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Materiales y Métodos: Se especificará cómo se llevó a cabo la investigación, incluyendo el tipo de investigación, diseño experimental (cuando se traten de investigaciones experimentales), equipos, substancias y materiales empleados, métodos, técnicas, procedimientos, así como el análisis estadístico de los datos obtenidos.
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Conclusiones: Son la generalización de los resultados obtenidos; deben ser puntuales, claras y concisas, y no deben llevar discusión, haciendo hincapié en los aspectos nuevos e importantes de los resultados obtenidos y que establezcan los parámetros finales de lo observado en el estudio.
Agradecimientos: Son opcionales y tendrán un máximo de tres renglones para expresar agradecimientos a personas e instituciones que hayan contribuido a la realización del trabajo.
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Realized ecological niche of the Mexican Spotted Owl (*Strix occidentalis lucida*) in Mexico

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ABSTRACT

Objective: To characterize the realized niche of the Mexican spotted owl (*Strix occidentalis lucida*) and compare the environmental values it uses within the Mexican physiographic provinces.

Design/methodology/approach: The environmental temperature variables (n=7), precipitation (n=7) and elevation (n=1) were extracted from 79 unique occurrences sites of *S. o. lucida*. These values were grouped by physiographic provinces: Sierra Madre Occidental (n=59), Sierra Madre Oriental (n=13) and Transverse Neovolcanic Belt (n=6). The climate and elevation of these sites were described and compared *via* non-parametric Kruskal-Wallis and Bonferroni-Dunn tests ($P \leq 0.05$).

Results: The presences of the spotted owls were both, dispersed and focally distributed, over the geographic space in Mexico. The temperature and elevation variables have similar characteristics in the assessed physiographic provinces. To be noted, the precipitation variables showed significant differences among sites.

Limitations on study/implications: This study describes the environmental characteristics of the realized niche of the Mexican spotted owl; however, it is necessary to investigate other habitat variables at a smaller scale.

Findings/conclusions: The temperature and elevation environmental characteristics of the ecological niche of the Mexican spotted owl was similar between physiographic provinces.

Keywords: Realized niche, climate, elevation, Mexican Spotted Owl.

INTRODUCTION

Resource availability and environmental conditions vary across a species range (Gaston, 2009), with differences especially marked in widely distributed species (Brown *et al.*, 1996). Under Hutchinson's (1957) concept, these differences can be observed by contrasting realized niche characteristics (N_R).

Image by Jim Kennedy at Pixabay

The N_R is defined as the set of biotic and abiotic factors that allow a specie's presence (Vázquez, 2005). In this sense, studies investigating it are scarce and focus on occupancy predictive models (fundamental ecological niche) derived from climatic, vegetation and elevation variables (Palma-Cancino *et al.*, 2020), in large regions at spatial resolutions of approximately 1 km^2 (Sutton *et al.*, 2020). This misinformation is accentuated in poorly observed species (Pearce and Boyce, 2006) which in turn, limits the available information to establish management and conservation measures for these species (SEMARNAT, 2010; USFWS, 2012).

The N_R characteristics are not clear in elusive birds with wide and discontinuous distributions such as the Mexican Spotted Owl (MSO; *Strix occidentalis lucida*). The MSO inhabits forests, from the southwestern United States to the physiographic provinces: Mexican Sierra Madre Occidental (SMO) Sierra Madre Oriental (SMOR), and the Transverse Neovolcanic Belt (TNB) (USFWS, 2012). This subspecies is listed in Mexico as threatened (SEMARNAT, 2010) and globally as near threatened (BirdLife International, 2020).

For the MSO, forest loss and fragmentation have been the main threats to its populations (Wan *et al.*, 2018), which has led to their habitats being the most studied ecological attribute of this raptor (Salazar-Borunda *et al.*, 2020).

Despite substantial evidence suggesting the wide range of environments used by MSO (Bowden *et al.*, 2015; Hoagland *et al.*, 2018; Silva-Piña *et al.*, 2018), studies explicitly quantifying and comparing the N_R between geographically distant populations are not available. Considering that the description of the environmental characteristics of the sites where this bird inhabit will enrich the available information to those responsible for their management and conservation, the objectives of this work were: i) to characterize the N_R of MSO in Mexico and ii) to compare their used environmental variables between Mexican physiographic provinces.

MATERIALS AND METHODS

Study area

The study area was defined as the range of the MSO distribution area in Mexico and included the physiographic provinces of importance for their conservation: Sierra Madre Occidental (SMO), Sierra Madre Oriental (SMOR) and the Transverse Neovolcanic **Belt** (TNB) (USFWS, 2012). This constitutes a continental surface of 733 131 km^2 and contains diverse climatic groups (De Alba and Reyes, 1998).

Occurrence data

The presences of MSO perch sites in Mexico were obtained from the Global Biodiversity Information Facility platform (GBIF, 2019; 83 points) and field observations collected between 2018 and 2020 (25 points). Repeated coordinates and with georeferencing error were removed from the database, using *spThin* (Aiello-Lammens *et al.*, 2015) and *remove.duplicates* (Pebesma and Bivand, 2005) in the R statistical software (version 4.0.5, R Core Team, 2021).

Environmental characteristics

Climate and elevation variables were obtained from WorldClim (version 2.1, Fick and Hijmans, 2017) at 30 arc-seconds (~1 km^2) of spatial resolution. The climate data represent the annual patterns of temperature (mean annual, maximum of the warmest month, minimum of the coldest month, the mean temperature of the wettest, driest, warmest, and coldest quarters) and precipitation (annual and of the wettest, driest, warmest, and coldest months).

Characterization of the ecological niche

The environmental (climatic and elevation) and presence variables were projected to the geographic space in QGIS (version 3.4.15, QGIS, 2018). To extract the environmental values for each presence point, the *Point Sampling Tool* add-on was used. These values were grouped by province into three groups: a) SMO, b) SMOR and c) TNB.

Statistical analysis

Descriptive and dispersion statistics were calculated for the environmental variables. All statistical analyses were performed in the R statistical software (version 4.0.5, R Core Team, 2021) with an α=0.05 significance level. In this phase, the normality of the data series was tested with the Kolmogorov-Smirnov test and the homogeneity of variance with the Levene test. To compare the environmental variables between groups, the Kruskal-Wallis and Bonferroni-Dunn nonparametric tests were used.

RESULTS AND DISCUSSION

Occurrence data

Seventy-nine records of the MSO presence were obtained (Figure 1).

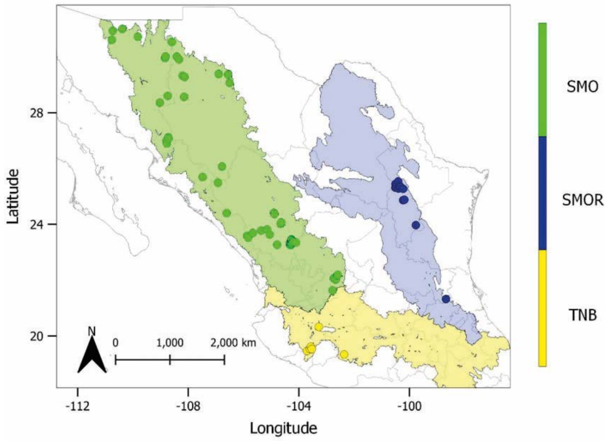

Figure 1. Occurrences of the Mexican spotted owl (points) in the Sierra Madre Occidental (SMO), Sierra Madre Oriental (SMOR) and Transverse Neovolcanic Belt (TNB) provinces.

The physiographic province with the most spotted owl records in Mexico was the SMO (n=59), followed by the SMOR (n=13) and TNB (n=6). It appears that the observations are distributed in a dispersed manner over the geographic space of the province with the most records and in a focal manner in the other two (in which there are probably poorly explored areas).

Realized ecological niche (N_R)

The N_R of MSO was characterized from environmental variables derived from temperature (n=7), precipitation (n=7) and elevation (n=1) in the physiographic provinces of importance in owl conservation (Table 1).

Table 1. Environmental ranges used by *Strix occidentalis lucida* in Mexico. All temperature variables are expressed in °C, precipitation in mm and elevation in masl.

Environmental variables	Physiographic provinces		
	SMO	SMOR	TNB
Annual mean temperature	10.50 - 24.11	10.35 - 24.00	10.45 - 20.78
Maximum temperature of warmest month*	23.00 - 38.90^{ac}	20.00 - 34.10^{b}	19.20 - 31.30^{ab}
Minimum temperature of the coldest month**	−4.9 - 12.10^{bc}	0.6 - 12.3^{ab}	1.0 - 8.4^{ac}
Mean temperature of wettest quarter	14.15 - 28.15	12.21 - 16.80	11.85 - 22.45
Mean temperature of driest quarter	8.0 - 24.27	7.90 - 19.08	9.75 - 19.51
Mean temperature of warmest quarter	15.06 - 29.31	12.64 - 27.60	12.30 - 22.81
Mean temperature of coldest quarter**	3.81 - 20.21^{a}	7.43-19.08	7.96-18.00
Annual Precipitation**	406 - 1247^{a}	462 - 1805^{b}	924 - 1342^{c}
Precipitation of wettest month **	101 - 289^{a}	75 - 335^{b}	207 - 282^{c}
Precipitation of driest month**	2 - 15^{a}	12 - 49^{bc}	1 - 10^{ac}
Precipitation of wettest quarter**	271 - 763^{a}	206 - 764^{b}	556 - 774^{c}
Precipitation of driest quarter**	11 - 55^{a}	45 - 152^{b}	12 - 38^{c}
Precipitation of warmest quarter**	206 - 673^{a}	169 - 681^{b}	403 - 542^{a}
Precipitation of coldest quarter	24 - 185	47 - 152	24 - 85
Elevation	353 - 2835	270 - 3555	1255 – 3300

Environmental variables (minimum value - maximum value) of the ecological niche of the Mexican Spotted Owl in the Mexican physiographic provinces: Sierra Madre Occidental (SMO), Sierra Madre Oriental (SMOR) and Transverse Neovolcanic Belt (TNB). **$P \leq 0.01$; *$P \leq 0.05$ (Kruskal-Wallis). Different literals indicate significant differences between sites (Bonferroni-Dunn, $P<0.05$).

The results suggest that MSO distributes in diverse environments. Some N_R variables are different among provinces (Figure 2); apparently, temperature extremes in short periods (maximums at the hottest and coldest months) and precipitation variables are characteristics that differ among realized niches.

Precipitation has been positively associated with the availability of trophic resources and, in turn, with the reproductive efficiency and survival of this raptor (Seamans *et al.*, 2002). In this study, the precipitation variables differed among sites, reflecting that the Mexican spotted owl may be more tolerant to this variable's fluctuation.

On other hand, the mean annual temperature and elevation are characteristics in common among N_R and probably determinant for site occupancy by the MSO. In this sense, the predictive importance of the temperature and elevation variables on this subspecies potential distribution was reported by Palma-Cancino *et al.* (2020), these, in turn, are associated with the MSO's thermoregulatory mechanisms (Ganey, 2004). Although the average elevation (2160 masl) of the sites coincides with the rugged topography described for the subspecies (Tarango *et al.*, 1997; Tarango *et al.*, 2001; May *et al.*, 2004), it seems that this owl is distributed in areas with a lower altitude than the reported minimum (2072 masl; Young *et al.*, 1997).

This research demonstrates that N_R analysis is an important tool to understand the environmental conditions in which widely distributed birds of prey inhabit and, at the same time, strengthen the knowledge of sensitive and understudied species. Therefore, this research provides a framework to explore other variables of the environment occupied by the MSO, *i.e.*, the description of the biotic and abiotic interactions and their impact on the population dynamics of the subspecies.

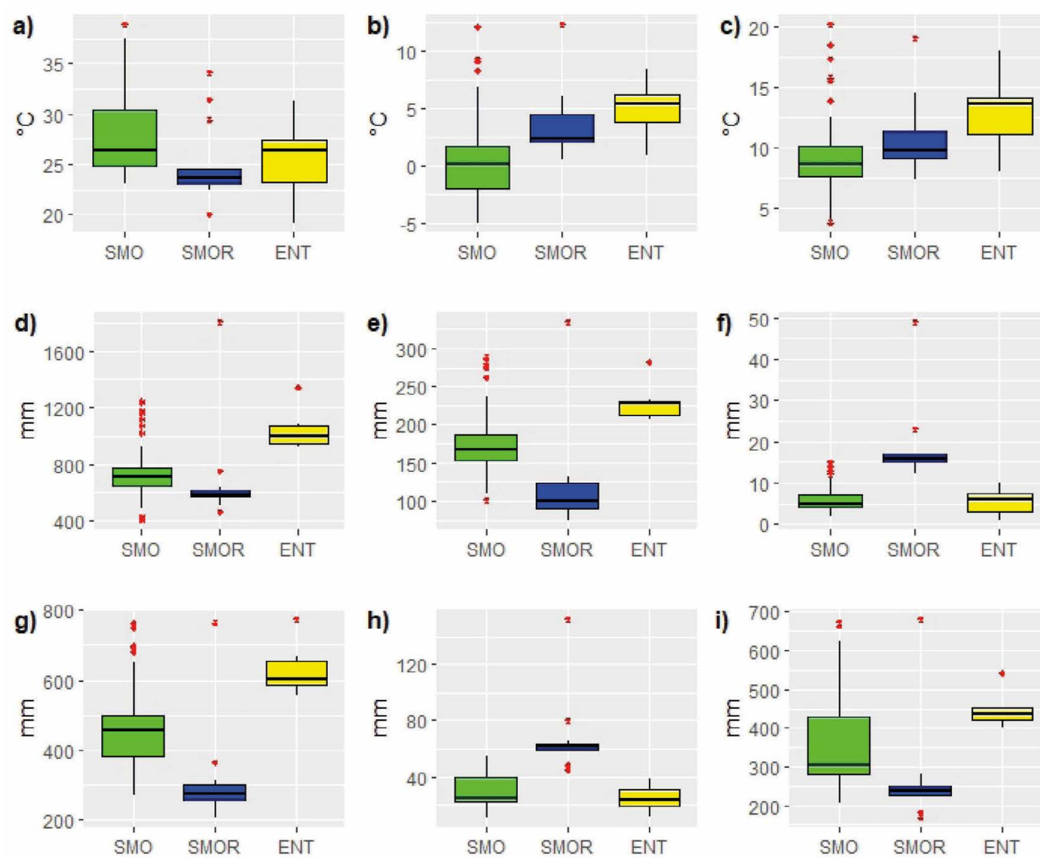

Figure 2. Environmental variables of Mexican Spotted Owl occurrences in the phisiographic provinces: Sierra Madre Occidental (SMO), Sierra Madre Oriental (SMOR) and Transverse Neovolcanic Belt (TNB). Variables derived from temperature (°C): a) maximum of the warmest month, b) of the coldest month, c) mean of the coldest quarter, and variables derived from precipitation (mm) d) annual e) mean of the wettest month, f) driest month, g) the wettest quarter, h) driest and i) warmest quarter.

CONCLUSIONS

The climatic and elevational characteristics of the N_R of the Mexican spotted owl (*Strix occidentalis lucida*) in Mexico were described. The Mexican physiographic provinces of importance for the conservation of this raptor have similar temperature and elevation ranges. However, the relation between this bird's presence and the environment is undoubtedly more complex. The generated data provide a general description of the thermal, elevational and precipitation regimes of this subspecies. They also provide a framework for exploring other N_R variables of this subspecies at a smaller scale.

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AP AGRO PRODUCTIVIDAD

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Colegio de Postgraduados

Feeding ecology of the catfish *Ictalurus punctatus* (Siluriformes: Ictaluridae) in a reservoir in Northeast Mexico

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ABSTRACT

Objective: To determine the main food of the catfish according to seasonal variability and the sex of the organism in the Venustiano Carranza Dam, Coahuila, Mexico.

Methodology: In total, 143 catfish stomachs from different seasons were examined. In the analysis of the stomach content, the detected organisms were determined until the taxonomic order rank. The seasonal and sex feeding variability were also analyzed. The Relative Importance Index and the Alimentary Index were applied. Non-parametric tests were carried out to compare stomach content between seasons and sexes.

Results: The total annual trophic spectrum for catfish consisted of 13 items, of which only the order Ephemeroptera was categorized as a frequent food. In the winter season the catfish consumed significantly more food compared to the other seasons, but there was no difference in the amount consumed by females and males ($p>0.05$).

Implications: This information is relevant to highlight the importance of the biological integrity of the terrestrial site which surrounds the reservoir as a source of food for the catfish.

Conclusions: Catfish channel in the Venustiano Carranza Dam is a generalist species (13 alimentary items). There was a difference in food consumed during the different seasons of the year. However, there was no difference between the sexes.

Keywords: Fishery, food resources, freshwater management.

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INTRODUCTION

Diversity and availability of food is a determining factor in fish populations because it affects parameters such as migration, behaviors, and temporal and spatial distribution (Behzadi *et al.*, 2018). The analysis of stomach contents of fish is a common practice to understand trophic relationships and flow of matter and energy

Image by F. Muhammad at Pixabay

in ecosystems. This knowledge contributes to fishery management programs and other inland waters fishing systems (Jacquemin *et al.*, 2014). There is great diversity in the way the different groups of fish feed and this also varies from one species to another. This can vary from a high degree of specialization to species which are generalist (Behzadi *et al.*, 2018; Mar *et al.*, 2014). The genus *Ictalurus* includes piscivor-omnivorous species, which have feeding preferences in bottoms of water bodies in semi-intensive or extensive systems (Arce-H *et al.*, 2017). Within this genus, one of the species with the greatest economic and nutritional importance worldwide is *I. punctatus*, whose production increased from 15.909 t in 1965 to 432.931 t in 2016 (FAO, 2021). In the federal state of Coahuila, Mexico, the species *I. punctatus* is reported as the second freshwater species of commercial importance, with a production of 281 t in 2017 (SIAP, 2017). In this context, it has been reported that in those aquatic species of commercial interest it is important to know the dietary diversity to maintain growth in their sizes and the viability of their populations (Hilling *et al.*, 2016). This is a factor of great importance to address the problem of food security in marginalized areas (Fisher *et al.*, 2017). Some studies on the food ecology and variability of the diet of channel catfish in freshwater systems, in the north-central part of the country, show a tendency of the populations of *I. punctatus* to consume mainly fish (Perciformes and Atheriniformes) (Tyus and Nikirk, 1990). In other regions of North America the contribution of elements from terrestrial ecosystems in the diet of *I. punctatus* have been reported (Edds *et al.*, 2002). For example, arthropods and seeds are important components for their diet too (Cardoza *et al.*, 2011). Herein we aimed to know if in our study area, *I. punctatus* shows selectivity in their eating habits from a seasonal and sexual perspective. The results of the present study allow us to increase information regarding the consumption patterns of *I. punctatus* resources in arid ecosystems, which may contribute to the management and maintenance of the populations of this species, thus promoting its sustainable use.

MATERIALS AND METHODS

Study area. The Venustiano Carranza Dam is in the northeast of the state of Coahuila, in northern Mexico, between coordinates 27° 25’ 06’’, 27° 32’ 21’’N and 100° 34’ 50’’, 100° 45’ 20’’ W (Figure 1). The reservoir has as main tributaries the Sabinas and Nadadores rivers and a storage capacity of 1.385 million m^3 of water. The average annual rainfall for the area is 375 mm, the months with highest rainfall are September and October, and the average annual temperature is 22 °C (CONAGUA, 2018). The main types of vegetation and soil cover for the surrounding area of the reservoir are the microphilic desert scrub, rosetophilic scrub, tamaulipan thornscrub, induced pasture, hydrophilic vegetation, secondary vegetation, and temporary agriculture (INEGI, 2017).

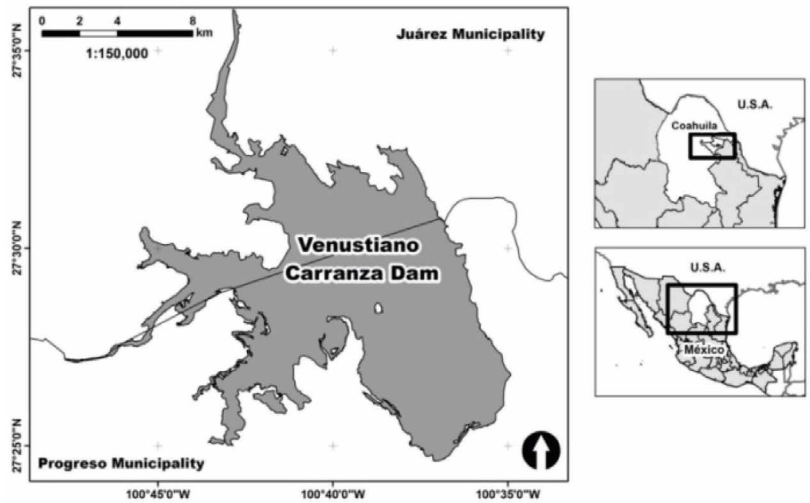

Figure 1. Geographic location of Venustiano Carranza Dam in Coahuila state, Mexico.

