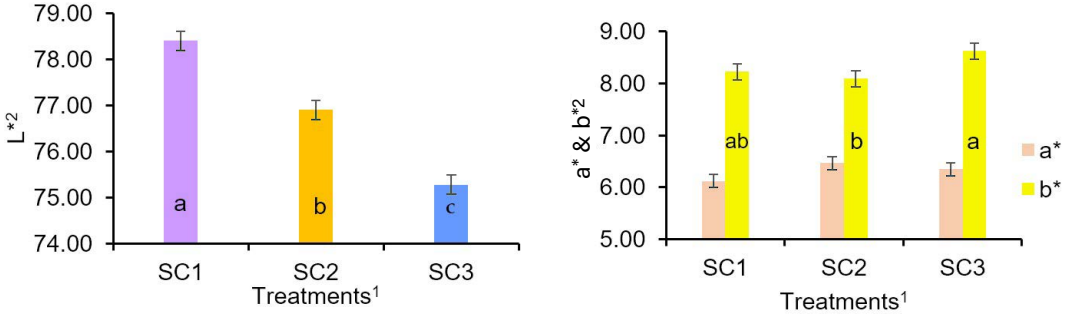

Figure 2. Luminosity, tendency to yellow and redness of Vienn-type sausages formulated with goat kid meat to substitute the pork meat.
[1] SC1: control sausage 100% pork meat; SC2: sausage with 50 % pork meat and 50% goat meat; SC3: sausage with 100% goat meat. [2] L*: luminosity; a*: red coordinates; b*: yellow coordinates.
a-c Means in bars with different letter differ statistically (Tukey, P<0.05).

2008). The value of L* decreases when goat kid meat is added to the treatments, and with lower content of pork fat in the sausages there is a lower value of L* (Kim *et al.*, 2011), because the meat, although lean, has a certain amount of fat, so as the goat kid meat is added the meat product becomes darker (lower L*).

The values with color tendency in a* (red coordinates) and b* (yellow coordinates) are shown in Figure 2. In b* a difference was found ($P<0.05$) between the Vienna-type sausages treated with goat kid meat to substitute the pork meat: b* increased in SC3 (8.62) and decreased in SC2 (8.09). On the other hand, no significant differences were found in a* ($P>0.05$), where SC2 obtained a value of 6.46, followed by SC3 with 6.35 and SC1 with 6.12. Opposite results were found in a* and b* from various studies in Vienna-type pork sausages (Wimontham and Rojanakorn, 2016) and pork sausages (Nuñez De González *et al.*, 2008). The oxidation of proteins and fat causes a deterioration in the color of meat products (Da Silva-Araujo *et al.*, 2021); in SC1 the lowest value of a* was found while in SC2 the lowest value of b*, both treatments had pork meat, which is why including goat kid meat in the formulation seems to decrease the oxidation of proteins and fat in cold meats.

The chroma, total color change (TCC) and coloration index (CI) presented a significant difference ($P<0.05$) between the different formulations (Table 2). These variables increased in Vienna-type sausages of SC3 and decreased in SC1. The hue value of sausages was not different ($P>0.05$). The study by Silva-Vazquez *et al.* (2018) obtained higher results. The values of coloration were affected when adding goat kid meat in the formulation. According to Álvarez *et al.* (2011), the ingredients and the added fat interfere in the change of coloration, which is why the coloration values increased when adding the goat kid meat.

Proximate analysis

In the proximate analysis, SC1 obtained the highest moisture and ash ($P<0.05$), while SC2 presented more fat and proteins ($P<0.05$), and SC3 higher content of carbohydrates ($P<0.05$; see Table 3).

Table 2. Results of coloration of the Vienna-type sausages with goat kid meat.