Collection and analysis of samples. Sampling was carried out seasonally in the period from July 2015 to June 2016. In total, 143 catfish individuals were analyzed, which were captured by commercial fishermen of the Venustiano Carranza Dam using gillnets of 2, 3 and 4 inches of mesh opening and 50 m in length. The seasons were considered as follows: spring (March, April and May), summer (June, July and August), autumn (September, October and November) and winter (December, January and February). Different biometric measurements such as weight, total length (TL), standard length (SL) with the support of a digital field balance (precision of 0.010 kg) and an ichthyometer (precision of 1 cm) were taken from each specimen (Espinosa-Pérez, 2014; Valdez-Zenil *et al.*, 2015). To determinate the trophic spectrum of the catfish, an analysis of the stomach contents of the captured organisms was performed. Sex was identified by direct observation of their state of gonadic maturity (Essner *et al.*, 2014). In some organisms the sex could not be determined so they were classified as not determined (Beltrán-Álvarez *et al.*, 2012). Stomachs were transferred to the laboratory for later analysis. The stomach content was analyzed in the laboratory with a stereoscope microscope and was determined to the taxonomic level of order (Cardoza *et al.*, 2011; Mar *et al.*, 2014). Taxonomic determination was based on specialized scientific literature. Undetermined plant or animal matter was considered detritus, with the exception of fish fragments (scales, spines, skin, etc.), which were classified as fish remains (Gerringer *et al.*, 2017). For each food type (item) the abundance (%N), weight (%W), frequency of occurrence (%OF) and volume (%V) were determined (Magnusson *et al.*, 2003; Mar *et al.*, 2014). To estimate the importance of the relation of each food type to total food consumed, the Relative Importance Index (RII) was applied (Pinkas *et al.*, 1970):

$$RII = (\%N + \%V) \times \%FO$$

Where %N is the numerical proportional abundance of a food type, %V the volume and %FO the frequency of occurrence. To categorize the food items, the Alimentary Index (AI) was applied, which groups the food types based on its relative importance (Lauzanne, 1975):

$$AI=\%OF \times \%V / 100$$

The classification used allows a differentiation between the most used (preferred) food resources, from those that are possibly a product of isolated or accidental eventuality. The result of AI for each item varies from 0 to 100% and is categorized as follows: a) preferential food (AI>50), b) secondary (25<AI<50), c) frequent (10<AI<25) and d) accidental (AI<10) (Lauzanne, 1975; Raymundo-Huizar and Saucedo, 2008). RII and AI were obtained for the total annual food spectrum, by seasons of the year and by sex of the organisms. Finally, because the assumptions of normality and homogeneity of variance for the analyzed data were not met, the non-parametric Kruskal-Wallis test was used to determine possible differences in food consumption (weight) between seasons. Similarly, the non-parametric Mann-Whitney test to determine differences in the food consumed (weight) between males and females was applied (Zar, 1999). Statistical analysis was performed with the Past ver. 3.25 software (Hammer *et al.*, 2001).

Results and Discussion

In total, 143 individuals of channel catfish were analyzed; of which 41 correspond to males, 64 to females and 38 of undetermined sex. The Total Length (TL) of the catfish analyzed varied from 23 to 48 cm. The total annual trophic spectrum for the catfish consist of 13 trophic items or categories, of which 11 correspond to the following orders, based on the Relative Importance Index: Ephemeroptera (mayflies nymphs), Charales (algae), Odonata (dragonfly larvae), Decapoda (crayfish), Cypriniformes (carp eggs), Perciformes and Characiformes (fish), Orthoptera (grasshoppers), Fabales (huizache seeds), Spirobolida (millipedes) and Hemiptera (bugs), as well as the categories of Fish Remains and Detritus (Table 1). According to the Alimentary Index, all food items for annual trophic spectrum were categorized as accidental foods (AI<10), with the exception of the order Ephemeroptera (AI=11.09), which was categorized as a frequent food.

Seasonal feeding analysis. In relation to the seasonal analysis, spring was the period in which the catfish's food spectrum showed the greatest diversity in the use of resources (10 food items). The Detritus and the Fish Remains were the most important resources for this season (63.66% of the RII). Summer showed the lowest diversity of resources (4 food items). Detritus and the order Charales (algae) were the most important resources in this season (79.56% of the RII). Decapoda (crayfish) and Charales orders represented 61.76% of the RII for the autumn season. For the winter season, the order Ephemeroptera (ephemeral) individually constitute 95.97% of the RII. For the spring and autumn seasons all food items were classified as accidental foods (AI<10), however, in the summer season the Detritus was classified as a frequent food (AI=12.90). Similarly, the order Ephemeroptera reached the category of secondary food (AI=37.50) for the winter season. For the last two seasons mentioned, all other food types were classified as accidental (Table 2). The food consumed by the channel catfish represented by weight in the winter season was significantly higher than in the rest of the seasons (Kruskal-Wallis; H=12.16, $p<0.05$). Average food consumed in this season was of 3.44±1.47 g.

Table 1. Annual trophic spectrum of the catfish in Venustiano Carranza Dam. Numerical Abundance (%N), Frequency of Occurrence (%FO), Volume (%V), Relative Importance Index (RII) and Alimentary Index (AI).

Alimentary item		%N	%OF	%V	RII	%RII	AI
Invertebrates	Ephemeroptera	85.920	19.608	56.572	2793.960	78.118	11.093
	Odonata	2.299	9.804	3.267	54.569	1.526	0.320
	Decapoda	1.437	9.804	0.879	22.702	0.635	0.086
	Orthoptera	0.287	1.961	0.395	1.337	0.037	0.008
	Spirobolida	0.287	1.961	0.263	1.078	0.030	0.005
	Hemiptera	0.287	1.961	0.128	0.814	0.023	0.003
Fishes	Cypriniformes	0.287	1.961	6.653	13.608	0.380	0.130
	Perciformes	0.287	1.961	1.417	3.341	0.093	0.028
	Characiformes	0.287	1.961	0.599	1.737	0.049	0.012
	Fish remains	2.586	15.686	20.489	361.964	10.120	3.214
Detritus	Detritus	3.736	25.490	6.227	253.956	7.101	1.587
Plants	Charales	2.011	13.725	2.825	66.389	1.856	0.388
	Fabales	0.287	1.961	0.287	1.125	0.031	0.006
	Total	100		100		100	

Table 2. Seasonal trophic spectrum to the catfish in Venustiano Carranza Dam. Relative Importance Index (%RII) and Alimentary Index (AI).

Alimentary item		Spring		Summer		Autumn		Winter	
		%RII	AI	%RII	AI	%RII	AI	%RII	AI
Invertebrates	Ephemeroptera	15.845	0.537	3.596	1.521	0	0	95.976	37.508
	Odonata	4.018	0.379	0	0	12.034	2.790	0.553	0.126
	Decapoda	7.846	0.522	0	0	36.123	6.816	0	0
	Orthoptera	1.425	0.211	0	0	0	0	0	0
	Spirobolida	1.170	0.141	0	0	0	0	0	0
	Hemiptera	0	0	0	0	6.497	0.788	0	0
Fishes	Cypriniformes	0	0	0	0	0	0	0.851	0.754
	Perciformes	0	0	0	0	0	0	0.214	0.161
	Characiformes	1.820	0.320	0	0	0	0	0	0
	Fish remains	23.694	4.357	16.840	6.202	11.155	2.472	1.922	1.714
Detritus	Detritus	39.969	6.479	49.212	12.904	8.546	1.529	0.484	0.295
Plants	Charales	2.996	0.646	30.352	7.552	25.644	3.026	0	0
	Fabales	1.216	0.153	0	0	0	0	0	0
	Total	100		100		100		100	

Feeding Analysis by sex of organisms. The food spectrum of the catfish was more diverse for females than for males (11 and 8 items, respectively). The order Ephemeroptera was the most important for both sexes. This order represented 93.74% and 91.79% of the RII for both females and males, respectively. The same order was the only one that reached the category of frequent food for both sexes (23.95 and 11.00 AI, for both females and males), the rest of the food was classified as accidental (Table 3). The food consumed by the catfish was 0.86±0.38 g for females, while for males it was 0.80±0.27 g, respectively. There is no significant difference in the food consumed between females and males (Mann-Whitney U=1196, p>0.05 for weight).

Table 3. Trophic spectrum for sex for the catfish in Venustiano Carranza Dam. Relative Importance Index (%RII) and Alimentary Index (AI).

Alimentary item		Female		Male	
		%RII	AI	%RII	AI
Invertebrates	Ephemeroptera	93.745	23.955	91.790	11.007
	Odonata	0.412	0.028	0.706	0.031
	Decapoda	0.046	0.001	1.988	0.106
	Orthoptera	0.065	0.011	0	0
	Spirobolida	0.058	0.007	0	0
	Hemiptera	0.051	0.003	0	0
Fishes	Cypriniformes	0.388	0.181	0	0
	Perciformes	0	0	0.567	0.087
	Characiformes	0	0	0.350	0.037
	Fish remains	3.372	1.427	0.298	0.025
Detritus	Detritus	1.755	0.335	2.075	0.215
Plants	Charales	0.048	0.002	2.226	0.117
	Fabales	0.060	0.008	0	0
	Total	100		100	

Some studies on *I. punctatus* suggest that the spatial and temporal variability of its feeding is due to multiple factors, among which stand out: availability of resources, ontogeny, physicochemical quality of water (mainly temperature), seasonality and interspecific competition. The interaction of these factors results in the composition of the diet for a given period (Haubrock *et al.*, 2018; Schmitt *et al.*, 2018). Because of its broad food spectrum, which includes aquatic and terrestrial resources, the channel catfish has been cataloged historically as an omnivorous-opportunistic species; generally, this diet presents variations in relation to the seasonal availability of resources (Edds *et al.*, 2002; Dagel *et al.*, 2010; Cardoza *et al.*, 2011; Braun & Phelps, 2016).

Studies for the species in reservoirs in the semi-arid zone of northern Mexico have shown that the catfish is generalist and flexible in its diet throughout the year. (Cardoza *et al.*, 2011). In the present study, this generalist behavior was consistent, because the food spectrum for the catfish in the Venustiano Carranza Dam consisted of 13 different taxonomic orders and the dominant items consumed show variability in relation to the seasons. Except for the order Ephemeroptera, all food items consumed annually were classified as accidental foods, since the individuals examined consumed significant amounts (high volume) of a specific food type in short periods of time (low frequency). However, certain preference for some types of food is reported for some reservoirs; for example, the preference for some species of forage fishes for the Lázaro Cárdenas Dam in Durango state, Mexico (Cardoza *et al.*, 2011). It is worth highlighting the role of the order Ephemeroptera in feeding of the catfish for the period evaluated. Although it reached only the category as a secondary food for the winter season, the order Ephemeroptera occurred in three of four seasons and was the only food that was not classified as accidental in the total annual balance. The particular importance of this order and other groups of insects has also been reported for other catfish populations (Hill *et al.*, 1995; Dagel *et al.*, 2010; Hilling *et al.*, 2016). Changes in catfish food preferences in relation to the seasons are also a reflection of their opportunistic and broad-spectrum eating habits (Braun & Phelps, 2016). The present study confirms this, through the occurrence in specific seasons of some food types, such as the orders Ephemeroptera and Odonata, that use the aquatic environment as reproduction site. We also emphasize the importance of algae (Charales) and Detritus for catfish feeding in the dam throughout the year. Although both items are cataloged in the annual balance as accidental food, they practically occur in all four seasons of the year, which represents a frequent resource for the catfish population. In the case of algae, there are studies from reservoirs in North America that suggest that the consumption of algae as part of the catfish diet is very important. Far from being accidentally consumed by individuals, the algae become selected food of a spectrum available in the aquatic environment (Dagel *et al.*, 2010; Cardoza *et al.*, 2011). The highest consumption of food in weight and volume documented in this study for the winter season, compared to other periods of the year is probably a result of the preparation of energy of the organisms for the reproductive period, which takes place from February to August, depending on the conditions such as water temperature or habitat (Wellburn, 1988). However, it is necessary to continue with investigations that complement the explanations of seasonal variability of catfish feeding. On the other hand, for systems of fisheries in reservoirs in Mexico, there are general norms that regulate the exploitation of commercial species such as catfish, which includes minimum catch sizes, amount of daily catch per species, establishment of periods of no-fishing or "veda", among other general aspects (DOF, 2006). However, despite the fact that the channel catfish is one of the most important freshwater species for food and recreation through semi-intensive and extensive cultivation in reservoirs, for the majority of fisheries there are no comprehensive, management programs that ensure their viability and sustainability over time (Braun and Phelps, 2016; Lara-Rivera *et al.*, 2015). Therefore, we consider it important for future planning and management to include the integral conservation of the reservoir system, specifically the conservation and restoration of riparian vegetation in the middle and upper part of the basin, avoiding ecosystem fragmentation (mainly by dams), maintaining, and recovering the original vegetation that surrounds the reservoir (Schnier *et al*., 2016). Some food types such as insects (Ephemeroptera and Odonata), algae (Charales) and Detritus are important components for catfish feeding and they need an acceptable biological integrity of the environment surrounds the reservoir to be available for fish populations. Numerous studies demonstrate the importance of the integrity of river and reservoir systems as a measure to favor the provision of food sources for channel catfish (Cardoza *et al*., 2011; Edds *et al*., 2002; Dagel *et al*., 2010; Braun and Phelps, 2016).

CONCLUSIONS

Thirteen food items for annual catfish spectrum were determined. The most important food was the order Ephemeroptera, since it was the only one that reached the annual category as frequent food. We detected seasonal differences in feeding of the catfish. For spring and autumn all foods were categorized as accidental, while for the summer and winter the Detritus and the order Ephemeroptera were categorized as frequent and secondary, respectively. In the winter season, more food was consumed compared to the other seasons of the year. There was no difference in food intake between females and males. Further complementary studies on the evaluation of the diet of other commercial and non-commercial species and their interaction in terms of competition with the channel catfish, determination of variability in feeding based on the species ontogeny, determination of areas of importance within the reservoir (important nutrition zones), assessments of population ecology, among others, are recommended.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Modelling potential distribution of the endemic ringtail (*Bassariscus astutus saxicola*) on an island of the Gulf of California

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ABSTRACT

Objetivo: Analizar la topografía de una isla del Golfo de California, México, mediante modelos digitales de elevación (DEM) de 30 m de resolución espacial para generar el primer modelo de distribución potencial para el carnívoro endémico *Bassariscus astutus saxicola*.

Diseño/Metodología/Enfoque: Se empleó el software Maxent para modelar la distribución potencial del babisuri en la Isla Espíritu Santo. Los muestreos se realizaron en 2015-2016 en ocho bahías en el oeste de la isla en donde se capturaron n=74 individuos.

Resultados: Las variables con mayores aportes a los modelos fueron elevación, (71.6%); índice de carga de calor (15%) y rugosidad del (11.8%). El modelo predijo ($p>0.5$) probabilidades de presencia del carnívoro en 3,018 hectáreas de la isla. SE obtuvo un valor alto de AUC (0.928), lo que indica que el modelo es exacto, y posteriormente se confirmó con un valor de pAUC=1.917.

Limitaciones/Implicaciones del estudio: El hábitat del *B. astutus saxicola* era poco conocido principalmente porque es una especie endémica, y no existen publicaciones sobre su distribución dentro de la isla.

Conclusiones: Este modelo muestra que las variables topográficas son útiles para explicar la distribución potencial del *B. astutus saxicola*, presumiblemente porque la topografía se relaciona con sitios que ofrecen refugio termal, alimento suficiente y cobertura de escape a depredadores, entre otras características del hábitat.

Keywords: carnívoro endémico; GIS; modelo de distribución, topografía.

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INTRODUCTION

The islands of the Gulf of California are ecosystems with a rich biodiversity and high number of endemic species (CONANP, 2000); however, the resident species are in many cases threatened due to various human activities, including tourism (Sanchez-Pacheco *et al.*, 2000). This is the case of the ringtail (ringtail cat, miner's cat) on an island in the Gulf of California, Mexico (Carnivora: Procyonidae) (Álvarez-Castañeda, 2000). In the IUCN (International Union for Conservation of Nature) Red List of Threatened Species, the ringtail is listed as Least Concern (LC) because it is common and widely distributed from central USA to Mexico (Barja and List, 2006). In Mexico, the distribution of *Bassariscus astutus* ranges from the desert region of the Baja California peninsula to Oaxaca. Three islands in the Gulf of California are included in

its distribution: Tiburón, Espíritu Santo, and San José (Lawlor, 1983). In Espíritu Santo Island, the endemic ringtail (*B. a. saxicola*) has crepuscular and nocturnal habits; it is an opportunistic forager, with an omnivorous diet (Rodríguez-Estrella *et al.*, 2000; Harrison, 2012), preferentially consuming arthropods, small mammals, and fruit (Poglayen-Neuwall and Toweill, 1988). It has been assumed that the diet of this species may be impacted by the numerous tourists that visit the island year-round (Álvarez-Castañeda, 2000); however although the ringtail consumes some food of anthropogenic origin, according to a recent study, such foods do not make up a significant percentage of its diet (Sansores-Sánchez, 2016).

In desert environments ringtails occur in habitats often associated with rocky outcroppings, cliffs, or steep slopes where their dens are found (Hall, 1981). These topographic features are not known on Espíritu Santo Island. Although ecological niche models evaluate the niche dynamics of a species and determines the most important environmental predictors that affect its potential distribution (Guisan and Zimmermann, 2000; Pearman *et al.*, 2008), it is possible to increase the reliability of these distribution models if they include topographic variables (slope, elevation, and ruggedness), and heat indexes generated on slopes according to their geographical exposure. In this context, the aims of this study were: 1) to analyze the topography of the island with a digital elevation model (DEM), and 2) to generate the first potential distribution model for an endemic carnivore (*B. astutus Saxicola*) that exists in the islands of the Gulf of California.

METHODS AND MATERIALS

Bassariscus a. saxicola was studied in the Espíritu Santo Island Complex (24° 24'-24° 36' N; and 110° 18'-110° 27' W) in an area of 10,390 ha. Mountain ranges run east–west, with a maximum height of 600 m; most of the east coast are cliffs, while the west portion of the island has a dozen bays, inlets, and coves, formed by the gradual slope of the mountains toward the sea (CONANP, 2000). The climate is dry-arid, with temperatures ranging from 11 °C to 44 °C; the annual average rainfall is 159.5 mm, with rainfall concentrated from July to October. The predominant vegetation is scrub vegetation, and in the bay mangroves (*Laguncularia racemosa*) predominate (CONANP, 2000; Carreño and Helenes, 2002) (Figure 1).

Capture of ringtail

The study was conducted in 2015-2016, through four survey trips: two in the dry season (May and July) and two during the rainy season (September and October). Ringtails were trapped in eight glens on the west of the island by means of ten Tomahawk Live Traps (Mod. 207, 81×25×30 cm), of which five were placed parallel to the coastline among the vegetation at the entrance to the glen, and five along the bottom of the ravine, 30 m apart. Fresh sardines were used as bait. Traps were baited before dark (19:00 h) and checked before dawn (4:00 h). Data of the captured animals were recorded, which included sex, physical condition, and morphometric measurements.

They were marked with a numbered metal ring at the base of the ear and later released at the same site where they were captured (Figure 2).

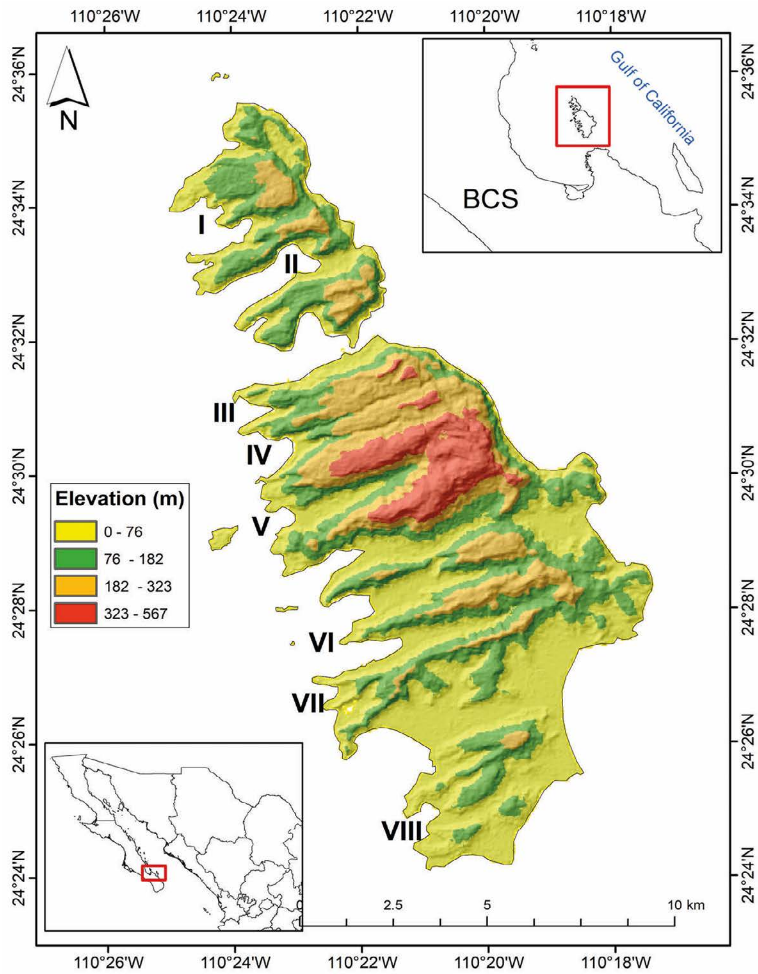

Figure 1. Study area of the endemic ring-tailed cat (*B. astutus saxicola*) of Espiritu Santo Island, Gulf of California, Baja California Sur (BCS). Ensenada grande Bay (I), El cardonal (II), El Candelero (III), Mesteño (IV), La ballena (V), El corralito (VI), El gallo (VII) and Dispensa Bay (VIII).

Figure 2. Ringtail *Bassariscus a. saxicola* from the Espiritu Santo Island.

Environmental variables

The literature reported that ringtail inhabits rocky outcroppings, cliffs, or steep slopes (Poglayen-Neuwall and Toweill, 1988). We found four topographic variables to be relevant for this species: a) elevation above sea level (masl), b) slope (0 to 90°), c) terrain ruggedness and d) heat load index (HLI). Terrain ruggedness quantifies the dispersion of the vector orthogonal to the terrain surface; this index is unitless and has values from 0 (flat sites) to 1 (canyons and cliffs) (Sappington *et al*. 2007). The HLI describes the amount of heat that is generated on a slope and is calculated by rescaling aspect from zero to one, with 0 being the coolest slope (northeast) and 1 being the warmest slope (southwest) (McCune and Keon, 2002). All these features were estimated through the spatial analysis tools available in ArcGIS 10.7.1, using terrain analysis tools and digital elevation models (DEM) from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) at 30 m spatial resolution. It was downloaded from the US. Geological Survey (USGS) Global Visualization Viewer at http://glovis.usgs.gov/.

Maxent modelling

The maximum entropy model algorithm (Maxent, V. 3.4.1) was used to determine the geographic potential distribution of ringtails (Phillips *et al*., 2006). The Maxent method for species distribution modelling uses presence and background data (hence absence data is not necessary) for predicting species distribution by a logistic regression model. We used the four topographic features and the presence records for the model. The default Maxent setting sampled 10,000 background points from the study area and set the minimum number of iterations to 500 and the regularization multiplier to one.

Model Accuracy Estimation

The area under the receiver operating characteristic curve (ROC) was used to evaluate the discriminative ability of the Maxent models. The Area under the curve (AUC) values greater than 0.70 were considered to distinguish between presence and potentially unsampled locations (Elith, 2000). Also, Maxent estimated the environmental variable contributions to the models with permutation importance (values from 0 to 100%). The use of AUC in predictive accuracy of presence data model has been criticized (Lobo *et al*., 2008); therefore, analysis of model performance using a partial-AUC procedure was carried out (Barve, 2011). This analysis was done using the NicheToolBox tool (available at: https://shiny.conabio.gob.mx). To validate the model precision, we used the following parameters: omission rate 0.05, random points percentage 50%, number of bootstrap iterations = 500 (Eq. 1). The equation used by the NicheToolBox tool is (Eq. 1), where random AUC = Random value of AUC generated from bootstrapping and perfect AUC = AUC value calculated for each iteration of the model with Maxent.

$$pAUCs = \frac{1}{2}\left(\frac{pAUC - random\ AUC}{perfect\ AUC - random\ AUC} + 1\right) \quad (1)$$

Results and Discussion

A total of n=74 ringtail specimens were captured. The sex ratio was 0.85 (n=34 females, n=40 males), of which 34 were adults and six males were juveniles. Most of the ringtail captures (n=22) occurred in the Ballena Bay. In this Bay, forty three individuals were captured in the dry and 31 in the rainy season. We captured most ringtails in the northern portion of the Island. All ringtail captures were conducted at elevations of 12-60 meters, slopes 0°- 30°, coolest slopes, and ruggedness 0-0.02 (Figures 3, 4).

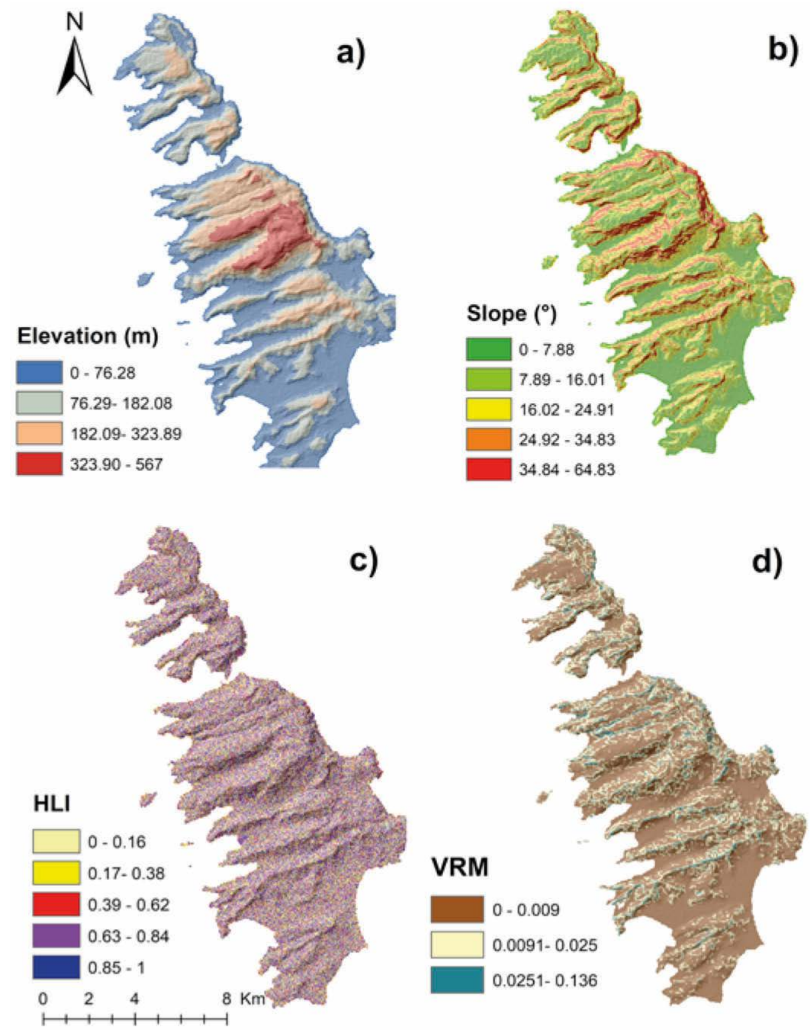

Figure 3. Topographic characteristics in Espíritu Santo Island Complex Baja California Sur, Mexico. a) elevation, b) slope, c) HLI, d) VRM.

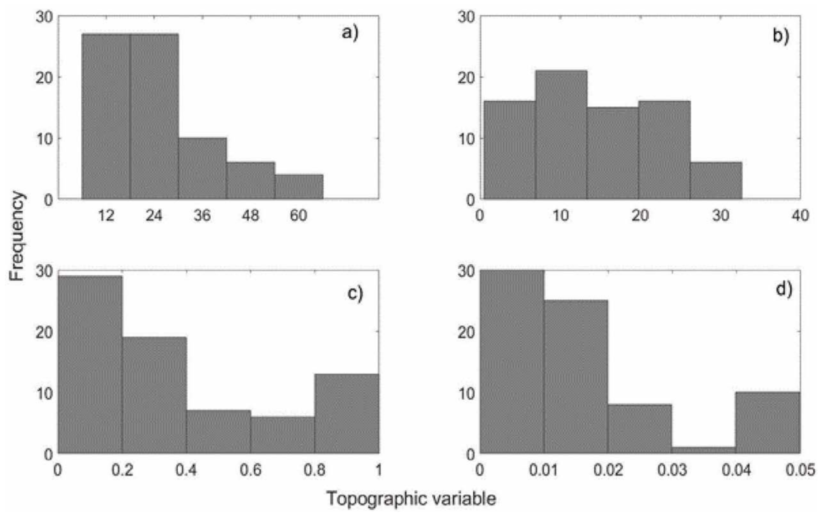

Figure 4. Topographic variables of ringtail captures. a) elevation, b) slope, c) HLI, and d) VRM.

The modeling showed that the potential distribution of the ringtail at a >0.5 probability was of 3,018 ha. The AUC was 0.928, which indicates that the model was able to distinguish between presence and potential presence. The variables that most contributed to determine the presence of ringtail were elevation with 71.6%, HLI with 15% and VRM 11.8%. It can be observed (Figure 5) that the areas of potential distribution were canyons containing west aspects. The ROC value was 1.917, this indicates that the model made a good prediction of the potential distribution of ringtails in the Espiritu Santo Island (Figure 6).

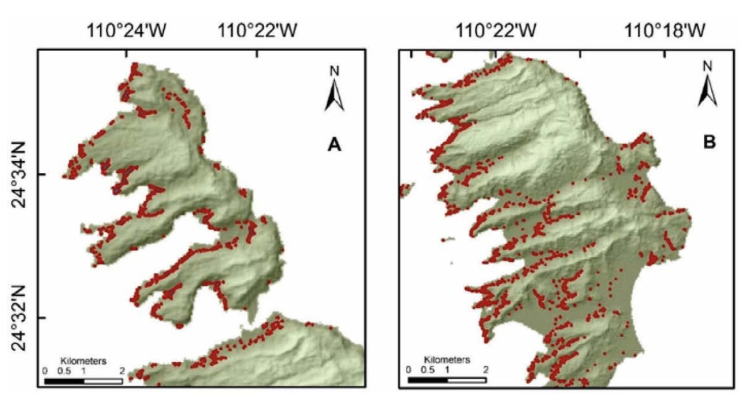

Figure 5. Maps of potential distribution with probabilities >0.5 (red polygons) of *B. a. saxicola* in the Espíritu Santo Island, Baja California Sur. Northern (A) and southern mountains (B).

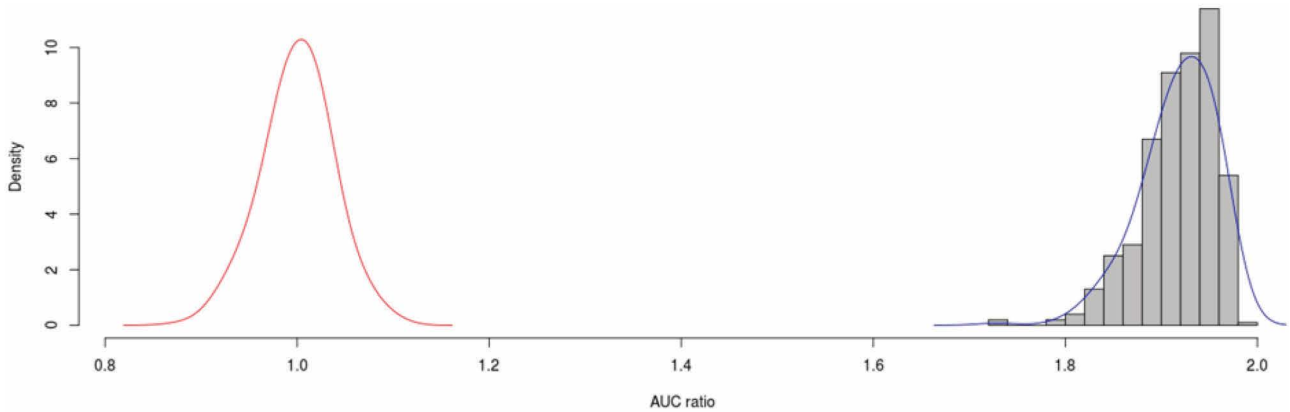

Figure 6. Partial AUC Distribution. The red line indicates the values obtained for the random AUCs derived from bootstrapping. The gray bars are the AUC derived from the Maxent model.

The presence of steep slopes, rocky sites, permanent water and vegetation cover are key elements of the ringtail habitat (Gehrt, 2003). On Espíritu Santo Island, elevation, coolest slope, and ruggedness (VRM) were the variables that most contributed in prediction model of ringtail habitat preferences. Ruggedness is a variable describing the heterogeneity of the elevation, slope, and aspect of a mountain (Sappington *et al*., 2007). We captured the ringtails in sites with the highest values of ruggedness on the island; and we obtained a high AUC value (0.928), which indicates that the model was accurate; we also confirmed it with a value of pAUC=1.917. Similar results were reported by Ray *et al*. (2018), when they calculated pAUC of the distribution model made with Maxent using only presence data.

This model shows that topographic variables are useful to explain the potential distribution of the ringtail, mainly because the topography is related to sites that can offer thermal refuge, sufficient food, and escape cover from predators, among other features. There are several studies that also show that topography is a key feature for determining the potential habitat of this species (Moreno *et al*., 2011; Bradie and Leung, 2017).

The distribution model that we obtained for this carnivore was expected to have a higher probability at higher elevations (>500 m) and isolated canyons. However, the model predicts that the ringtails are distributed mainly in the western bays. This distribution match (overlap) with sites visited by tourists, and according to by Sansores-Sánchez (2016), at these sites the ringtails feed mainly on insects and Ficus palmeri fruits. Apparently, at these sites, tourism does not have an influence on the ringtails' diet and its presence.

P permanent water is a factor that influences the presence of ringtails (Chevalier, 1984), but on the Espíritu Santo Island fresh water is not available, suggesting that ringtail obtains water from metabolic processes. In the Espíritu Santo Island, it is possible that ringtail fulfill its water requirements through the consumption of fruits of *Ficus palmeri* and cacti plants (*Stenocereus gummosus*, *Ferocactus* sp, *Mamillaria* sp, and *Echinocereus* sp) (Sansores-Sánchez, 2016).

According to home range studies, ringtail requires about 40 ha per individual (Toweill and Teer, 1980). Espíritu Santo Island has an area of 10,390 ha. In this study, we determine that the potential distribution of ringtail covers an area of 3,018 ha, suggesting that the size of population in the island (considering 40 ha of home range per individual) could be of 75 individuals. This information needs to be validated by conducting capture studies at random sites within the potential distribution map defined for the Espíritu Santo Island.

This study was conducted in one of the three islands of the Gulf of California. To design better conservation strategies for the ringtail, we recommend to define the potential distribution of ringtail for the two other islands (San José and Tiburón islands) of the Gulf of California. We still have the challenge to complement ringtail surveys on the east side of the Espíritu Santo lsland where we could not conduct surveys at inaccessible areas due to sea waves.

CONCLUSIONS

The topographic variables are useful to determine the potential distribution of the ringtail since they offer thermal refuge, sufficient food, and escape cover from predators, among other habitat features.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Diet and sexual segregation of bighorn sheep (*Ovis canadensis mexicana* Merriam) in Sonora, Mexico

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ABSTRACT

Objective: To determine the diet of the bighorn sheep and identify differences in its composition between sexes and periods (reproductive and segregation).

Design/methodology/approach: The study was conducted at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico. To determine the plant species in the bighorn sheep feces the micro histological technique and a cell catalog of plants from the study area were used. From the diet information, the relative frequency, the Shannon-Weaver diversity index and the Kulczynski similarity index by sex and period (reproductive and segregation) were determined.

Results: The diet of the bighorn sheep included 40 plant species, being herbaceous (36.1±4.4%) and grasses (26.8±8.9%) the most common. The male diet during the segregation period was mainly composed of grasses (36.2%) and female diet by herbaceous (30%) and grasses (29.8%). There were no differences in the diversity of the diets in males and females during the segregation period (H´=1.0), overall, their diets were very similar (80%).

Limitations/implications: Collect a greater number of fecal samples by sex and period (reproductive and segregation) and to analyze the nutritional content of the plants consumed by bighorn sheep.

Findings/conclusions: In this study, the sexual segregation exhibited by the bighorn sheep was not due to food preferences.

Key words: diversity, fecal sample, similarity.

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INTRODUCTION

The bighorn sheep (*Ovis canadensis mexicana* M.) is a species that has high ecological and economic values. However, illegal hunting, habitat destruction and competition with exotic and feral species have restricted the distribution of their populations to the state of Sonora (Wehausen, 1996; Creeden and Graham, 1997). The Official Mexican Norms classify it as a species subject to special protection (Diario Oficial de la Federación [DOF], 2010). This species has developed survival strategies, specifically sexual segregation, which occurs at the end of the reproductive season when the groups of adult males separate from the groups of females, offspring, and

juveniles (Bleich *et al.*, 1997; Barboza and Bowyer, 2000). It is established that during segregation, males, to regain their body condition (after the reproduction period) and establish dominance over other males, require higher food diversity and of better nutritional quality. In contrast, females select safer sites, but with low forage abundance and lower nutritional quality (Main *et al.*, 1996; Tarango *et al.*, 2002). The sexual segregation exhibited by wild herbivores has implications on nutrient cycling, ecological succession and species diversity in the ecosystems (Bowyer *et al.*, 2001; Espinosa *et al*. 2006; Jansen *et al.*, 2009).

Although bighorn sheep has been widely studied in the United States (Festa-Bianchet, 1988; Wehausen, 1996; Bowyer *et al.*, 2001; McKinney and Smith, 2007), in Mexico the reported research works for this species are few (Tarango *et al.*, 2002; Guerrero *et al.*, 2003; Guerrero-Cárdenas *et al.*, 2016). In this regard, in Sonora, it has been documented that during the segregation period male and female diets were similar, indicating that this behaviour was not related to food preferences (Tarango *et al.*, 2002). Understanding the causes of sexual segregation is important to implement specific habitat management and improvement actions for males and females (Bowyer *et al.*, 2001; Pérez-Barbería *et al.*, 2007). Therefore, the objective of this study was to identify the composition of the bighorn sheep's diet by sex and period (reproductive and segregation) in the Wildlife Conservation Management Unit (UMA) Rancho Noche Buena at Hermosillo, Sonora, Mexico. In this study, it was assumed that the composition of the diet of males and females during the period of sexual segregation was different.

MATERIALS AND METHODS

The study was conducted from August 2014 to August 2015, at the Wildlife Conservation Management Unit (UMA) Rancho Noche Buena (29° 07' 58.67'' N, 112° 02' 11.48'' W), located at Hermosillo, Sonora, Mexico (Figure 1). It has a 5,063-ha extension, an arid-warm climate, an elevation between 200 m and 800 m.a.s.l. In it, bighorn sheep inhabits and is used as a game species. The dominant vegetation type is microphyllous desert scrub. The mean annual precipitation is 365.7 mm, with rains from July to September, the average relative humidity is 43% and mean annual temperature 24.8 °C, with a maximum of 48.5 °C in August and a minimum of −4 °C in January (López *et al.*, 1999).

Diet composition and diversity

The micro histological technique was used to identify the composition of the diet of the bighorn sheep. It consists of comparing and quantifying the plant structures included in a reference catalog and the observed structures in fecal samples of bighorn sheep (Fracker and Brischle, 1944; Sparks and Malechek, 1968, Holechek *et al.*, 1982).

To prepare the catalog, plant species samples were collected from the bighorn sheep distribution sites within the study area. These were classified by biological form (shrubs, arboreal, herbaceous, grasses and succulents), family and species. Sheep feces were collected in field trips during the reproductive period (only during May 2015 due to the sheep hunting season) and the sexual segregation period (October 2014, June and July 2015), during which the sheep were observed and located with Leica® 15×56 binoculars, at distances of between 700 m and 900 m. Once the sheep were located, they were followed with a Swarovski® 60×85 telescope, until they were seen defecating. Subsequently those feces were collected, each sample was recorded, noting the date, sex, period, and then processed in the laboratory.

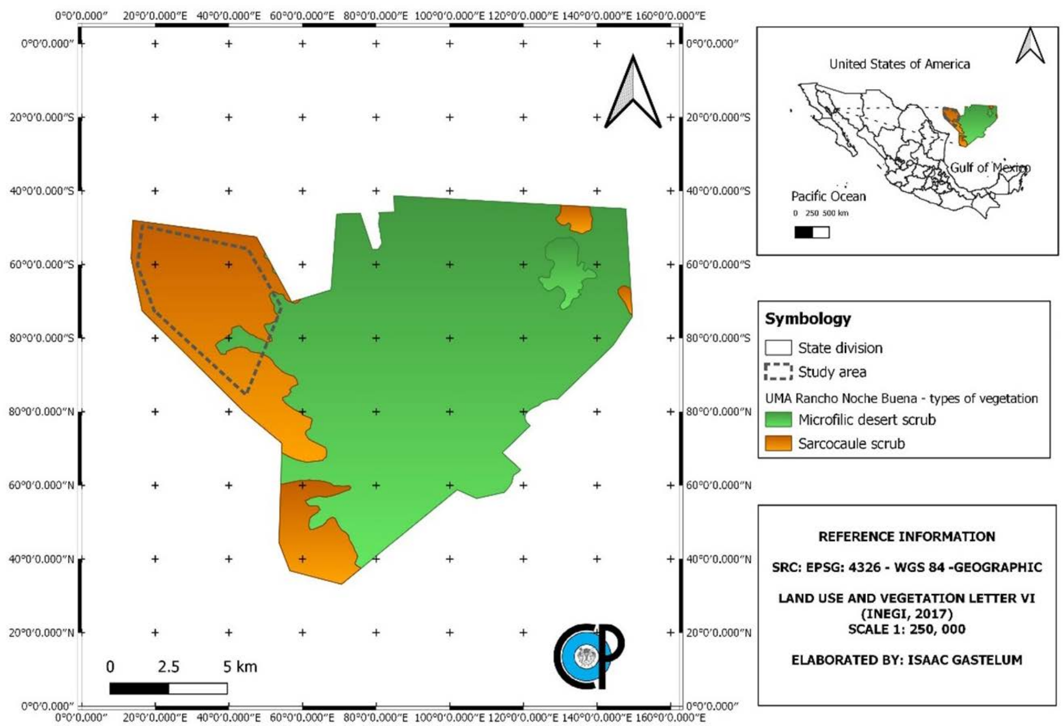

Figure 1. Location and types of vegetation in the UMA Rancho Noche Buena, municipality of Hermosillo, Sonora, Mexico.

The assessment of the bighorn sheep diet was done by collecting, preparing and analyzing seven samples from males and 12 from females during the reproductive period and five samples from males and nine from females during the segregation period. From each fecal group, classified by sex and period, a composite sample was prepared for micro histological analysis. From each sample, five slides were prepared and ten fields per slide were observed with a Leica® DM 4000B microscope with 10X objective and 10X ocular.

The species percentage within the diet by sex and period was calculated by relative frequency following Fracker and Brischle (1944). Species diversity in the diet was calculated using the Shannon-Weaver index (1949). To determine the degree of similarity between diets by sex and period, the Kulczynski index (1928) was calculated using the Past 3.0 statistical software.