Treatment[1]	Color[2]			
	Chroma	Hue	ΔE	BI
SC1	10.29^{b}	53.17^{a}	17.78^{c}	16.53^{b}
SC2	10.40^{b}	51.29^{a}	19.26^{b}	16.99^{b}
SC3	10.76^{a}	53.42^{a}	20.80^{a}	18.06^{a}
SEM	0.10	0.95	0.20	0.12
P-value	0.004	0.233	0.000	0.000

[1] SC1: sausage control with 100% of pork meat; SC2: sausage with 50% of pork meat and 50% of goat meat; SC3: sausage with 100% of goat meat. SEM: standard error of the mean.
[2] Chroma: saturation index; Hue: Hue angle (tonality); ΔE: total color change, BI: browning index.
a-c Means in the same column with different letters are different ($P<0.05$).

Similar results in the moisture content were reported in frozen goat sausages with 100% NaCl (Da Silva-Araujo *et al.*, 2021) and in goat meat sausages with 10% of pork fat (Leite *et al.*, 2015). The moisture did not present difference between the sausages, although SC1 had a higher content, which is why it is deduced that pork meat has a higher water percentage (72.8-70.43%; Okrouhlá *et al.*, 2008) than goat meat (69.80-64.20%; Webb, 2014). The ash content increased ($P<0.05$) in SC1, since pork meat has more ash (1.13%) than goat meat (1.11%) (USDA, 2021). Diego-Zarate *et al.* (2021) found an increase in the ash when incorporating powdered dehydrated nopal, while the goat sausages with 30.00% pork fat presented similar values with 3.75% (Leite *et al.*, 2015), as well as in frozen goat sausages with 100% NaCl (Da Silva-Araujo *et al.*, 2021) with 3.97%.

The percentage of fats did not present difference ($P>0.05$) between treatments. Other studies presented results with more fat; for example, Malekian *et al.* (2016) in sausages elaborated with 100% goat meat obtained 15.47% of fat, while Leite *et al.* (2015) in goat sausages with 10% pork fat obtained 11.89% in fats. These contrasts show that when there is higher water content there is lower percentage of fat (Leite *et al.*, 2015), so it is deduced that SC2 presented higher percentage of fat because there was lower water content.

Similar results in protein were found by Diego-Zarate *et al.* (2021) in Vienna-type pork sausages and by Méndez-Zamora *et al.* (2015) in Frankfurter sausages. This similarity can be because the emulsions made with pork fat have higher protein and moisture percentage (Álvarez *et al.*, 2011); on the other hand, the protein content in goat kid meat is 20.60% while pork meat contains 10.28% (USDA, 2021), which is why this can indicate that the fat in pork meat, as well as the added fat and the addition of goat kid meat improved the protein content in SC2.

In Vienna-type pork sausages that Diego-Zarate *et al.* (2021) used as control, they obtained a similar percentage to those evaluated here, while Malekian *et al.* (2016) evaluated sausages with different combinations of goat and bovine meat, where it was shown that adding rice bran in the formulation increased the carbohydrate content. Starch is used as binding agent or extensor in low-fat meat products by emulsing them or restructuring them with added water (Totosaus, 2009), and as the percentage of starch

Table 3. Proximate analysis of Vienna-type sausages with goat kid meat.

Treatment[1]	Composition (%)[2]				
	Moisture	Ashes	Fat	Protein	Carbohydrates
SC1	65.88	3.24[a]	13.45	10.81	6.62[ab]
SC2	65.49	3.15[a]	13.81	10.97	6.57[b]
SC3	65.71	2.78[b]	13.21	10.96	7.33[a]
SEM	0.32	0.04	0.33	0.13	0.23
P-value	0.706	0.000	0.476	0.662	0.079

[1] SC1: sausage control with 100% of pork meat; SC2: sausage with 50% of pork meat and 50% of goat meat; SC3: sausage with 100% of goat meat. SEM: standard error of the mean.
a-b Means in the same column with different letters are different ($P<0.05$).
[2] Mean comparisons for carbohydrates was carried out with Fisher test, where a-b in the same column are different ($P<0.05$).

in this study's treatments (SC1, SC2 and SC3) was the same, and when comparing the results with Malekian *et al.* (2016).