RESULTS AND DISCUSSION

The bighorn sheep diet, considering the two periods, reproductive and segregation, was composed of 40 species grouped in 20 families. It has been documented that bighorn sheep in northern latitudes consume a greater number of species. For example, in the northern United States and southern Canada, a consumption of more than 200 species is reported (Brown *et al.*, 1977; Seegmiller and Ohmart 1981). In contrast, in Arizona (Krausman *et al.,* 1989) and California (Seegmiller and Ohmart, 1981) a bighorn sheep diet with a smaller number of plants (58 and 32, respectively) has been recorded. In Caborca, Sonora, Mexico, the sheep consumed 41 species (Tarango *et al.,* 2002), in Baja California Sur 47 (Guerrero *et al.,* 2016) and in Coahuila 49 species (Gastelum, 2020).

Males consumed 31 species and females consumed an equal number, from which, nine species were consumed only by males and another nine only by females (Table 1). Males during the reproductive period consumed more herbaceous species (38.6%) and in the segregation period more grasses (36.2%) (Figure 2).

The females during the segregation period mainly consumed herbaceous (30%) and grasses (29.8%); and more herbaceous in the reproductive period (47.6%) (Figure 2). During the segregation period, *Aristida adscensionis* (Figure 3) predominated in male (20.7%) and female diets (27.2%) (Table 1).

Although the diet of males and females in the segregation period was similar (IS=80), grasses were more important for males. In this regard, Ruckstuhl and Neuhaus (2000) mention that the digestive tract of males is more adapted to digest fibrous food with a low digestibility percentage, such as grasses (Figure 3). This has also been documented in other bovids, such as the American bison (*Bison bison* L.) in Kansas, United States (Post *et al.*, 2001).

The composition of the diet of wild herbivores depends on the availability of forage (Morrison *et al.*, 1992). For example, in the Sonoran Desert and much of North America, shrub species represent the sheep's diet basis because they are available throughout the year (Sandoval, 1979; Watts, 1979; Leopold and Krausman, 1991). In addition to shrubs, the grasses that sprout annually are species preferred by sheep, mainly because of their nutritional content and a high digestibility (Tarango *et al.*, 2002; McKinney and Smith, 2007). In this regard, during the reproductive period, the consumption of herbaceous plants by males and females increased, since it is in spring when the regrowth of these annual plants begins; during this period, males and females used the steepest portions of the mountains, where the humidity conditions in the canyons favor their availability. Although the female diet was the most diverse during the reproductive period (H´=1.2), no differences were observed between their diets and that of males in the segregation period (H´=1.0) (Figure 2).

The greater diet diversity in the reproductive period could be due to the rain's onset in May and the greater forage availability (López *et al.*, 1999). The diet similarity was greater (IS=96) between males in the segregation period and females in the reproductive period (Table 2). In contrast, the diet of segregated males and males in the reproductive period registered greater differences (IS=67) (Table 2).

Table 1. Composition of the diet of male and female bighorn sheep by family, species, and period in the UMA Rancho Noche Buena, Sonora, Mexico.

Family	Species	Reproductive period (%)		Segregation period (%)	
		Males	Females	Males	Females
Trees					
Fabaceae	*Acacia willardiana*	2.2	1.7	4.7	9.8
Burseraceae	*Bursera microphylla*	0.7	0.8		0.9
Fabaceae	*Cercidium microphyllum*	9.7	9.2	11.4	5.5
Fabaceae	*Olneya tesota*	2.2		0.5	
Shrubs					
Burseraceae	*Bursera laxiflora*	0.7			
Rhamnaceae	*Colubrina glabra*	1.5			
Rhamnaceae	*Condalia globosa*		1.7		0.9
Asteraceae	*Encelia farinosa*				0.9
Fabaceae	*Hoffmannseggia densiflora*				0.4
Labiatae	*Hyptis emoryi*	0.7			
Euphorbiaceae	*Jatropha cardiophylla*				0.4
Euphorbiaceae	*Jatropha cinerea*			0.5	
Euphorbiaceae	*Jatropha cuneata*				1.7
Acantahaceae	*Justicia candicans*	1.5	5	1	1.7
Malvaceae	*Kosteletzkya malvavizcana*		0.8	0.5	
Krameriaceae	*Krameria erecta*			2.6	
Krameriaceae	*Krameria grayi*		2.5		3.8
Zygophyllaceae	*Larrea tridentata*	0.7			
Solanaceae	*Lycium brevipes*		2.5		0.4
Fabaceae	*Mimosa laxiflora*	1.5	6.7	1.6	3.4
Fabaceae	*Senna covesii*	0.7			0.9
Buxaceae	*Simmondsia chinensis*	7.5	3.3	8.8	7.2
Forbs					
Malvaceae	*Abutilon incanum*	0.7	6.7	0.5	2.6
Amaranthaceae	*Alternanthera pungens*		0.8		0.9
Asteraceae	*Ambrosia confertiflora*		1.7	2.6	0
Primulaceae	*Anagallis arvensis*		4.2		1.7
Malvaceae	*Anoda cristata*	7.5	14.2	4.1	2.6
Sapinadaceae	*Cardiospermum corindum*	1.5	0.8	0.5	
Ranunculaceae	*Clematis drummondii*	4.5	0.8	2.1	
Fabaceae	*Dalea emoryi*	1.5	1.7		1.3
Solanaceae	*Datura disocolor*	0.7		1.6	
Euphorbiaceae	*Ditaxis lanceolata*	1.5	1.7	1	3.4
Asteraceae	*Dyssodia concinna*	0.7			
Malvaceae	*Herissantia crispa*	3.7	4.2	4.7	1.3
Malvaceae	*Hibiscus denudatus*	2.2		0.5	
Malpighiaceae	*Janusia gracilis*	2.2	0.8		
Asteraceae	*Verbesina encelioides*	11.9	10	10.4	16.2
Grasses					
Poaceae	*Aristida adscensionis*	12.7	11.7	20.7	27.2
Poaceae	*Bouteloua barbata*	13.4	3.3	15.5	2.6
Succulents					
Cactaceae	*Lemaireocereus thurberi*		0.8	1.6	0.9

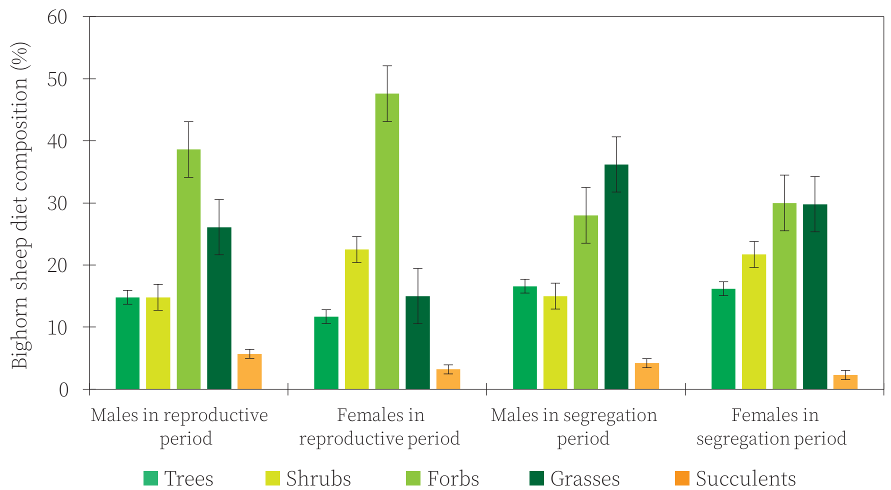

Figure 2. Composition of the bighorn sheep diet by sex, period (reproductive and segregation) and biological form at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico.

Figure 3. Zacate tres barbas (*Aristida adscensionis*), the most important species in the diet of the bighorn sheep at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico (Photograph by N. Dreber).

Table 2. Percentage values of the Kulczynski similarity index (IS) in the males and females diet composition by period (reproductive and segregation) at the UMA Rancho Noche Buena, Hermosillo, Sonora, Mexico.

	Males in segregation period	**Males in reproductive period**	**Females in segregation period**	**Females in reproductive period**
Males in segregation period	100			
Males in reproductive period	67	100		
Females in segregation period	80	73	100	
Females in reproductive period	96	89	75	100

The similarity between the diet of females in the reproductive and segregation period was IS=75. This can be explained by the hypothesis on segregation proposed by Main *et al*. (1996), who propose that females during the segregation period occupy steeper areas and with more visibility to evade predators, at the cost of a less diverse diet and lower nutritional quality. Authors such as Tarango *et al*. (2002), recorded that, once the reproductive season was over, the groups of males (made up of class III and IV males) separated from the females' groups (females, lambs and juvenile males). However, they indicated that, although the groups were spatially separated, they tended to use the same areas at different times (Bleich *et al*., 1997; Tarango *et al*., 2002; Pérez-Barbería *et al*., 2007).

This sheep behaviour during its forage activity could explain the 80% similarity in the diet composition of males and females during the segregation period. In the present research, it was recorded that in the reproductive period the females grouped with class III or IV males, that distributed in lower places of the mountains and foraged in streams. On these sites, shrubs and grasses are more common than in the higher areas. In contrast, during the segregation period, females were in higher areas, generally alone or with other females, lambs, and occasionally juvenile males.

The above is consistent with that reported on sexual segregation in bighorn sheep (Miller and Gaud, 1989; Tarango *et al*., 2002). Although during the reproductive period the females tend to occupy the same sites as in the segregation period (with few plants cover and adequate visibility), males make local trips to these sites in search of reproductive females, to establish dominance and form reproductive groups. Once the reproductive period is over, they separate from the females and look for places where the forage is more abundant and of greater nutritional value (Ruckstuhl and Neuhaus, 2000; Tarango *et al*., 2002). This explains the greater similarity (75%) in the female diet between periods in relation to the male diet (67%).

The results on the similarity of the diet of males and females coincide with that reported by Miller and Gaud (1989) in Arizona, whose similarity varied between 40% and 80%. In the present study, the similarity in the diet composition of segregated males and females was 80%, while between males (segregation period) and females (reproductive period) it was 96%. As already mentioned, in the Sonoran Desert the groups of males in the reproductive period move from their foraging sites to the areas used by the females to establish reproductive groups. However, females tend to occupy the same sites regardless of the reproductive period (Tarango *et al*., 2002).

Based on the results of this research, the hypothesis of the present work that the composition of the diet of segregated males and females was different is rejected. The results of this study can be applied to estimate the carrying capacity in the Sonoran Desert, where the bighorn sheep is the main game species and is preferably extensively managed. It is recommended to continue with this line of research and study the forage availability by season and period, carry out bromatological analyses of the consumed plant species to know their nutritional contribution and probable deficiencies in bighorn sheep individuals. This information is essential to establish management programs, habitat improvement or supplementation programs according to the needs of the UMA Rancho Noche Buena and its surrounding areas.

CONCLUSIONS

Herbaceous and grasses predominated in the bighorn sheep diet. During the segregation period, males consumed mostly grasses, and females herbaceous and grasses. However, in the reproductive period, herbaceous plants were the main species in the diet of males and females. The similarity of the diets of males and females in the segregation period was high. Therefore, sexual segregation exhibited by the bighorn sheep at the UMA Rancho Noche Buena was not due to forage selection.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Hematological and Biochemical Profile of Spider Monkey (*Ateles geoffroyi* Kuhl) in Captivity

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ABSTRACT

Objective: To estimate the hematological and biochemical reference values in *Ateles geoffroyi* individuals in captivity.

Design/Methodology/Approach: Eleven males and 23 females were captured and blood was collected from the coccygeal vein; conventional techniques were used to analyze the samples.

Results: Mean corpuscular volume (MCV; $P<0.03$) and platelets (PLT; $P<0.04$) were significantly higher in females than in males. In relation to biochemical blood values, the difference was not significant in male and female groups.

Study Limitations/Implications: Hematological and biochemical reference values of *A. geoffroyi* are within normal health parameters; they are between the ranges reported for other species of Neotropical primates and can be used as a reference in the health management of this species in captivity.

Findings/Conclusions: Hematological and biochemical parameters of captive specimens of *A. geoffroyi* are described, which provide reference indicators for the health management of the species.

Keywords: reference values, Neotropical primates, blood chemistry, hematology.

INTRODUCTION

Anthropogenic activities impact the habitat of populations of wild primates, as is the case of the spider monkey (*Ateles geoffroyi*). This species inhabits from the southeast of Mexico to the northwest of Colombia (Di Fiore *et al.*, 2008), and it fulfills an important role in the ecosystems as disperser of tropical forest tree seeds, and as prey of top predators (Chaves *et al.*, 2011).

Image by Markéta Machová at Pixabay

Arroyo-Rodríguez and Mandujano (2006) mention that when the habitat is fragmented, the species of primates can reduce their ability to move in the habitat to obtain quality foods, which has an impact on physiological alterations at the hematological and biochemical levels. In this sense, it is possible that *A. geoffroyi* is under risk of extinction according to the Red List of Threatened Species because the ecological characteristics required by the species for their diet are so sensitive that due to the fragmentation of their habitat their populations have reduced in size (Cuarón *et al.*, 2008), and they possibly present changes in their hematological and biochemical profiles, so it is important to study and record their parameters to generate preventive health measures.

A way to generate information about the hematological and biochemical parameters is to evaluate the individuals of *A. geoffroyi* in captivity in zoos and other captivity models in Mexico, since in absence of local reference values for wild populations of *A. geoffroyi* or in captivity, reference values of another species of the same genus are used (Ríos, 2015; Zambrano, 2016). For this reason, the objective of the study was to describe the reference values for the hematological and biochemical profiles of adult males and females of *A. geoffroyi* under conditions of captivity. The parameters generated in the study can be considered as reference values to determine the health status of this species in captivity and as reference of the physiological functions in the wild primate populations and those in captivity.

MATERIALS AND METHODS

Specimens studied and biological material collection: During the years 2018 to 2019, 15 specimens of *A. geoffroyi* were captured in the zoo, *Parque Zoológico y Jardín Botánico Miguel Ángel de Quevedo* (ZOOMAQ), registered as Property and Facility for Wild Life Management (*Predio e Instalación para el Manejo de Vida Silvestre*, PIMVS) and located in the city of Veracruz, Veracruz. Another 19 specimens of *A. geoffroyi* (9 monkeys from the Pipiapan locality and 10 from the locality of Tanaxpi) were studied in the Management Unit for Wild Life Conservation (*Unidad de Manejo para la Conservación de la Vida Silvestre*, UMA) "Hilda Ávila de O'Farril", a unit devoted to the research of primates. This UMA is located in the Catemaco-Coyame highway, municipality of Catemaco, Veracruz, Mexico (geographic coordinates of location: 18.46122 N, −95.04587 W). In total, both from the ZOOMAQ and the UMA, 11 males and 23 females of *A. geoffroyi* were captured in captivity. The monkeys were anesthetized with darts with syringes of 3 mL with a dose of 5 mg kg^{-1} of ketamine chlorhydrate (Ketanil®, Wildlife Pharmaceuticals, Windsor, USA), loaded in a CO_2 rifle (JM Standard®, Daninjet, Børkop, Denmark).

From each specimen, 4 mL of blood tissue were obtained from the coccygeal vein and placed in tubes with ethylenediaminetetraacetic acid (EDTA) and the rest of the sample was placed in serum separating tubes. All the samples were conserved at 4 °C and 6 h after the harvest they were processed. The animals captured were subjected to a complete physical exam and each was weighed, and then the specimen was placed in a cage until complete recovery from anesthesia.

Hematic cytometry: The total recount of erythrocytes (red blood cells – RBC) was carried out, and packaged cells volume (PCV), hemoglobin (Hb), leukocytes (white blood cells – WBC), and platelets (PLT) were estimated; RBC indexes: mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Blood smears stained with fast hemocolor were carried out (Diff-Quick ™, Hycel, Mexico), where 100 cells were counted in each of them for the differential recount of leukocytes. This information was generated with a complete hemogram in an MD-8® automatic analyzer (Beckman Coulter, California, USA).

Blood chemistry: The concentration of glucose, ureic nitrogen in blood, urea, total protein, albumin, globulin, albumin/globulin rate, creatinine, cholesterol, triglycerides, alkaline phosphatase, calcium and iron. These parameters were quantified with a chemical analyzer ARCHITECT® ci16200, Abbott Core Laboratory (Abbott, Abbott Park, Illinois, USA).

Data analysis: The values obtained from the erythrocyte parameters and blood chemistry were described through descriptive statistics by group (Zoo *vs* UMA) and by sex (females *vs* males) of the primates sampled. These parameters were compared through the Kolmogorov-Smirnov test that compares the median and the ranges at 95% of reliability between group of primates (Zoo *vs* UMA) and by sex (females *vs* males); the comparison included 10000 bootstrap resamples as a method to evaluate the reference ranges at 95% of reliability; the inferior reference limit was defined at 2.5% percentile and the superior limit at 97.5% percentile; to determine whether there were differences between the values of the groups studied, the Mann-Whitney's *U* test at $P<0.05$ was applied. The analyses were carried out with the SPSS V. 19 software.

RESULTS AND DISCUSSION

The average weight of females was 5.5±0.6 kg and the size 65-70 cm, while the males had 6.0±1.3 kg of average weight and a size of 80-90 cm. The hematological and biochemical values analyzed in males and females are presented in Table 1 and 2. The MCV ($P<0.03$) and PLT ($P<0.04$) were significantly higher in females than in males, without significant differences between the hematological and biochemical values. The values of platelets ($p=0.018$), neutrophils ($p=0.021$), eosinophils ($p=0.002$), basophils ($p=0.009$), lymphocytes ($p=0.006$) and monocytes ($p=0.042$) were significantly different (Table 3), which is associated to the type of management of the monkey population (Zoo *vs* UMA), such as exposure to different infectious agents, diet, weight, age and characteristics of captivity (Chen *et al*., 2002; Xie *et al*., 2013).

The hematological values provided important data about the health of the monkeys studied such as the analytes, which are biomarkers of the possible presence of a disease. On the other hand, this report of reference values for *A. geoffroyi* constitutes basic information to be contrasted with other populations of the species in captivity and to determine their health status (Ríos, 2015; Zambrano, 2016).

Table 1. Blood parameters of *Ateles geoffroyi* specimens in captivity.

Analyte	Females n=23				Males n=11				*U*-test
	Mean±SD	**Median**	**Min-Max**	**95% CI**	**Mean±SD**	**Median**	**Min-Max**	**95% CI**	**p-value**
RBC ($\times 10^{12}$ L^{-1})	5.2±0.6	5.3	3.3-6	5.1-5.6	5.4±0.3	5.3	4.7-5.8	4.9-5.5	0.4
Hb (g dL^{-1})	14.2±1.4	13.7	12.3-17.2	13.2-15.1	14.2±1.7	14.4	9.3-17	13.4-14.9	0.6
HCT (%)	41.2±4.7	42.6	28-47.9	39.1-43.2	41±2.2	40.3	36.4-44.5	39.4-425	0.3
MCH (pg)	27.4±2	27.4	24.5-31.6	26.6-28-3	26.1±1.8	25.9	23.5-30	24.9-27.3	0.08
MCHC (g dL^{-1})	34.4±1.5	34.2	31.1-38	33.8-35.1	34.5±1.8	34.2	32.2-38.6	33.3-35.7	0.7
MCV (fL)	79±3.6	77.8	73.7-85.1	77.4-80.6	75.7±3.4	75.3	70.4-83.7	73.4-78.1	0.03
WBC (× 10^3 mm^3)	11.2±3.4	10.6	5.5-21.2	9.7-12.7	9.9±3.8	8.6	5.5-19.1	7.2-12.5	0.16
PLT (× 10^3 mm^3)	342.4±96.2	338	191-542	300.8-384	272±142.6	263	65-571	176.2-367.9	0.04
Band neutrophils ($\times 10^3$ L^{-1})	0.1±0.1	0.08	0.0-0.4	0.07-0.1	0.07±0.09	0	0.0-0.2	0.0-0.1	0.1
Segmented neutrophils ($\times 10^3$ L^{-1})	6.6±3.2	6.1	1.9-17.3	5.2-8.1	6±3.1	5.8	2.2-13.8	3.9-8.1	0.4
Eosinophils ($\times 10^9$ L^{-1})	1±1.8	0.3	0.0-6.8	0.2-1.8	0.7±1.3	0.3	0-4.6	0.1-1.5	0.6
Basophils ($\times 10^9$ L^{-1})	0.04±0.06	0	0.0-0.2	0.01-0.07	0.06±0.1	0	0.0-0.3	0.01-0.1	1
Lymphocytes ($\times 10^9$ L^{-1})	2.8±1	3.1	0.4-4.8	2.3-3.3	2.7±1.1	2.6	0.9-4.4	1.9-3.4	0.8
Monocytes ($\times 10^9$ L^{-1})	0.4±0.4	0.3	0.0-2.1	0.2-0.6	0.3±0.2	0.2	0.0-0.7	0.1-0.4	0.7
Band neutrophils % de WBC	0.6±0.6	1	0.0-2	0.3-0.8	0.8±0.6	1	0.0-2.0	0.4-1.2	0.3
Segmented neutrophils % de WBC	61.1±12.3	65	36.0-82	55.7-66.4	60.6±10.3	60	45-77	53.6-67.8	0.7
Eosinophils % de WBC	4.2±2.7	4	0.0-11	3.0-5.4	4.1±2.1	5	1-8	2.7-5.6	0.9
Basophils % de WBC	0.5±0.5	1	0.0-1	0.3-0.7	0.4±0.5	0	0.0-1.0	0.1-0.8	0.7
Lymphocytes % de WBC	30.3±11.3	29	16.0-57	25.3-35.2	30.6±9.5	33	14.0-43.0	24.1-37.7	0.6
Monocytes % de WBC	3.1±3.7	2	0.0-17	1.5-4.7	3.2±3.4	3	0.0-12	0.9-5.6	0.8

Table 2. Biochemical values of Ateles geoffroyi in captivity.

Analyte	Females n= 23				Males n=11				*U*-test
	Mean±SD	Median	Min-Max	95% CI	Mean±SD	Median	Min-Max	95% CI	p-value
Glucose (mg dL^{-1})	103.5±1.8	103.5	101-106	102 -105	102.5±3.8	101.5	99.3-110.5	101.2-10.9.5	0.9
BUN (mg dL^{-1})	26.8±4	27	24.5-28.4	25.2-30.4	22.5±1.7	22	20.4-25.5	19.2-24.8	0.1
Total proteins (g dL^{-1})	5.9±0.8	6	4.9-7.2	4.9-6-8	4.9±1.2	4.7	3.9-5.8	4.2-5.6	0.4
Albumin (g dL^{-1})	2.5±0.9	2.4	1.9-4.1	1.8-3.5	2.0±0.4	1.9	1.6-3.8	1.9-3.5	1
Globulins (g dL^{-1})	4.2±0.6	4.4	3.6-5.4	3.2-4.9	3.8±1.4	3.7	3.0-5.0	3.2-4.5	0.9
Alb/Glob Relationship	0.8±0.2	0.8	0.5 -1.2	0.4-1.0	0.65±0.02	0.65	0.54-0.70	0. 62-0.68	1.2
Creatinine (mg dL^{-1})	0.6±0.1	0.57	0.4-0.8	0.5-0.8	0.5±0.3	0.5	0.33-0.70	0.4-0.6	0.8
Cholesterol (mg dL^{-1})	92.1±4.9	89.7	91.4-98.2	90.9-97.8	96.5±3.3	96	93.4-98.2	94.5-98.1	0.3
Triglycerides (mg dL^{-1})	118.5±15.7	115.1	100.4-150.3	117.1-148.6	120.4±10. 4	118.4	110.5-149.5	117.8-140.5	0.7
AP (U L^{-1})	300.4±8.4	300.4	295.5-320.3	299.8-318.4	290.3±11.3	300.5	285.6-315.5	288.5-314.2	0.3
Calcium (mg dL^{-1})	5.4±0.7	5.5	4.6-6.1	4.2-6.6	4.2±0.2	4.2	4.0-5.6	4.0-4.9	0.8
Phosphorus (mg L^{-1})	4.1±1.1	4.1	2.4-5.6	3.8-5.9	3.5±1.5	3.5	2.9-5.0	3.1-5.0	1
Iron (ug dL^{-1})	99.7±7.7	100.4	89.5-110.4	92.4-108.8	100.3±14.4	100.5	88.9-116.5	98.2-112.5	0.6
AST (SGOT) (IU L^{-1})	79.7±6.2	79.3	70.4- 90.8	71.3-89.2	82.9±1.5	82	80.0-85.6	81.2-84.3	0.4
ALT (SGPT) (IU L^{-1})	20.4±6.0	19.2	12.3-29.4	18.2-27.6	18.4±4.0	18.2	14.5-26.0	17.8-23.0	0.7
CK (IU L^{-1})	291.6±23.7	290. 1	250.3-320.2	264.6-319.2	289.5±35.7	289	260.4-315.9	270.8-310.6	0.9
LDH (IU L^{-1})	237.8±33.5	247.9	190.5-250.5	188.6-249.6	232.4±40.4	235	180.4-243.5	210.3-239.6	0.7
LDT (mg dL^{-1})	18.5±4.4	18.6	10.5-25.5	9.4-21.2	20.2±3.2	20	17.6-24.6	19.7-23.4	0.5
HDT (mg dL^{-1})	8.8±4.6	7.15	4.5-18.4	5.5-16.7	7.5±5.6	7	5.6-12.3	7.0-10.4	1.2
Amylase (U L^{-1})	315.3±24.0	305	287.4-350.2	298.5-345.5	329.4±35.6	330	289.0-360.4	310.5-350.3	0.9
Lipase (U L^{-1})	81.9±7.6	83.6	70-92	79.2-91	85.4±3.4	85.5	80.4-85.7	81.2-83.3	0.2

Most of the hematological indexes obtained in this study were similar to those reported by Ríos (2006) in *A. chamek* and they are within the parameters proposed by International Species Information System (ISIS, Calle and Joslin, 2015), but they were lower than those reported in *A. fusciceps* (Zambrano 2016); the red blood cell count was higher in this study, and it can be conditioned to the altitude where the monkeys are in captivity, as index of lower oxygen pressure (Castañeda *et al.*, 2013).

Table 3. Comparison of hematological values of A. geoffroyi in captivity.

Hematological values	UMA Hilda O		ZOOMAQ	p
	Pipiapan n=9	Tanaxpi n=10	n=15	
RBC ($\times 10^{12}$ L^{1})	5.0±0.91	5.28±0.44	5.45±0.36	0.550
Hb (g dL^{1})	13.4±2.07	15.14±1.50	14.09±1.18	0.137
HCT (%)	39.4±5.53	42.3±3.3	41.44±3.3	0.344
WBC (x10^{3} mm^{3})	11.14±3.7	11.3±3.0	10.22±4.0	0.403
PLT (x 10^{3} mm^{3})	400±101	319±68.47	271.9±127.5	0.018
Segmented neutrophils	52±12.78	67.6±5.42	61.93±10.97	0.021
Eosinophils % de WBC	6.33±2.54	4.8±2.29	2.6±1.63	0.002
Basophils % de WBC	0.22±0.44	0.9±0.316	0.4±0.5	0.009
Lymphocytes % de WBC	39.7±11.62	23.7±6.41	29.33±8.7	0.006
Monocytes % de WBC	1.22±0.97	2.3±1.05	5.0±4.73	0.042

The red blood cells found in this study when comparing them to other non-human primates, indicate a balance of erythropoiesis and destruction of erythrocytes (Ihrig *et al.*, 2001; Yu *et al.*, 2019; Yeo *et al.*, 2019). The hematocrit (HCT) was found to be higher in the monkeys studied, which indicates a state of balance in terms of the water balance regulator mechanism (Armstrong and Johnson, 2018), while the recount of white blood cells (WBC) was found within the normal parameters (García-Feria *et al.*, 2017) and the recount of platelets was similar in comparison to other values in primates (Ferreira *et al.*, 2018). However, the increase of eosinophils found is attributed to helminthic infections in the monkeys studied (Rahimi and Khanaliha, 2018).

In this study there was no evidence of any effect from the sex (male *vs* female) on the biochemical parameters of the monkeys studied, effect that has also not been reported in other studies of Neotropical primates (Rovirosa-Hernández *et al.*, 2012; Canales-Espinosa *et al.*, 2015; García-Feria *et al.*, 2017).

In this study, the males had significantly higher weight and size than the females, resulting from their sexual dimorphism (de Thosy *et al.*, 2001), but with similar concentrations of creatinine, as a result of a similar diet, since the dietetic intake and the muscular mass promote similarities in the content of creatinine (Kaneko, 1989). The levels of cholesterol, triglycerides, HDL and LDL of the monkeys studied suggest that they have an intake rich in proteins, while the transaminases, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and blood ureic nitrogen (BUN) suggest a normal hepatic function (Rovirosa-Hernández *et al.*, 2012; Canales-Espinosa *et al.*, 2015; García-Feria *et al.*, 2017).

CONCLUSIONS

This study describes the hematological and biochemical parameters of specimens in captivity of *A. geoffroyi*, with reference values that provide indicators for the health management of this species in captivity.

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Compliance with ethical standards

This project was approved by the Bioethical and Animal Welfare Commission of the Veterinary Medicine and Animal Science School of the Universidad Veracruzana.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Migratory Seasonality and Phenology by Birds in a Temperate Forest with Two Disturbance Conditions

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ABSTRACT

Objective: The objective was to infer the effect of the variables phenology (migration-non-migration), seasonality (rainfall-dry season), sex and forest condition on the abundances of birds (resident-migratory) in a semi-preserved and disturbed oak pine forest.

Design/Methodology/Approach: The study was carried out in Monte Tlaloc, Estado de México, in two conditions of apparent disturbance, semi-preserved oak pine forest and disturbed oak pine forest. Ten bird samplings were carried out with "count on point" with a fixed radius of 25 m, covering the 4 seasons of the year and migratory periods. With this data, the Relative Abundance Index (RAI) was estimated. Generalized linear models were elaborated to infer the effect of the variables phenology, seasonality, sex, and forest condition on the abundances of birds.

Results: The RAI of the birds registered in the semi-considered pine forest indicates that the species with the lowest presence was *Aphelocoma ultramarina* (0.002) and with the highest frequency *Empidonax* sp. (0.13), unlike to that found in the disturbed pine forest where the lowest RAI corresponded to *Colaptes auratus* (0.003) and *Ptiliogonys cinereus* (0.23) had the highest appearance. The Generalized Linear Model suggested that forest condition and phenology are significantly related to the frequency of species.

Study Limitations/Implications: In this study it was found that the abundance of birds was affected by the condition of the forest and that the phenology (migration-non-migration), seasonality (rain-dry season), sex and condition of the forest were related to the abundance of birds. Four species classified as under Special Protection and two Threatened according to NOM-059 were registered as well as the presence of four endemic species which highlights the importance of conserving these ecosystems.

Findings/Conclusions: The fauna communities present in Monte Tláloc highlight the importance of conserving the pine-oak forests since this site is part of the Trans-Mexican Volcanic Belt.

Keywords: Indices, generalized linear model, disturbed, semi-conserved.

Image by Nature-Pix at Pixabay

INTRODUCTION

Phenomena such as migratory seasonality and phenology in birds have allowed understanding their population dynamics in some regions of the world, since approximately half of the species of birds perform migratory movements (Cueto *et al*., 2015), coexisting with the resident avifauna on the routes and corridors that they use. However, the possible coexistence between migratory and resident birds seems to be regulated, among other factors, by the quantity, quality and availability of resources in the habitat, including those that are vital and/or limiting in it, and affecting their tolerance (Shelford, 1913; Odum and Warren, 2006). In Mexico, deforestation, loss-fragmentation of their habitats, change of land use, and wildfires, among others, have progressively affected the plant physiognomy, creating a broad heterogeneity of ecological niches (Almazán-Núñez *et al*., 2009). This heterogeneity can result in space-time fluctuations or in positive, negative or null ecological interactions for generalist, specialist and flexible species, respectively, particularly of avifauna (Díaz-Bohórquez *et al*., 2014; López-Segoviano *et al*., 2019).

Monte Tláloc is located in Estado de México on the Trans-Mexican Volcanic Belt (TVB). The TVB is considered as one of the most important centers of endemism in the country and a priority terrestrial region (Bolaños-González *et al*., 2017), which is important seasonally and in phenology for avifauna in general; and, in particular, for migratory avifauna because it is distributed on one of the main migration routes in the American Continent, the Central. In this route, presumably their assemblages converge at different space-time scales in the use of the habitat (Romero-Díaz *et al*., 2018). In Monte Tláloc, the birds have chief ecological functions, for example as biological controllers or seed dispersers. Therefore, it is relevant to evaluate phenology (migration-non-migration) and seasonality (rainfed-dry) of the use of the habitat by birds (resident-migratory), in two disturbance conditions of semi-conserved pine-oak forest vs disturbed pine-oak forest.

MATERIALS AND METHODS

The study was carried out in the orography system known locally as Monte Tláloc, site dominated by mixed conifer forests. It is located in the limits of Ixtapaluca and Texcoco, in east Estado de México between coordinates 19° 24’ 44” Latitude North and 98° 42’ 45” Longitude West, and maximum elevation of 4120 masl (Villanueva-Díaz *et al*., 2016; Figure 1).

Sample design

A systematic sampling was implemented, contemplating two apparent disturbance conditions, selected according to Romero-Díaz *et al*., (2018): 1) semi-conserved pine-oak forest (CPOF), which was characterized by presenting a tree, shrub and herb cover in its totality, native vegetation, and presence of water bodies; and 2) disturbed pine-oak forest (DPOF) that was characterized by having sites of secondary and introduced vegetation, open areas without plant cover, presence of livestock and feral animals

(Figure 2). Each condition had 11 choice units with pre-determined distances of 200 m between them (Ralph *et al.*, 1996).

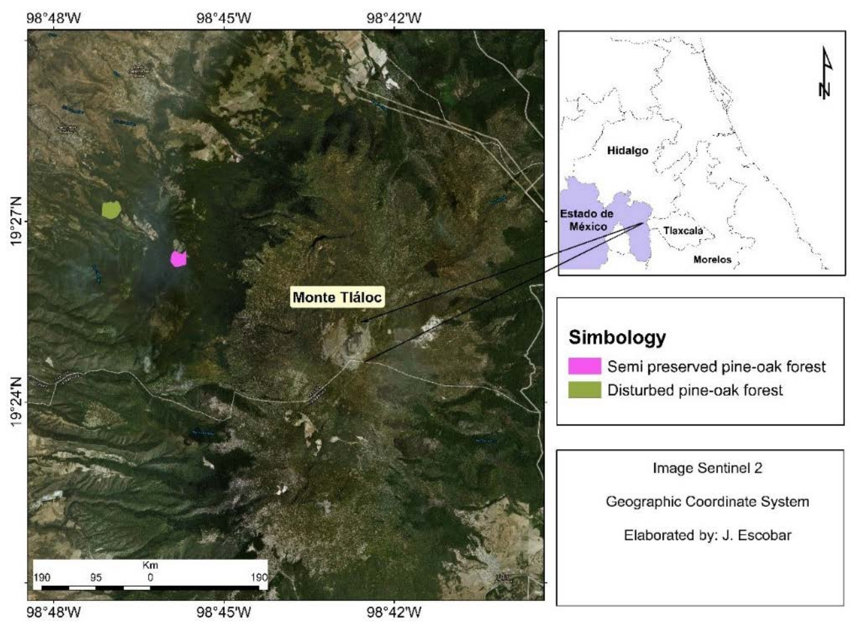

Figure 1. Location map of the study area, Monte Tláloc.

Figure 2. Image of a semi-preserved pine-oak forest (left) and a disturbed pine-oak forest (right).

Bird monitoring

From September 2019 to June 2020, monthly bird monitoring is carried out in the two conditions, CPOF and DPOF. These are carried out through the Recount scheme in a fixed radius point of 25 m with intensive search. The observations were carried out with binoculars of Bushnell brand with water vision with resolution 8x42x and the taxonomic identification of birds was performed with standard field guides (Peterson and Chalif, 1989; National Geographic Society, 2011). The sampling was carried out at two times: morning (06:00-11:00) and afternoon (17:00-19:00), time intervals where avifauna presents the highest peaks of daytime activity. Environmental variations (rain and drought) were obtained according to what was reported by the National Meteorological System (Sistema Meteorológico Nacional, SMN), meteorological station # 15017, Coatepec, for the period of 2019-2020.

The abundance of birds was evaluated with the relative abundance index (RAI, frequencies recorded) proposed by Carrillo *et al.* (2000). This index was analyzed in EstimateS 9.1.0 (2018), using presence-absence data.

Effect of phenology (migration-non-migration), seasonality (rainfed-dry), sex and condition variables of the forest on the abundance of birds

From the frequency databases of the birds and their abundances, a matrix of scenarios was formulated that was analyzed through a generalized linear model (GLM) in the R Statistics software. Before the generation of the GLM, four predicting variables were defined: 1) condition of the forest, 2) seasonality, 3) phenology, and 4) sex of birds registered. The response variable was the frequency of records in each level of variable (Table 1).

Table 1. Predictor variables and levels.

Predictor variables	Levels
Condition forest	1) Semi-preserved 2) Disturbed
Seasonality	1) Rainfall 2) Dry
Phenology	1) Migratory 2) No migratory
Sex	1) Male 2) Female

The GLM model was analyzed with a Poisson distribution, because the data refers to absolute frequencies. The function of link or parametrization was logit, which is used to estimate the expected value of Y (response variable) as a linear combination of predicting variables. The model entered into the software R was the following:

$$\begin{aligned} Call{:}gml\ (formule\ &= Frequency \sim Sex + Phenology + Seasonality + Forest\ Condition \\ &+ \mathrm{Sex} * Phenology + Sex * Seasonality + Sex * Forest\ Condition \\ &+ Phenology * Seasonality + Phenology * Forest\ Condition \\ &+ Seasonality * Forest\ Condition + Forest\ Condition * Seasonality \\ &* Phenology,\ family = poisson\ (log),\ data = Dataset2) \end{aligned}$$

Validation of the GLM model

To determine the adjustment of the model, the amount of variance, the standard error, and the Z value that measures the difference between statistics observed and expected by the model were estimated. In the GLM, these parameters are known as deviance, which is an indicator of the variability of the data. Therefore, both the deviance of the null model and the residual deviance were estimated. The latter measured the variability of the response variable that is not explained by the model. The Akaike Information Criterion (AIC) was also estimated; this index evaluates the adjustment of the model to the data, as well as the complexity of the model. With smaller AIC, there is better adjustment. The AIC is very useful to compare similar models with different degrees of complexity or equal models (same variables) but with different link functions.

RESULTS AND DISCUSSION

A total of 527 individuals were found in both zones (CPOF=304; DPOF=223). In CPOF, 58 individuals of migratory birds and 246 individuals of resident birds were registered, and in DPOF 49 of the individuals corresponded to migratory birds and 174 to resident birds. In Monte Tláloc, according to NOM-059, four species were found that are classified as under Special Protection and two as Threatened. According to the UICN, two species under some threat were found in the study area; one of them in the category of Vulnerable and the other as Almost Threatened; likewise, five endemic species were found.

Seasonally, it was observed that the higher number of individuals from bird species was found in the dry season in CPOF (53%) and in DPOF (59%) in the rainy season. Ramírez-Albores (2013) reported similar results in the municipality of Nanacamilpa, Tlaxcala, which is located at a distance of less than 20 km from Monte Tláloc. This author also mentions an increase of bird diversity in conserved pine forests. The Relative Abundance Index (RAI) of the birds recorded in CPOF suggests that the species with lower presence in the study zone was *Aphelocoma ultramarina* (0.002) and in higher proportion *Empidonax* sp. (0.13) (Figure 3), compared to DPOF that was *Colaptes auratus* (0.003) and *Ptiliogonys cinereus* (0.23) with higher appearance (Figure 4). It is important to point out that the abundances of all the species were not graphed, and only those of the most representative were chosen for both sites.

Regarding the sex of the individuals present in each of the forest conditions, females predominated in CPOF (53%) and males in DPOF (52%).

In general the females presented the highest number of individuals in both conditions (n=268). One of the main reasons why more females were found in the CPOF condition is the possibility that the birds in this condition increase their reproductive success; for example, Huhta (1996) studied the effect of the plot size of pine forest, presence of human disturbances in the use of nests by the pied flycatcher (*Fidecula hypoleuca*) in a pine forest of similar conditions than those in Monte Tláloc. This author found that the nests were more preyed upon in neighboring landscapes or immerse in agricultural fields where predators of this species predominate, while in forest landscapes predation also happened in felled places where the nests were more visible.

The more open forests and with low forest density are used for the pied flycatcher, where the availability of food is lower.

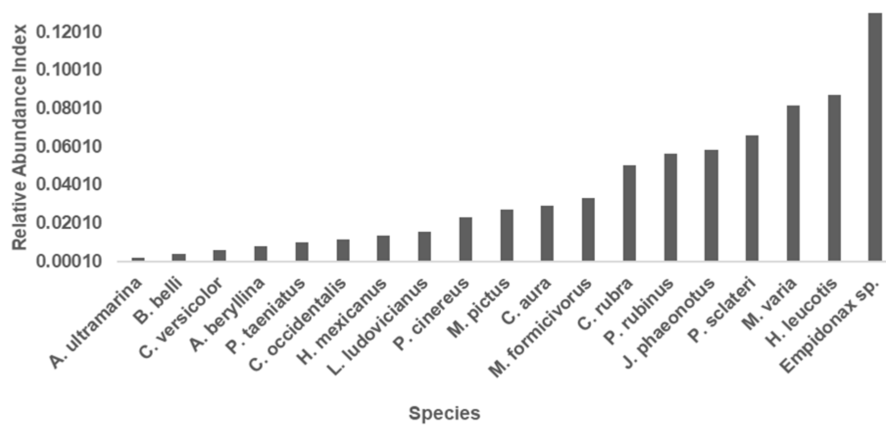

Figure 3. Relative Abundance Index of bird species in the semi preserved Pine-Oak Forest of Monte Tláloc.

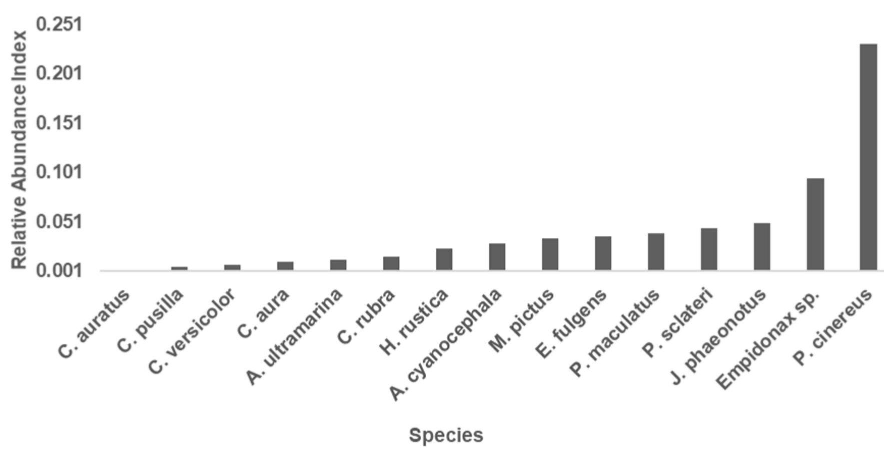

Figure 4. Relative Abundance Index of bird species in the disturbed Pine-Oak Forest of Monte Tláloc.