Texture

The hardness and cohesiveness were different ($P<0.05$) between the sausages (Table 4), which were higher in SC3 and lower in SC1. The adhesiveness presented a trend ($P=0.068$; considering $\alpha=0.10$), where SC1 and SC3 obtained high adhesiveness.

Similar elasticity results (0.81 mm) were reported in the study by Méndez-Zamora *et al.* (2015), while hardness (86 N), adhesiveness (−20.59 g s) and cohesiveness (0.23) were not within the range of the Vienna-type sausages with goat kid meat. The results obtained in this study with goat kid meat showed increments in hardness, since there is higher water holding and improved protein-water bonds.

The results found in adhesiveness and cohesiveness of the sausages formulated with goat kid meat to substitute the pork meat in Vienna-type sausages indicated that the adhesive and cohesive behavior of the sausages is similar to the control; that is, the restructuring of the sausages compared to the formulation of elastic gels in the products was not affected (Méndez-Zamora *et al.*, 2015). Similarly, in the study conducted by Da Silva-Araujo *et al.* (2021) there was no effect found in elasticity, although they did present slightly higher values (0.95-0.98 mm) than the Vienna-type sausages of this study. The adhesiveness results of the Vienna-type sausages were similar in adhesiveness and elasticity of Frankfurter sausages (Méndez-Zamora *et al.*, 2015).

The cohesiveness values in this study varied when substituting pork meat with goat kid meat, the same effect that Gadiyaram and Kannan (2004) found when elaborating sausages with bovine, porcine and caprine meat; these authors indicated that the type of meat affects the texture properties. On the other hand, Wimontham and Rojanakorn (2016) reported that cohesiveness, hardness and adhesiveness increased when reducing the content of sodium nitrate and including powdered gac aril (*Momordica cochinchinensis*) in Vienna-type sausages made from pork meat.

The gumminess, chewiness and resilience of sausages with goat kid meat to substitute the pork meat were different ($P<0.05$; Table 4). These variables were higher in SC3 and lower in SC1. The gumminess varied compared to that presented by Bratcher *et al.* (2011),

Table 4. Evaluation of the texture of Vienna-type sausages with goat kid meat.

Treatment[1]	Hardness (N)	Adhesiveness (g s)	Springiness (mm)	Cohesiveness	Gumminess (g)	Chewiness (g mm)	Resilience
SC1	46.17^{c}	−32.82^{a}	0.8124^{a}	0.3647^{c}	16.90^{c}	13.74^{c}	0.1557^{c}
SC2	68.27^{b}	−53.68^{a}	0.8142^{a}	0.4391^{b}	30.06^{b}	24.46^{b}	0.2186^{b}
SC3	92.59^{a}	−37.48^{a}	0.8275^{a}	0.5373^{a}	49.85^{a}	41.23^{a}	0.2857^{a}
SEM	1.49	6.48	0.0058	0.0094	1.18	0.96	0.0067
P-value	0.000	0.068	0.150	0.000	0.000	0.000	0.000

[1] SC1: sausage control with 100% of pork meat; SC2: sausage with 50% of pork meat and 50% of goat meat; SC3: sausage with 100% of goat meat. SEM: standard error of the mean.
a-c Means in the same column with different letters are different ($P<0.05$).

who evaluated the texture in Frankfurter sausages elaborated with goat meat and three different types of fat, where chewiness and resilience in this study were similar. Meanwhile, the gumminess of SC2 was similar to that of goat sausages evaluated by Gadiyaram and Kannan (2004).

Gumminess is related with hardness and cohesiveness, while chewiness with hardness, cohesiveness and elasticity (Gadiyaram and Kannan, 2004); therefore, as hardness, elasticity and cohesiveness increased when using goat kid meat, the gumminess and chewiness between treatments also increased. The fat in the sausages provokes an effect on the resilience (elastic recovery of samples to return to their original shape), and the higher the fat the lower the resilience (Andrès *et al.*, 2006). Then, the resilience increased when adding goat kid meat to the formulation; this characteristic of texture was lower in SC1 because the pork meat has more fat.