The Generalized Linear Model suggests that the forest condition is significantly related with the frequency of bird species. For example, the semi-conserved condition had a higher presence of these and at the same time obtained higher number of females than males, so the forest condition also influenced the sex of the avifauna present (Table 2). The GLM indicated that the variables phenology (Residents) and forest condition (Semi-conserved) increase the probability of finding a higher abundance of species. The seasonality variable (Rains) increases their abundance. All the interactions were significant, which indicates that phenology, seasonality, forest condition and sex have a relationship with bird abundance (Table 2). The model explained a high total deviation (84.9%) and that 15.1% of the variance that was not explained by the model correspond to other variables of the ecosystem that were not evaluated in this study; the value of AIC obtained was 116.5.

The number of bird species found in both forest conditions suggests that the degree of disturbance is not a key factor for their presence, given that the environmental and structural conditions of the habitat in a spatial context determine their correct biological-ecological functioning (Armstrong and Nol, 1993; Bó et al., 2007; Mateo et al., 2011; García-Quintas, 2015).

Connell (1978) in his hypothesis of the intermediate disturbance mentions that the disturbances can cause space-time fluctuations in the local and regional biological diversity; in contrast with conserved zones, which can increase the establishment of positive ecological interactions (generalist species) and negative (specialist species) in the use of the habitat. This argument explains why the abundance of species was mostly specialist in the semi-conserved pine-oak forest; on the contrary, in the disturbed forest the highest presence of birds was the generalist species.

Table 2. Generalized Linear Model for the two conditions of semi-preserved and disturbed forest, considering only the variables that were significant as a function of the abundance of birds.

Variables:	Estimate	Standar error	Z	Significance
(Intercept)	−1.5766	0.8172	−1.929	0.053696.
Phenology (Migratory/Resident)	2.1101	0.3245	6.502	7.90e-11 ***
Condictions of forest (BPES/BPEP)	2.428	0.5101	4.76	1.94e-06 ***
Sex (Female/Male)	0.4773	0.2629	1.816	0.069441
Seasonality (Rainfall/Dry)	0.7716	0.2647	2.915	0.003555 **
Condictions of forest (BPES/BPEP): Sex (Female/Male)	−0.372	0.1719	−2.164	0.030455 *
Phenology (Migratory/Resident): Condictions of forest (BPES/BPEP)	−0.6438	0.2013	−3.198	0.001385 **
Condictions of forest (BPES/BPEP): Seasonality (Rainfall/Dry)	−0.653	0.1745	−3.743	0.000182 ***

Birds are species with a very broad influence in the ecosystems or habitats that they inhabit, and their presence or absence is related to various spatial and temporal factors (Valdez-Leal *et al*., 2015). Bird migration is affected by diverse reasons; for example, it is known that the reproductive period responds to the change in the weather (Capllonch *et al*., 2015; Gordo and Avilés, 2017), which could explain the considerably lower number of migratory species compared to the presence of resident species.

CONCLUSIONS

This study allowed understanding how the avifauna communities are influenced by natural phenology-seasonality processes and the preference that they have for one of the two types of disturbance conditions of the forest. It was observed that seasonal processes influence the presence of birds (migratory and resident) and that these fauna communities concentrate important species that are found in a category of risk or endemic to the place. These results set the standard to develop techniques for conservation and maintenance of the forests both in Monte Tláloc and in the other neighboring mountains of the Trans-Mexican Volcanic Belt.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Wild Turkey (*Meleagris gallopavo mexicana* L.) Monitoring: Innovation in Sampling and Estimator of Population Density

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ABSTRACT
Objective: To estimate the population of wild turkey (*Meleagris gallopavo, mexicana*) and its density in ecosystems of distribution.
Design/Methodology/Approach: A method based on random sampling with a population density estimator was designed. The design was based on the observation of wild turkeys that go to attraction sites (feedlots) of 2,500 m^2 (50×50 m) counted in 12 h a day, three consecutive days. For all the random sites, the criterion of one site for every 300 ha of surface under study was used. The study was carried out on March 1, 2 and 3, 2019, in 3,000 ha of pine-oak forest, in Monte Escobedo, Zacatecas, Mexico. Observations were made from a fixed point 25 m away from each site, from 6:00 a.m. to 6:00 p.m. The attraction sites were located at a random distance within 10 systematically fixed transects in the study area.
Results: The results showed a population of 66 wild turkeys in 3,000 ha, with a density of 0.022 wild turkeys ha^{-1}.
Study Limitations/Implications: The application of the method was useful for monitoring wild turkey in the pine-oak forest, showing that it is a method that does not affect the population, which does not require long sampling times, is reliable, low-cost, and easy to carry out. The method is not reliable in ecosystems that do not allow the location of high visibility sites.
Findings/Conclusions: Considering the distribution of wild turkey in Mexico, the method is a new alternative applicable to population studies of wild turkey.

Keywords: Wild fauna; population; density; *Meleagris gallopavo*; sample size.

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INTRODUCTION

For more than two decades, the "line transect" method has been used to estimate wild turkey population and abundance (Buckland *et al.*, 2007) with its estimator for population density (PD)=(n) f(0)/2L. Despite being the most widely used (Anderson *et al.*, 2001) and obtaining great benefits from its use (Ruette *et al.*, 2003), its application for monitoring wild turkey populations is limited by the assumptions of the method, such as the impossibility of walking the transects in steep terrain, the movement of the wild turkeys along the transects that makes it impossible to count them, and the high probability of observing the same turkeys along other transects, which together yields unreliable results.

Image by Lisa Johnson at Pixabay

Various estimators have been proposed for monitoring wild turkey populations in North America. These estimators have been useful in defining population trends over time, and as an objective to evaluate the management activities carried out on the species and to assess the outcome of reintroductions in different ecosystems (Dahlheim *et al.*, 2000; Rosenstock *et al.*, 2002; Clemente-Sánchez and Tarango-Arámbula, 2007; Khan *et al.*, 2016;). The study of wild turkey (*Meleagris gallopavo mexicana*) populations is sustained on the application of methods based on transect walks, scoring the number of wild turkeys observed on either side of the previously established transects in the study area. Other methods such as "capture and recapture" have also been used, with the problem of the impact produced during the marking process for later observation, the high number of turkeys needed for the estimation, and the loss of organisms due to trauma because of their capture, in addition to the time required to obtain the results of the estimation. In addition, these methods present complications in meeting the assumptions for their operation and application. Therefore, it is necessary to develop new estimators based on random sampling and statistical principles that allow predicting the size and density of the population. Only in this way would it be reliable to infer the number of wild turkeys to be managed for its harvest. Therefore, the objective of this study was to develop and apply a new method based on attraction sites to estimate the wild turkey population.

MATERIALS AND METHODS

In March 2019, in an area of 3000 ha 15 km north of the city of Monte Escobedo, in the mountain range of the state of Zacatecas, Mexico, sampling was carried out to determine the population density and size of wild turkey for harvesting purposes. The study included areas within and outside of Wildlife Management and Conservation Units (*Unidades de Manejo para el Aprovechamiento y Conservación de la Vida Silvestre*, UMA). In the study area, 10 linear transects of 2000 m separated 150 m from each other were systematically traced. Within each transect a random value between 0 and 2000 m was selected to locate the 50×50 m attraction site. This way, the 10 sites or sampling plots were established with considerable visibility for counting wild turkeys. On the first, second and third day of March 2019, 10 observers were placed, one per sampling site, for which 10 hiding places for observation (1×1×1 m) 30 m from each site were built. An observer was placed in each observation hiding lace to count wild turkeys during three consecutive days from 6:00 am to 6:00 pm. Observers entered the observation sites three days after the occurrence of turkeys was recorded at each site. The sites were baited with yellow corn and oats in bales 15 days before they began to enter the bait. A database was constructed with the following variables: site number, transect number, date, time of observation, number of wild turkeys observed, total females, total males, total juveniles, male/female ratio, and adult/juvenile ratio.

Method rationale. In order to be confident that a sample is representative of the population, it must be created randomly (Ghahramani, 2000; Prasanna, 2013). For finite populations (transects), random samples within transects are defined as a set of observations x_1, x_2,... x_n that constitute a random sample of size n, for a finite population of size N, provided that they are selected in such a way that each subset of n elements among the N elements of the population have the same probability of being chosen. Being a finite population (attraction sites), we can enumerate its constituent elements and then select a sample with the help of a table of random numbers, or through computer programs that generate such numbers (Murray and Stephens, 2005). There are various ways of selecting a random sample, taking care not to violate the hypotheses of statistical theory. Since we are interested in making inferences about population parameters, such as the mean μ and standard deviation σ that we calculated from the sample observation, and since the selection of a random sample is governed by chance, the values obtained from these statistics will be as well (Rosenthal, 2000; Crespo, 2018). To apply the method of attraction sites for wild turkeys, the assumptions of the method are a) All the members of the population have an equal probability of being counted. b) No member of the population has the possibility of being counted more than once. c) The members of the population are spatially distributed in an aggregated manner. d) Sampling of the attraction sites is random. e) Mortality and recruitment during the period when the data are obtained are not significant.

Population and density. The method is designed for the sampling of wild turkeys that are spatially distributed in an aggregated manner at a certain time of the year (March to May) for reproduction in pine-oak, pine-aspen, pine, and other forest ecosystems, where sites with high visibility can be located.

The population is calculated from the total count of wild turkeys per site, adjusted for overlapping or overexposure of schedules at the sites, plus individuals that cannot be counted more than once due to their distance from the sites.

$$P_{total} = TTOS + TTDS \qquad \text{(Equation 1)}$$

Where; P_{total}=total population. $TTOS$=Total number of turkeys in overlapping schedules. $TTDS$=Total number of turkeys at distant sites that cannot be counted more than once.

The density value for the sampling area is calculated in number of wild turkeys per hectare according to the following estimator:

$$DP_{ha^{-1}} = P_{total} / TSA \qquad \text{(Equation 2)}$$

Where; $DP_{ha^{-1}}$ =population density in wild turkeys ha^{-1}. TSA=Total study area.

Sample size. Based on the standard deviation and mean obtained from a set of values, we would expect a reliable estimate of the population to allow inferring about the actual size of the population. The method of attraction sites establishes the convenience of calculating the recommended sample size (n) from the sampling. In this study, the application of this method was carried out for five years, using different sample sizes, and it was observed that the accuracy is not improved when more than 10 attraction sites with three replicates are used per 3000 ha in pine-oak forest vegetation. The repetitions correspond to the three days in which the present study was conducted.

Confidence limits. To estimate the confidence limit, a probabilistic analysis is not necessary, since the maximum limit is given by the total number of wild turkeys observed in all sites divided by capture effort (repetitions). This is based on the assumption that there will not be more than the observed total in the study area, given the effect that the attraction site has on the movements of the wild turkey once baited. The lower limit will be the result of the calculated total population (P_{total}).

Statistical analysis. The population density and confidence limits were performed with the Microsoft Excel 2010 software.

RESULTS AND DISCUSSION

The data obtained at the end of March 1, 2 and 3, 2019, in the study area of 3000 ha in 10 attraction sites are presented in Table 1, where one can select the number of wild turkeys overlapping in their schedules and the schedule ranges that were observed.

With the purpose of observing the total number of wild turkeys by time overlap and the total number of turkeys considered by the distance of the sites, Table 2 shows that there are two overlaps in the time ranges of 9-10 h and 10-11 h.

Overlapping schedules gave a total of 150 wild turkeys (76+80) plus 44 wild turkeys (8+36) from sites that could not be visited by other turkeys because of their distance and schedule range. Having obtained the total number of wild turkeys under the previous criteria, we have the total observed population, and now it must be adjusted by the capture effort, which is three days, giving a total of 200/3=66 wild turkeys. Now, the population density is calculated with Equation 2.

$$DP_{ha^{-1}} = P_{total} / TSA$$

Replacing;

$$DP_{ha^{-1}} = 66/3{,}000=0.022$$

It can be said that the population in the study area is at least 66 wild turkeys and at most 150 wild turkeys with a density of at least 0.022 wild turkeys ha^{-1}, and at most 0.05 wild turkeys ha^{-1}.

The female:male ratio was 2.98:1 (179 females/60 males) and the adult:juvenile ratio was 6.82:1 (239/35).

Table 1. Record of turkeys observed in 2019 in three consecutive days (R), within 10 attraction sites in pine-oak forest of Monte Escobedo, Zacatecas.

Site	Date	R	Turkeys observed	Range time of observation	Females	Males	Juveniles
1	01/03/19	1	15, 12	9-10, 10-11	10, 9	5, 3	0, 0
	02/03/19	2	21,	9-10	15	0	6
	03/03/19	3	8, 11	9-10, 14-15	11, 8	0, 0	0, 0
2	01/03/19	1	8, 5	9-10, 11-12	8, 0	0, 5	0, 0
	02/03/19	2	5, 7	9-10, 10-11	5, 5	0, 2	0, 0
	03/03/19	3	4	10-11	4	0	0
3	01/03/19	1	2, 15	13-14, 15-16	2, 9	0, 6	0, 0
	02/03/19	2	3, 12	13-14, 15-16	3, 8	0, 0	0, 4
	03/03/19	3	9	17-18	7	0	2
4	01/03/19	1	9	17-18	4	5	0
	02/03/19	2	11	17-18	6	5	0
	03/03/19	3	9	10-11	0	0	9
5	01/03/19	1	7	17-18			
	02/03/19	2	0				
	03/03/19	3	0				
6	01/03/19	1	5	8-9	0	0	5
	02/03/19	2	9	9-10	7	2	0
	03/03/19	3	2	9-10	2	0	0
7	01/03/19	1	0				
	02/03/19	2	3	10-11	3	0	0
	03/03/19	3	0				
8	01/03/19	1	18	10-11	12	6	0
	02/03/19	2	18	10-11	12	6	0
	03/03/19	3	10	14-15	8	2	0
9	01/03/19	1	7	10-11	4	3	0
	02/03/19	2	8	14-15	5	3	0
	03/03/19	3	4	14-15	3	0	1
10	01/03/19	1	3, 9	16-17, 10-11	0, 4	0, 5	3, 0
	02/03/19	2	5	16-17	0	0	5
	03/03/19	3	0				
		Total	274		179	60	35

R=replica

Our results agree with those reported for several states in the United States of America, where for pine-oak ecosystems in New Mexico, USA, they report densities of 3 wild turkeys mi^{-1} equivalent to 0.011 wild turkeys ha^{-1}; in Texas in the same habitat 5 wild turkeys mi^{-1} equivalent to 0.019 wild turkeys ha^{-1} (McLaughlin, 2014). However, our results do not agree with those reported in Mexico in the sierra of La Michiía, Durango (Garza and Servin, 1993) with pine-oak vegetation where they report densities ranging from 1.6 wild turkeys km^2 (0.0000016 wild turkeys ha^{-1}) to 6.0 wild turkeys km^2 (0.000006 wild turkeys ha^{-1}), results that would be expected to be like those of the Monte Escobedo Mountain range. Perhaps because of the method used in La Michiía, the results are quite underestimated, since they are not based on observed animals, but rather signs of their presence. These methods frequently lead to erroneous estimates (Clemente-Sánchez and Tarango-Arámbula, 2007). In another study, Erxleben *et al.*

Table 2. Overlap of turkeys observed in time ranges in three days of sampling within 10 attraction sites in a pine-oak forest in Monte Escobedo, Zacatecas.

Site	Time ranges (h) with the number of turkeys observed									
	9-10	**10-11**	**11-12**	**12-13**	**13-14**	**14-15**	**15-16**	**16-17**	**17-18**	**Total**
1	15,11,21	12				8				67
2	8,5	7,4	5							29
3					2,3		15,12		9	41
4		9							9,11	29
5									7	7
6	5,9,2									16
7		3								3
8		18,18				10				46
9						7,8,4				19
10		9						3,5		17
Total	76	80	5		5	37	27	8	36	274

(2010), with Rio Grande wild turkeys in North, Central and South Texas conducted a study to test the distribution of wild turkeys using radio telemetry. They observed great variation in the distribution of the populations, which resulted in the assumptions of the line transect method not being met, since the distribution of the wild turkey was not homogeneous. In this study, the transect sample was not random, so the authors recommend that before applying any population estimation method, a prior study of its distribution should be made.

CONCLUSION

The monitoring of wild turkey populations is based on the gregarious habits of the species, the type of ecosystem, their movements over time, as well as their interaction with the presence of humans and the selection or use of habitat during the day. The population estimators currently used lack reliability due to the impossibility of meeting the assumptions of their application.

The population of wild turkey in the study area of Monte Escobedo, Zacatecas, showed good abundance, with characteristics of a stable population from the number of adults and their relationship with juveniles.

The method of attraction sites is a new alternative to obtain reliable estimates of characteristic parameters of the population, such as the density of wild turkeys per surface unit and the size of the population.

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AP AGRO PRODUCTIVIDAD

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Cost-benefit analysis of the production of juvenile tropical Gar "pejelagarto" (*Atractosteus tropicus* Gill): comparing four feeding schemes

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ABSTRACT

Objective: To determine the production cost and profitability of different feeding strategies during tropical gar larviculture.

Design/methodology/approach: Growth and survival obtained from the evaluation of an experimental diet with cornstarch, compared to a conventional strategy (commercial diet for rainbow trout co-feed with *Artemia nauplii*). The experimental diet was evaluated with co-feeding with *Artemia*, and with no *Artemia*. The production cost was estimated for each strategy and the unit cost per juvenile was calculated, as well as their sale cost. For economic analysis, their cost-benefit ratio and the breakeven point were also determined.

Results: Direct feeding with no *Artemia* strategy during larviculture is not profitable. According to the cost-benefit ratio, comparing the strategy with the experimental diet in co-feeding with the conventional strategy, the profitability of the first was greater. The breakeven point between the profitable strategies was similar, but the greater survival with the experimental diet suggests a higher impact on the optimization of the production system.

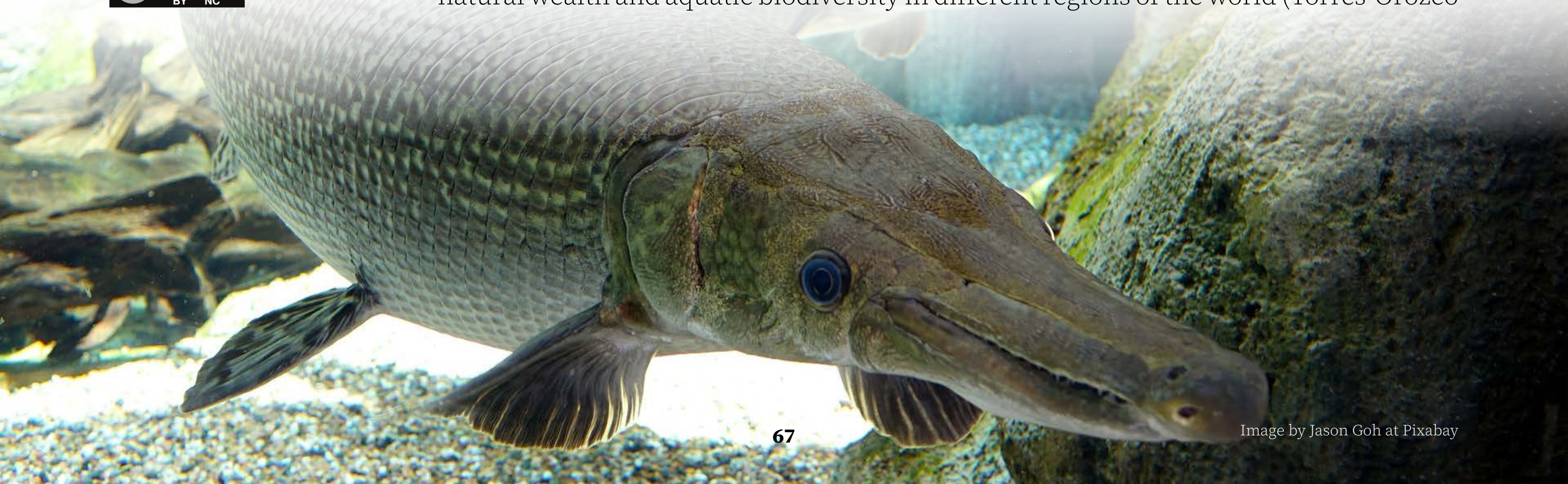
Limitations on study/implications: The lack of economic analysis on the tropical gar larviculture affect indirectly the tropical gar production system as there is no accurate information on its production costs.

Findings/conclusions: From a financial point of view, the feeding strategy using an experimental diet with co-feeding is the most profitable process in larviculture.

Keywords: native fish, financial feasibility, co-feeding, breakeven point, system optimization.

INTRODUCTION

Aquaculture production is dominated by high commercial value fish, generally exotic, although there is a demand for native species, based on the need not to lose the natural wealth and aquatic biodiversity in different regions of the world (Torres-Orozco



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& Pérez Hernández, 2011). Aquaculture of native fish represents an improvement to the quality of production of these resources, particularly in tropical areas (Márquez-Couturier & Vázquez-Navarrete, 2015).

At the state of Tabasco, Mexico, one of the most exploited native species is the tropical gar *Atractosteus tropicus* (Márquez *et al.*, 2013). In recent years, fishing pressure and environmental factors have decreased their catches over time (Márquez-Couturier & Vázquez-Navarrete, 2015; Palma-Cancino *et al.*, 2019a). Aquaculture of this species has had important advances since the beginning of this century as a fishing alternative (Márquez *et al.*, 2006). Its reproduction in captivity is known (Márquez *et al.*, 2013), as well as its enzymatic activity during development (Guerrero-Zárate *et al.*, 2014; Frías-Quintana *et al.*, 2015), it's fattening and production costs during this stage (Palma-Cancino *et al.*, 2019b), and the design of diets and feeding strategies during their larval development and pre-juvenile production (Frías-Quintana *et al.*, 2010, 2016, 2017; Nieves-Rodríguez *et al.*, 2018; Palma-Cancino *et al.*, 2019a).