Differences in hardness, cohesiveness, gumminess and chewiness were found in the study by Diego-Zarate *et al.* (2021), but not in elasticity. These authors debated whether this is because of the ingredients and amount used in the formulation of these sausages. Then, it can be said that goat kid meat used to substitute pork meat in Vienna-type sausages affects their texture properties because the hardness, cohesiveness, gumminess, chewiness and resilience increased.

Sensory evaluation

The sensory evaluation of the attribute redness, odor and flavor of Vienna-type sausages formulated with goat kid meat to substitute pork meat did not show difference ($P>0.05$; Table 5). These attributes were valued as "I like it" (4.0), which indicates that the preference of these attributes did not influence when 100% of goat kid meat was used to substitute pork meat in the Vienna-type sausage formulation.

Similar results were obtained in the sensory analysis of sausages with goat meat evaluated by Paulos *et al.* (2015). Wimontham and Rojanakorn (2016) evaluated the acceptance in Vienna-type sausages with pork meat in which the content of $NaNO_2$ decreased and powdered gac aril was added; additionally, the odor is acceptable without decreasing $NaNO_2$, but the acceptability decreases if powdered gac aril is added in higher concentrations. The condiments have a great influence in the odor and flavor of meat

Table 5. Evaluation of the attributes of redness, odor and flavor of the Vienna-type sausages formulated to substitute pork meat with goat kid meat.

Treatment[1]	Pink color	Odor	Taste	Hardness	Juiciness	Overall acceptability
SC1	4.0	4.0	4.0	4.0	4.0	4.0
SC2	4.0	4.0	4.0	4.0	4.0	4.0
SC3	4.0	4.0	4.0	4.0	4.0	4.0
P-value	0.705	0.455	0.433	0.679	0.584	0.850

[1] SC1: sausage control with 100% of pork meat; SC2: sausage with 50% of pork meat and 50% of goat meat; SC3: sausage with 100% of goat meat.
P-values<0.05 are different (Friedman test).

products (Paulos *et al.*, 2015); in this case they were the same condiments and the same amount added in the treatments, which is why the addition of goat kid meat to substitute pork meat in Vienna-type sausages presented the same acceptability, since pork meat is commonly used in cold meats. When increasing the fat, the color intensity and brightness in sausages decreases, while when increasing the salt the color intensity and brightness increases (Ventanas *et al.*, 2010). Although goat kid meat contains less fat than pork meat, this did not affect the evaluation of redness.

The hardness, juiciness and global acceptability of the goat sausages did not present a difference ($P>0.05$) in these attributes with a degree of acceptance of 4.0 (I like it). This indicated that the attributes were acceptable using 100 (SC3) and 50 % (SC2) of goat kid meat to substitute pork meat in the formulation of Vienna-type sausages.

Paulos *et al.* (2015) obtained similar results in hardness, juiciness and global acceptability. Although pork meat was replaced with goat kid meat, the attributes were not affected. The addition of ingredients could decrease the hardness of the cold meats (Bratcher *et al.*, 2011), so the change of meat in the formulation did not interfere in the sensory evaluation of these attributes.

CONCLUSIONS

The cooking loss improved when 50% pork meat and goat kid meat (SC2) were combined. The water holding increased with 100% goat kid meat (SC3). SC1 (100% pork meat) presented higher luminosity. The color red increased when combining pork meat and goat kid meat in 50%. The yellowness and color change increased in SC3. SC2 presents higher fat and protein, although less carbohydrates. SC3 increased the texture parameters. The Vienna-type sausages of treatments SC2 and SC3 had sensory acceptance. The goat kid meat in 50% can be used in the elaboration of Vienna-type sausages.

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