Yet, there is a notable lack of research on their production costs due to their feeding strategies during the larval stage (Palma-Cancino *et al.*, 2019a). Another gap in scientific studies on the economics of the pejelagarto is the lack of an adequate analysis of the operational costs of production, as well as a unit cost of the pre-juvenile fish. This makes it difficult to estimate the real value of the product and generates uncertainty for potential tropical gar producers in relation to the adequate selling price of the hatchlings. The purpose of this research is to estimate the real cost of production of *A. tropicus* larviculture, to compare the unit costs per pre-juvenile, the cost-benefit ratio when using different feeding schemes to a conventional one, and to estimate the break-even point for each production scheme.

MATERIALS AND METHODS

Biological data and feeding schemes. To assess the production costs and their corresponding cost-benefit analysis, biological data generated by Palma-Cancino *et al.* (2019a) in the Tropical Aquaculture Laboratory of the Universidad Juárez Autónoma de Tabasco were used; where the response in growth, survival and cannibalism of *A. tropicus* to different feeding schemes (two of them including an experimental diet proposed by Frías-Quintana *et al.*, 2016) were evaluated. The feeding scheme for each treatment was initiated from larval seeding (five days after hatching). The feeding treatments were defined as follows: control treatment (C): conventional diet, consisting of floating extruded trout feed with 45% protein and 16% lipids, Silver Cup® brand (Alimentos de Alta Calidad El Pedregal S. A. de C. V.) with 10 initial days of co-feeding with *Artemia salina* nauplii (Biogrow ®); treatment 1 (T1) consisted on Silver Cup® diet without co-feeding; treatment 2 (T2) an experimental cornstarch diet (Frías-Quintana *et al.*, 2016) with co-feeding the first 10 days with *A. salina*; and treatment 3 (T3) consisted only of the experimental cornstarch diet. The averages weight and length, as well as the survival percentage for each treatment (feeding scheme), are presented in Table 1.

Table 1. Growth parameters (mean±SD) and survival (percentage) obtained at the end of *Atractosteus tropicus* larviculture (45 days after hatching), under four different feeding schemes. Biological data obtained from Palma-Cancino *et al*. (2019a).

Treatment	Weight (g±SD)		Length (mm±SD)		Survival (%)
	Initial	Final	Initial	Final	
C	0.029±0.002	2.16±0.73	17.40±0.60	87.50±9.35	15.56
T1	0.029±0.002	1.78±0.45	17.40±0.60	80.44±7.38	5.56
T2	0.029±0.002	3.37±1.46	17.40±0.60	97.74±13.07	32.33
T3	0.029±0.002	2.18±0.83	17.40±0.60	84.51±12.82	1.00

C (Control): Conventional diet consisting of floating extruded trout feed with Silver Cup®, 45% protein and 16% lipids and 10 initial days of co-feeding with *Artemia salina* naupliius (Biogrow®); T1: Silver Cup® diet without co-feeding; T2: experimental cornstarch diet with co-feeding the first 10 days with *A. salina*; T3: experimental cornstarch diet.

Production costs and unit costs per organism. An individual cost per juvenile was estimated for each diet, based on the operational and feeding costs. Operational costs consisted of energy, labor and broodstock maintenance costs. The energy costs (C_E) were calculated by estimating the total Kwh expenditure of the pump and thermostat and multiplying them by the current rate established by the Comisión Federal de Electricidad (Federal Electricity Commission, CFE) for 2021; the labor costs C_L, consisting of a wage for a worker, using the daily minimum wage as a reference, according to that established by the Diario Oficial de la Federación (Official Journal of the Federation, DOF, 2020), which currently consists of 5.37 USD daily for 50 days (duration of the culture from spawning). The broodstock maintenance cost (C_{BM}) is a fixed cost, equivalent to 18.91 USD, estimated for the maintenance of five males and one female for the duration of larviculture, from Palma-Cancino *et al*. (2019b).

The feeding costs were calculated using the inert diet commercial price as reference (F_D) and the price of live feed (F_L), in the Silver cup® treatments; while in the experimental diet treatments, the feeding cost was estimated by adding individually the unit costs of ingredients (for T2 and T3) and live feed (only for T2). For both cases, a cost per kilogram was determined and multiplied by the total feed expense used in Palma-Cancino *et al*. (2019a). As the costs would represent only the expense generated for a culture of 3,600 organisms, it was extrapolated to an estimate for 16,000 organisms, 80% of the minimum 20,000 viable eggs per spawn of a 3-4 kg female estimated by Márquez *et al*. (2013).

The equation to calculate each treatment total costs (TC) was as follows:

$$TC = C_E + C_L + C_{BM} + \left(\left(F_L + F_D\right) * 16000\right)$$

Finally, the unit costs (CpU) arose from a ratio between the TC of each treatment, and a 16,000 individuals batch of multiplied by the survival (S_T) in each treatment, following Palma-Cancino *et al.* (2019a). The equation used was as follows:

$$CpU = \frac{TC}{S_T * 16000}$$

Cost-benefit ratio and breakeven point. To calculate the cost-benefit ratio (*BCR*) for each of the treatments, we used the total cost of larviculture and the generated income (*TS*) for the total viable organisms for sale (same as that used to calculate the *VCpU*) multiplied by the unit price per pre-juvenile (*SpU*) of 0.38 USD wholesale, according to personal observations made by the authors on-farm in the state of Tabasco. Both values were adjusted using a minimum acceptable rate of return (MARR) of 10% (*r*) at a five-year (*t*) prospection. The equation was adjusted from Kay *et al*. (2012), and Palma-Cancino *et al*. (2019b) as follows:

$$BCR = \sum TS(1-r)^{-t} / \sum TC(1-r)^{-t}$$

To estimate the breakeven point for the number of pre-juveniles (*BQ*), the previously mentioned selling price per unit of *SpU*=0.38 USD was used. The fixed costs ($F \times C$) were calculated with the proportion of the annual depreciation of the 50-day cropping system, estimated at 61.69 USD, based on the system described by Palma-Cancino *et al*. (2019b); and the sum of the C_E, C_L, and C_{BM} for 50 days, equivalent to 297.14 USD, so $F \times C$=358.83 USD. The equation used was the following modified from Sathiadhas *et al*. (2009):

$$Breakeven\ Quantity(BQ) = \frac{F \times C}{(SpU - CpU)}$$

All calculations were performed in the Microsoft Office 365 Excel software (Microsoft Corp., USA).

RESULTS AND DISCUSSION

Production costs and unit costs per pre-juvenile. The total costs (*TC*) of production of each treatment are presented in Table 2. A considerable cost in live feed is observed for treatments C and T2. The improved survivals when using *Artemia* sp. as live feed reported by Escalera-Vázquez *et al*. (2018), Sáenz de Rodrígañez *et al*. (2018) and Palma-Cancino *et al*. (2019a), suggest this is a necessary expense to control mortality to some extent during this larviculture process.

The unit costs (Table 3) revealed the high cost of producing without using initial co-feeding, given that T1 and T3 were the highest obtained per pre-juvenile. These results differ from those reported by Frías-Quintana *et al*. (2016), who recommend eliminating the use of *Artemia nauplii*, since using only the experimental corn starch-based diet would increase survival and reduce costs. In contrast, the lower T2 unit cost suggests optimization of the production cycle when using the experimental diet compared to Silver Cup®, which concurs with the same author. Specifically, the high unit cost in T1 is due to the low organism survival obtained by Palma-Cancino *et al*. (2019a), which also concurs with Frías-Quintana *et al*. (2017) who obtained low survival when using Silver Cup® feed without co-feeding, during the larviculture of *A. tropicus*.

Table 2. Total operational costs (TC) breakdown for a 16,000 batch of *Atractosteus tropicus* larvae, estimated for each treatment. All values are in USD. [1]Mexico prices of electricity by the Comisión Federal de Electricidad (CFE). [2]Minimum daily wage in Mexico according to DOF (2020).

Treatment	Energetic cost[1]	Labor cost[2]	Breeder mantainance cost	Live feed cost	Inert feed cost	TC
	USD					
C	9.79	268.44	18.91	41.36	17.08	355.59
T1	9.79	268.44	18.91	0	6.39	303.53
T2	9.79	268.44	18.91	41.36	16.68	354.78
T3	9.79	268.44	18.91	0	16.68	313.42

C (Control): Conventional diet consisting of Silver Cup® floating extruded trout feed with 45% protein and 16% lipids, with 10 initial days of co-feeding with Artemia salina nauplius (Biogrow®); T1: Silver Cup® diet without co-feeding; T2: Experimental corn starch diet with co-feeding with *A. salina* the first 10 days; T3: Experimental corn starch diet.

Table 3. Cost production per juvenile of tropical gar from an egg-spawning of approximate 16,000 larvae. Viable juveniles were estimated using the survival rate observed during larviculture in Palma-Cancino *et al*. (2019a).

Treatment	Viable juveniles	Unitary cost (USD)
C	2,490	0.14
T1	160	1.96
T2	5,173	0.07
T3	890	0.35

C (Control): Conventional diet consisting of Silver Cup® floating extruded trout feed with 45% protein and 16% lipids, with 10 initial days of co-feeding with *Artemia salina* nauplius (Biogrow®); T1: Silver Cup® diet without co-feeding; T2: Experimental corn starch diet with co-feeding with *A. salina* the first 10 days; T3: Experimental corn starch diet.

The obtained results indicate that the designed T2 corn starch diet (Frías *et al*., 2016; Palma-Cancino *et al*., 2019a) has a lower production cost when compared to the commercial Silver Cup® diet, used during the larviculture of pejelagarto. This coincides with the results by Barragán *et al*. (2017), who elaborated balanced diets for tilapia (*Oreochromis* sp.), reporting lower production costs compared to commercial balanced feeds. Similarly, Miranda-Gelvez & Guerrero-Alvarado (2015) managed to substitute fishmeal with 10% Sacha Inchi (*Plukenetia volubilis*) meal in the feed of juvenile tilapia vermelha (*Oreochromis* sp.), obtaining good growth without affecting product performance, reducing feeding and production costs. However, since the analyzed experimental diet here is not yet large-scale manufactured, the estimated price used of its cost is susceptible to the agricultural input market volatility.

The usage of live feed for some larviculture systems continues to be indispensable because these feeds provide most of the nutritional elements that guarantee the survival and optimal development of the larvae (Abdó-De La Parra *et al*., 2010). In our research, a higher survival percentage, greater weight and length were observed in the feeding strategies containing *Artemia*. This coincides with Luna-Figueroa *et al*. (2010), in a study evaluating the effectiveness of three live feeds (*Moina wierzejski*, *Artemia franciscana* and *Panagrellus redivivus*) in co-feeding with Aquarian Tropical Flakes® diet, in *Pterophyllum* scalare larvae; obtaining higher larval survival supplying *A. franciscana* nauplii. Specifically, in pejelagarto, Saenz de Rodrigáñez *et al*. (2018), obtained higher survival and growth in co-feeding using *Artemia* nauplii during the first days after hatching, when compared to other types of live feed and micro-encapsulated food, justifying that the use of *Artemia* nauplii to acclimate pejelagarto larvae to inert diets is a suitable practice for *A. tropicus* the larviculture.

Exogenous feeding, or first feeding of organisms completing larval development, is the critical period in the production of seed for aquaculture. Three strategies have been developed to use artificial diets in fish, direct use, late weaning and progressive weaning (Lazo, 2000). In the present study we used progressive weaning at C and T2, supplying artificial feed progressively with a live feed from the start of exogenous feeding; and direct use at T1 and T3. Over time, the proportion of artificial diet is increased, and live feed is reduced, a critical process in carnivorous fish rearing (Márquez *et al*. 2013); this process success depends on both supplied live and inert feed and is reflected in the survival of larvae and their growth, ultimately impacting on the reduction of production costs (Paz *et al*., 2020).

It is to be noted that using experimental diets in *A. tropicus* larviculture is usually feasible (Huerta-Ortiz *et al*., 2009; Frías-Quintana *et al*., 2010; 2016; 2017; Nieves-Rodríguez *et al*., 2018), and can significantly reduce production costs by increasing biomass availability when compared to commercial diets. Similarly, it is important to highlight that using co-feeding and adequate live feed during the first days of culture is necessary to succeed in obtaining the best growth and survival results (Saenz de Rodrigáñez *et al*., 2018; Escalera-Vázquez *et al*., 2018).

Cost-benefit ratio and break-even point. The results of the cost-benefit analysis determined better financial performance for T2 with respect to the others (Table 4). According to the cost-benefit ratio results (*BCR*), only T2 and the conventional strategy (C) are financially profitable (T2=3.45 and C=1.66), since it is necessary that the to be financially profitable (Tran *et al*., 2020).

The lack of profitability in treatments without co-feeding is not surprising. Ajiboye *et al*. (2010), Saenz de Rodrigáñez *et al*. (2018), and Escalera-Vázquez *et al*. (2018) establish how vital the use of live feed is during the beginning of exogenous feeding in larvae of carnivorous tropical fish species.

The use of an experimental diet with corn starch in co-feeding (T2), presents a better financial performance overall, generating arguments from a bioeconomic point of view to sustain the hypothesis that this feeding strategy would optimize the production system of *A. tropicus* pre-juveniles. The latter differs from Márquez *et al*. (2013) who affirms that conventional treatment with commercial rainbow trout diets and weaning at 12 days with *Artemia* nauplii is the most efficient way to carry out the larviculture of the species. The economic results here also partially differ from Frías-Quintana *et al*. (2016) who propose that direct feeding with an experimental corn starch diet optimizes the larviculture of rainbow trout but agrees that using such an experimental diet increases the production of viable pre-juveniles for sale.

Table 4. Results of cost-benefit ratio (BCR) and break-even quantity (BQ) analysis for a tropical gar juvenile production under four different feeding schemes. * Financially profitable; ** Not financially profitable.

Treatment	BCR	BQ (quantity)
C	1.66*	1,496
*T*1	0.12**	−236
*T*2	3.45*	1,158
*T*3	0.65**	11,961

C (Control): Conventional diet consisting of Silver Cup® floating extruded trout feed with 45% protein and 16% lipids, with 10 initial days of co-feeding with *Artemia salina* nauplius (Biogrow®); T1: Silver Cup® diet without co-feeding; T2: Experimental corn starch diet with co-feeding with *A. salina* the first 10 days; T3: Experimental corn starch diet.

The estimated breakeven quantity for the feeding strategies was relatively similar for C and T2, due to the similar margin in unit production costs and the fact that fixed costs are the same in all treatments. This similarity in sales units (pre-juveniles for this study) is more important for T2 since expecting a relatively low survival of animals during larviculture (30-40%), the investment is recovered with the sale of approximately 25% of the total pre-juveniles produced. This suggests that the rest of the pre-juveniles would be directly profitable and reducing their selling price would optimize the larviculture product system for pejelagarto larviculture. The above agrees with Janssen *et al*. (2018) who comment that an adequate diet in broodstock maintenance and during the early life of larvae or fry is indispensable to generate bioeconomically profitable larviculture programs.

Overall, the financial results obtained here indicate an increase in the economic benefit using the experimental diet designed according to the specific nutrient requirements of *A. tropicus* by Frías-Quintana *et al*. (2016), in co-feeding with *Artemia* nauplii. The latter applies to controlled laboratory conditions, as further trials are required to optimize the production system when using such a diet and feeding strategy. This work presents a first approach to the bioeconomic analysis of *A. tropicus* larviculture on a pilot-commercial scale. However, it is recommended to continue researching production with experimental diets to obtain better yields from each spawning of the reproductive females. It is considered that the cost-benefit ratio of pre-juvenile production will improve, making this system-product more profitable, not only through the correct diet selection but also through the “gene pool” improvement of the species in captivity, as suggested by Vázquez-Navarrete & Márquez-Couturier (2015) and Janssen *et al*. (2018), long-term captive breeding programs by themselves optimize the production costs of aquaculture systems.

Finally, this research provides evidence to suggest a lower selling price of *A. tropicus* pre-juveniles, especially at wholesale, as this could increase farming efforts for the species, incentivize its consumption, help to combat the displacement of this native species by invasive species such as *Oreochromis niloticus* or *Hypostomus plecostomus*, and combat overfishing by offering high nutritional quality farm-produced meat. All the above would significantly increase the sustainability of the cultivation of pejelagarto in Mexico.

CONCLUSIONS

Under controlled conditions, the feeding strategy for *A. tropicus* larvae using an experimental diet of corn starch and progressive weaning with *Artemia* sp. nauplii is more financially profitable for the larviculture of the species. It is recommended to continue research with experimental diets to optimize the production system and scale it up to the pilot-commercial level.

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AGRO PRODUCTIVIDAD

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Productive performance and carcass characteristics of New Zealand white and California rabbits and their crosses

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ABSTRACT

Objective: To evaluate the growth, performance, and carcass characteristics as well as the individual and maternal heterosis effects of New Zealand White (NZ), California (CA) rabbits and their crosses.

Design/methodology/approach: 450 offspring rabbits, from 48 females (does) mated to six stud rabbits, were evaluated, recording the weight (BLW) and litter size at birth (LSB) and weaning (LSW), as well as the weight (AWW), gain (AWG), consumption (AWC), and feed conversion (CONV) for 8 weeks post-weaning. The carcass live weight at slaughter, warm carcass weight with head, carcass yield and parts of the carcass were evaluated.

Results: The assessment showed differences ($P<0.05$) in LSB and LSW with values of 10.47 and 9.78 kits respectively, when NZ was used as the paternal breed, results suggest individual heterosis of 5.91% for litter size and 12.44% for the weaning weight. Regarding the productive performance and carcass characteristics, the California breed showed superiority as a paternal breed, with average values of 36.11 g in AWG and 2.90 in CONV. The average individual weight at the end of the fattening, at 70 days of age, was 2.09 kg and the carcass weight was 1.16 kg. Post-weaning heterosis for the evaluated characteristics during fattening was positive and moderate.

Limitations on study/implications: It is necessary to carry out genetic improvement studies, with different crossing systems and to evaluate results based on productive and reproductive performance.

Findings/conclusions: When using NZ as a paternal breed, the reproductive characteristics of the offspring were superior compared to the ones obtained from CA. In contrast, the reproductive variables were superior in CA breed in comparison to NZ.

Keywords: rabbit breeding, litter size, weight gain, carcass yield.

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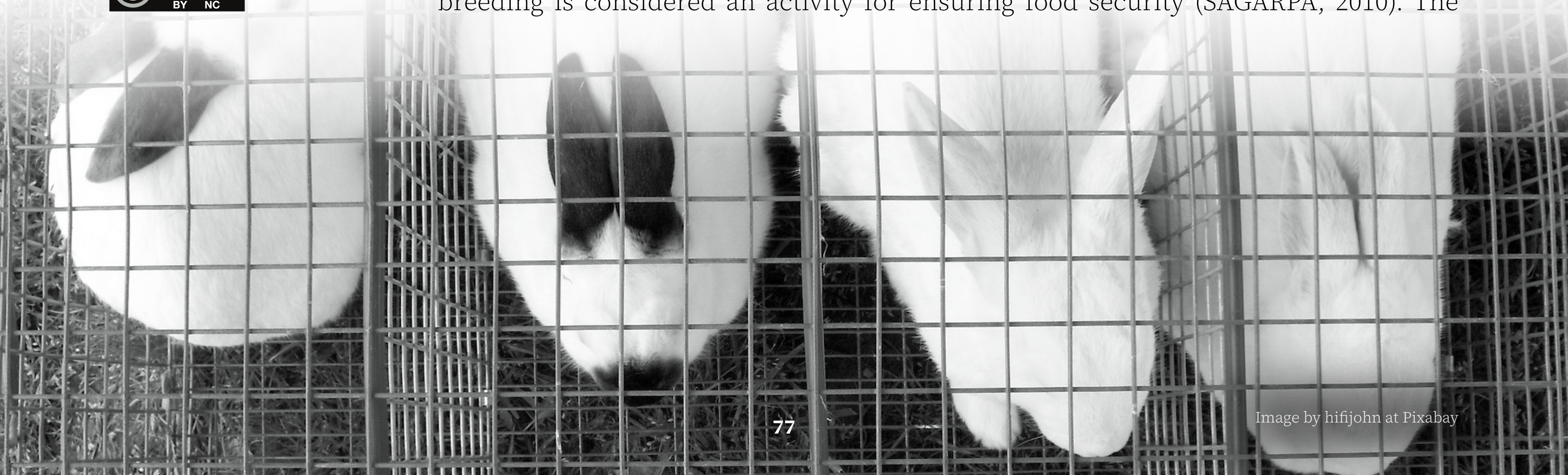
INTRODUCTION

In Mexico, rabbit breeding in family-based farms is carried out with New Zealand White (NZ), California (CA) and Chinchilla breeds, as well as a wide range of crosses, constituting a source of income and good quality protein for rural families, thus, rabbit breeding is considered an activity for ensuring food security (SAGARPA, 2010). The



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estimation of productive, reproductive and profitability indexes in rabbit farms can aid in the calculation of their potential performance (Lukefahr and Cheeke, 1991), besides offering useful information about pure breeds and commercial crossbreeds. NZ White and CA breeds have great potential as pure breeds, maximizing the percentage of heterosis in their crosses and used in the creation of genetic lines (Blumetto, 2007). They have good muscle conformation, high prolificity and growth rate (Ortiz and Rubio, 2001). Heterosis between crosses of these breeds is greater in reproductive characteristics than in growth characteristics, manifesting itself in a greater number of kits at weaning. This superiority is greater when the breeds differ widely in gene frequencies with a minimum of genotype-environment interactions (Falconer and Mackay, 1996), requiring further research in local rabbit populations. The objective of this research was to evaluate the productive performance, carcass characteristics and individual heterosis of some productive traits in NZ, CA rabbits and their crosses.

MATERIALS AND METHODS

Ethical Statement

Sampling, handling, and slaughter of the animals were carried out following the Experimental Regulation Protocol and following the Mexican Official Standard (Norma Oficial Mexicana, NOM-033-ZOO-1995), which refers to the humane slaughter of domestic and wild animals; the above, approved by the Colegio de Postgraduados, Mexico.

Study site

From February to December 2019, research was conducted at the rabbit production module of the Colegio de Postgraduados, Campus Montecillo, located at 19° 27’ 34.8’’ LN and 98° 54’ 15.8’’ LO, in Texcoco, Estado de Mexico.

Feeding

Controlled commercial feed was provided to obtain the average weekly intake (AWI) in two variants; for does, with a 15.55% protein, 16.26% fiber and 2.91% fat content; for the fattening progeny with 16.5% protein, 15% fiber and 3% fat.

Experimental procedure

Data were obtained from a 48 first-calving females sample from a rabbit population of 160 females. Preweaning characteristics of NZ and CA females and their crosses were evaluated. During the first stage, NZ and CA breeders were mated with six males, three NZ and three CA, and classified into four genetic groups (treatments): T1: NZ×NZ, T2: CA×CA, T3: NZ (sire)×CA (dam) and T4: CA (sire)×NZ (dam). In the second stage, six weaned kits were selected from each female and transferred to fattening cages with an identification ear tattoo and weighed individually for five weeks. At the end of the fattening stage, 350 randomly selected animals were slaughtered to evaluate their carcass characteristics.

Evaluated characteristics

Preweaning stage. Maternal ability was recorded in the parents: nest preparation, live and stillborn kits, their viability from birth to weaning, litter size and weight at birth and weaning (35 days) and mortality.

Fattening stage. Weight (AWW), weight gain (AWG), feed intake (AWC) and feed conversion (CONV) were evaluated weekly, using 112 replicates per treatment.

Carcass evaluation. After slaughter, the carcass was fractionated following the protocol by Blasco *et al*. (1992). Live weight at slaughter, carcass weight with head, carcass yield and carcass parts (leg, loin, arms, kidney, liver, green and red viscera) were measured and classified by sex.

Individual heterosis (H) was estimated by the difference between the average of the reciprocal crosses minus the average of the parents divided by the average of the parents (Falconer and Mackay, 1996).

Statistical analysis

In the preweaning stage data, an analysis of variance was performed using the PROC GLM of SAS statistical software (SAS, 2012), with a one-way classification model. To evaluate the parents for preweaning progeny performance, two groups of treatments were formed, the first with progeny from NZ parents and the second with progeny from CA parents. For the analysis of the fattening stage, the PROC MIXED of the SAS statistical software (SAS, 2012) was used, which included the fixed effects of treatment, time and their interaction. To ascertain mean differences, a Tukey's test (α<0.05) was used.

$$\text{Model: } Y_{ijkl} = \mu + R_i + \delta_{ji} + S_k + (RS)_{ik} + \varepsilon_{ijkl}$$

Where: Y_{ijkl}=Growth trait in the *ijk*-th evaluated doe; μ=Overall mean; R_i=Fixed effect of *i*-th genetic group; δ_{ji}=Error of *j*-th animal within *i*-th genetic group; S_k=*k*-th week of evaluation; $(RS)_{ik}$=Effect of genetic group × week interaction; ε_{ijkl}=Random error.

The carcass evaluation considered live weight at slaughter as a covariate, according to the model:

$$Y_{ijkl} = \mu + R_i + \beta\left(X_{ij} - \overline{X}\right) + \varepsilon_{ijkl}$$

Where: Y_{ijkl}=Carcass characteristic in *ij*-th evaluated rabbit; μ=Overall mean; R_i=Fixed effect of the *i*-th genetic group; $\beta\left(X_{ij} - \overline{X}\right)$=Effect of the covariate live weight of rabbits at slaughter ε_{ijkl}=Random error.

RESULTS AND DISCUSSION

Litter size and litter survival in the pre-weaning period

Table 1 shows differences (P<0.05) in litter size at birth (LSB) and weaning (LSW), values that concur with Piles *et al*. (2005) who indicated superiority in LSB and survival of the NZ breed and the NZ×CA crosses. Statistical analyses showed no differences (P>0.05) between breeds in birth weight (LWB). The mean number of kits per female at parturition was 10.40 and at weaning 8.94 for NZ and CA breeds, which is higher than that described by Vásquez *et al*. (2007), in the NZ breed, in the Sabana de Bogotá, Colombia.

Table 1. Analysis of pre-weaning variables of the New Zealand and California breeds and their reciprocal crosses.

Variable	Treatments			
	NZW Parents	CA Parents	SEM	P>F
Litter size at birth	10.47 a	10.32 b	±0.08	0.034*
Number live-born kits	9.78a	9.67a	±1.02	0.057
Mortality at birth	0.53a	0.64a	±0.56	0.054
Litter weight at birth (g)	574.87a	586.46a	±17.13	0.090
Litter size at weaning	9.03 a	8.85 b	±0.19	0.045*
Average weaning weight (g)	972.02 a	909.99 b	±31.81	0.029*
Total mortality (birth–weaning)	1.37a	1.25a	±0.36	0.331
Total percentage of mortality	12.43a	11.71a	±4.42	0.370

a,b,Means within rows with different literals are different (P < 0.05*), SEM: standard error mean. NZ: New Zealand parents, CA: California parents

Litter weight at birth and weaning

The average litter weight at birth (LWB) was 580.66 g, with an individual weight of 56.1 g, and an average individual weaning weight of 941 g (Table 1). The results at birth are similar to those of Diaz (2006), who reported birth weights of 50 to 75 g in the NZ breed and crossbred progeny. The present results are higher than those reported by Ponce de León *et al*. (2002) who reported birth weights of 562.22 g for NZ parents. Contrastingly, Gallego (2016) reported that the offspring of NZ parents reached a higher weight at weaning than the progeny of CA parents, attributable to the additive effects of NZW males and the individual heterosis possessed in this trait; contrary to what was obtained in the LWB variable. Offspring from CA parents at weaning obtained a lower average weight (909.99 g), similar to the values reported by Lukefahr *et al*. (2000). New Zealand White females were superior to CA females in their reproductive traits. The contribution of maternal effects was higher in the NZ breed (Table 1).

The heterosis obtained for live births and survival during the preweaning period, within the four genetic groups, was positively superior by 5.91 and 4.99%, respectively, from the crossbred progeny (Table 2), coinciding with Brun and Baselga (2005), that report positive heterosis effects of the crossbred progeny and values with a 6% superiority. The heterosis found in birth weight was 5.29%, a value lower than that reported by Youssef (2004) who indicates a 6% superiority in the birth weight of the NZ breed and reciprocal crosses with CA.

Table 2. Direct effects of heterosis on litter size at birth, survival rate, birth and weaning weight and percentage of heterosis in rabbit breed.

Maternal breed	Litter size at birth	Survival rate (%)	Birth weight (g)	Weaning weight (g)
California	10.36 b	92.32 a	574.46 a	962.98 b
New Zealand White	10.44 a	94.73 a	589.07 a	919.42 a
Heterosis (%)	5.91	4.99	5.29	12.44

a,b, Means within columns with different literals are different (P<0.05*).

The progeny of the NZ×CA cross showed a superior weaning weight (12.44%) in relation to its parental breeds which, complemented with litter survival at birth, demonstrates it was the cross with the best performance of the evaluated genetic groups. This heterosis is considered of medium and moderate impact on the productivity in breeding systems and concurs with Gallego (2016) and Youssef (2004) who report similar results with a 13% value.

Fattening phase

Table 3 shows the means of the evaluated breeds in the fattening phase. The CA progeny had a higher increase (P<0.05) in AWG, with a mean of 35.99 g and a ratio of 2.90 kg feed per kg live weight, compared to offspring from NZ parents. However, there were no differences between breeds for weight and weekly feed intake variables.

Table 3. Analysis of fattening stage variables (g) in the New Zealand (NZ), California (CA) rabbit breeds and their crossbreeds.

Variable		AWG	AWW	AWC	CONV
Treatment (T)	(NZ)	33.62 b	1914.96 a	104.58a	3.22 b
	(CA)	35.99 a	1970.57a	101.97a	2.90 a
	NZ×CA	34.54 ab	1946.49a	104.97a	3.03 ab
	CA×NZ	36.11 a	1979.39a	103.22a	3.00 ab
	SEM	±0.67	±54.13	±3.09	±0.12
Week (W)	ONE	33.98a	941.20a	60.90a	1.81a
	TWO	35.97a	1184.06a	81.46a	2.28a
	THREE	37.11a	1466.61a	110.45a	3.06a
	FOUR	33.52a	1724.06a	121.31a	3.81a
	FIVE	34.76a	1968.92a	143.30a	4.22a
	SEM	±0.78	±31.96	±2.31	±0.11
Interactión (p>F) T×W		0.0049**	0.8228	0.6675	0.0359*

a,b, Means within columns with different literals are different (P<0.05* y P<0.01**). AWG: average weekly gain, AWW: average weekly weight, AWC: average weekly consumption and CONV: average feed conversion.

These results coincide with those by Piles *et al.* (2005) where the superiority of the CA compared to NZ regarding weight gain and feed conversion was reported and no differences were found in feed intake and final weight.

The obtained values in this study for the evaluated crosses are higher than those reported by Palmieri (2006) who crossed CA with NZ breeds and reported post-weaning weight gains of 30 g per day. Blumetto (2007) recorded a daily weight gain of 35.54 to 36.51 g, similar to those reported in the present study. The heterosis in weight gain and final weight in the four genetic groups was 33.33 and 24.75%, respectively (Table 4). These are of high heritability and higher than those found by Zaghloul *et al.* (2019) and Khalil and Al-Homidan (2014) who report heterosis of 18 to 34% in weight gain and 19 to 20% at final weight.

Table 4. Direct effects of individual heterosis on progeny characteristics in the fattening phase of rabbit breeds.

Paternal breed	Weight gain	Final weight	Feed consumption	Feed conversion
California	36.05 a	1974.98a	102.59a	2.95 a
New Zealand White	34.08 b	1930.72a	104.77 b	3.12 b
% Heterosis	33.33	24.75	22.58	23.44

a,b. Means within columns with different literals are different (P<0.05*).

Regard feed consumption and CONV, the heterosis found was 22.58% and 23.44%, respectively, which are of moderate tendency. The results described here were superior to those found by Youssef (2004) and Piles *et al.* (2004) who reported a 20% heterosis in the feed intake and 22% in CONV.

Table 5 shows the superiority of the progeny from CA breed parents in live weight at slaughter (2094.87 g) and carcass weight (1164.21 g); no differences were found in yield and carcass parts (P>0.05).

Table 5. Analysis of the carcass characteristics in New Zealand (NZ) and California (CA) rabbit breeds and their crosses.

Treatment	Live weight (g)	Carcass weight (g)	Dressing percentage (%)	Loin(g)	Legs (g)	Arms (g)	Kidney (g)	Liver (g)
NZ	1920.74b	1055.97b	55.23a	172.18a	273.48a	139.74a	21.81a	70.44a
CA	2078.54a	1156.18a	55.51a	176.81a	272.50a	145.49a	21.90a	70.62a
NZ×CA	1964.75b	1083.65b	55.29a	175.75a	274.97a	138.19a	21.93a	70.56a
CA×NZ	2111.20a	1172.24a	55.52a	178.50a	273.00a	150.71a	21.73a	70.56a
SEM	130.38	±86.92	±1.96	±31.02	±28.01	±19.81	±1.48	±2.55
P>F	0.0028**	0.0312*	0.7900	0.7911	0.9859	0.7323	0.9073	0.9816
By sex								
Males	2029.16a	1120.60a	52.20a	175.94a	277.14a	144.44a	21.92a	70.34a
Females	1994.05a	1107.90a	55.53a	175.04a	269.58a	142.17a	21.77a	70.74a
SEM	±155.17	±103.43	±2.33	±36.91	±33.33	±23.57	±1.76	±3.03
P>F	0.1246	0.3798	0.2561	0.8477	0.0959	0.3962	0.4293	0.2164

a,b. Means within columns with different literals are different (P<0.05*).

Carcass characteristics

Gender did not influence the evaluated characteristics. Trocino *et al*. (2003) indicate that sex influences the weight and parts of the carcass at slaughter when the live weight is greater than 2.5 kg. Barrón *et al*. (2004) indicate that rabbits are slaughtered before puberty with an average weight of 2.1 kg. The results obtained are similar to those reported by Boicoc (2002), who registered a slaughter weight of 1998 g for NZ and 2040 g for CA breeds beds and shows the importance of heterosis in the crossbreeding of rabbits, whose reported weights were 2160 g at the end of fattening in a CA×NZ cross.

In carcass yield, a general average of 55.38% was obtained for all the crosses, higher than the 52% reported by Boicoc (2002) in the progeny of NZ males with CA female crosses.

Regarding carcass parts, the loin and legs are the most economically important, representing 40% of the carcass, of which 16% is the loin and 24% the legs. There were no differences ($P>0.05$) between parental breeds.

CONCLUSIONS

The crosses between NZ parental breed rabbits showed better reproductive performance and viability in litter size at birth and weaning. Offspring from CA parents reported higher birth weights than the offspring from NZ parents. The results on the productive behavior of the CA×NZ cross progeny indicate that they are better when CA is used as the parental breed, with higher weekly weight gain and better feed conversion.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Lactation Curve, Milk Production of Pelibuey Ewes and Preweaning Growth Rate of the Lambs

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ABSTRACT

Objective: To estimate the lactation curve and milk production of Pelibuey ewes and their relationship with preweaning growth rate of the lambs.

Design/Methodology/Approach: Forty-five Pelibuey ewes were milked during 70 days in Montecillo, Mexico, in 2018, to estimate the daily and total milk production. The lactation curve was fitted with the incomplete gamma function. In addition, the effects of type of birth and ewe weight at milking on milk production were analyzed, and correlations were calculated between ewe milk production and growth rate of the lambs, per week and for the entire lactation.

Results: A "typical" lactation curve was found, average ewe milk production for the whole lactation, weighted for the number of lambs suckling, was 131±8 L, with 444±24 g d^{-1}. Ewe weight at milking had an effect ($p<0.01$) on milk production. Positive correlations were found ($p<0.05$) between ewe milk production and preweaning growth rate of the lambs.

Study Limitations/Implications: There is a strong dependency of the lambs on the milk production of the Pelibuey ewe, a factor of great relevance so that lambs can gain body weight and survive during lactation.

Findings/Conclusions: Pelibuey ewes produce less milk than dairy ewes. Therefore, lambs should be weaned at a maximum of 10 weeks of lactation.

Keywords: maternal ability, live weight, lamb survival.

INTRODUCTION

Sheep production in Mexico is an activity that has attained great advances in the productive and commercial aspect because mutton represents an important option for the diet, product that is consumed primarily as a traditional dish known as "barbacoa".

Image by JamesDeMers at Pixabay

The predominant hair breeds in Mexico are Pelibuey and Blackbelly (Hinojosa-Cuéllar *et al.*, 2012). Of these, the most frequently used in Mexico in grazing and mixed systems is Pelibuey, primarily due to its adaptation to various agro-climate environments, which currently is a factor of great consideration because of the climate changes affecting the animals (Núñez-Domínguez *et al.*, 2016; Tsartsianidou *et al.*, 2021), and also due to its characteristics of prolificacy and rusticity (Ramón-Ugalde and Sanginés-García, 2002) and resistance to gastrointestinal nematodes (Zaragoza-Vera *et al.*, 2019). In sheep production systems for meat in grazing without dietary supplementation, the production and quality of the ewe milk is vital for the lambs during the first weeks of life (Peniche *et al.*, 2015), so a strong relationship has been found between the growth rate and the survival of the lambs with milk production (MP) of the ewe during lactation (Afolayan *et al.*, 2009; Naik *et al.*, 2016).

In hair sheep, information about MP and associated characteristics is very limited, for example knowledge about the lactation curve (Adewumi and Olorunnisomo, 2009; Güngör and Atasoy, 2020), as well as the relationship between the ewe's MP and the lambs' daily weight gain (LWG) during the lactation. Understanding the lactation curve is important because it allows the sheep producer to make decisions about animal management, such as monitoring the diet, the health state, discarding animal, which are factors that impact the economy of milk production (Takma *et al.*, 2009; Tekel *et al.*, 2019). In Mexico there are studies carried out in hair sheep (Peniche *et al.*, 2015; Chay-Canul *et al.*, 2019) where the MP was evaluated; however, in these studies the relationship between MP and the lamb's growth rate (LGR) was not determined, and in hair lamb production systems for supply it is important to understand the milk production of the ewes. Therefore, the objectives of this study were: 1) to fit the lactation curve of Pelibuey ewes, 2) to estimate the total and daily milk production of the ewes, 3) to evaluate the effects of the number of lambs suckling and the ewe weight at milking on the MP, and 4) to calculate the correlations between the MP and the LGR, per week and total.

MATERIALS AND METHODS

Location, animals and management

This study was performed in the Sheep and Goat Reproduction Laboratory belonging to Colegio de Postgraduados, Campus Montecillo, located in Montecillo-Texcoco, Estado de México. This place is located in coordinates 19° 29' Latitude North and 98° 53' Longitude West, at 2250 masl. The climate is classified as temperate sub-humid with summer rains (García, 2004).

Forty-five second birth Pelibuey ewes were used with an initial average weight of 49.1±13.6 kg, of which 27 were of single birth and 18 of double birth. The ewes began lambing on May 17, 2018. Since lambing, the ewes were fed with a commercial diet (Table 1) that had 14% raw protein and 2.96 Mcal kg^{-1} digestible energy.

Likewise, they always had access to clean and fresh water. The daily serving was divided into equal parts in the morning and the afternoon, while alfalfa was offered only in the mornings. The health program of the ewes included elimination of gastrointestinal nematodes at the beginning of the study, and sodium Levamisol (Prolevan®) was used in a dose of 1 mL for every 20 kg of live weight; for vaccination against pneumonic pasteurellosis, symptomatic carbon, malign edema, and enterotoxemia, the Vaccine:bobac 8 was used in the last third of gestation in a dose of 2.5 mL per ewe; in addition, 2 mL of the ADE vitamin complex per ewe were used. The ewes started to be milked manually in the mornings (08:00 h) on day five post-lambing to allow the consumption of colostrum by the lambs, and since then every seven days for 10 weeks, with a total of 70 days in lactation. Therefore, the first record of MP was since day 5 post-lambing. In this study three milking sessions were carried out every week at intervals of 2 h each (08:00 to 14:00 h). To measure the MP the double weighting method (DWM) of the lamb was used (Benson *et al.*, 1999), which consists in weighing the lambs before and after suckling to have an estimation of milk produced by the ewe in every session, and later removing through manual milking the residual milk contained in the udder. This measurement was carried out in each session of 6 h and repeated every week during the 10 total weeks of the trial. In the day prior to the first measurement, the lambs were put away in a pen at 18.00 h to separate them from their mothers, although between mothers and lambs sight and smell were possible, but not suckling. The ewes were put away in a separate pen, without considering the type of birth. On the next day, start of the first session, the lambs were allowed to exit their pen to seek their mothers and once they located the ewe their live weight was taken, after which they were allowed to suckle until emptying the udder. Once the lamb was no longer suckling it was weighed again, to therefore have an estimator of the ewe's milk production. This procedure was repeated in the next two sessions and throughout the lactation. The MP of the three sessions was added and the amount of residual milk that corresponded was added to this, thus obtaining an estimator of the MP produced in 6 h. The resulting value was multiplied by four, to have an estimator of the MP produced in 24 h, under the assumption that the amount of milk produced was constant during the day (Cardellino and Benson, 2002). The assumption was also made that this MP measured every week represents the average daily milk production for the week that it was measured (Al Jassim *et al.*, 1999). Milk production of the ewe per week was recorded, and for the whole lactation period.

Statistical procedure

To fit the lactation curve, the incomplete gamma function or Wood's model (Wood, 1967) was used, because its three parameters are linked to the biology of the lactation curve (Portolano *et al.*, 1996), and because it has had good results in milk production studies in ewes (Ángeles Hernández *et al.*, 2014; Nava-García *et al.*, 2019). Fitting the lactation curve was done based on the average of the individual lactation curves, both for the group of ewes with one lamb and with those that had two lambs. The model is: $y_t = at^b\ e^{-ct}$, where: y_t is the milk production in day t, e is the base of the natural logarithm, a, b and c are parameters of the curve, where a represents the milk production at the beginning of the lactation, while *b* and *c* represent the limit decline of the curve before and after the peak of lactation, respectively. With the purpose of analyzing the model linearly, a logarithmic transformation was carried out, and the model resulted as follows: $\log y_t = \log a + b \, log \, t - cn$, after which the parameters *a*, *b*, and *c* were estimated through multiple linear regression. After obtaining parameters *a*, *b*, *c*, according to Nezamidoust *et al*. (2013) and taking the average of all the ewes, the following were obtained: the peak of lactation (PLA) as: $Y_{max} = a(b/c)be - b$, the time until the peak of lactation (TPLA) as: b/c, and the persistence as: $(S) = -(b+1)\ln$ c. Only the value of Y_{max} was obtained with the NLIN procedure of the statistical package SAS (2004).

Then, an analysis of variance was performed using the GLM procedure of SAS (2004) to evaluate the effects that the independent variables can have, such as type of birth of the offspring (single and double) and ewe weight at milking (as covariable) on the dependent variable total MP. Finally, the correlations between MP of the ewe and LGR were calculated, per week and total. It should be clarified that the LGR was used because the weight of the lambs before and after suckling represented an estimator of the ewe's milk production, which was an objective of the study, not the weight gains of the lambs, so they were not weighed for this purpose.

RESULTS AND DISCUSSION

The lactation curves of ewes with one and two lambs are shown in Figure 1. The lactation peaks (maximum milk production) in ewes with one and two lambs were found in the second and third week of lactation, respectively.

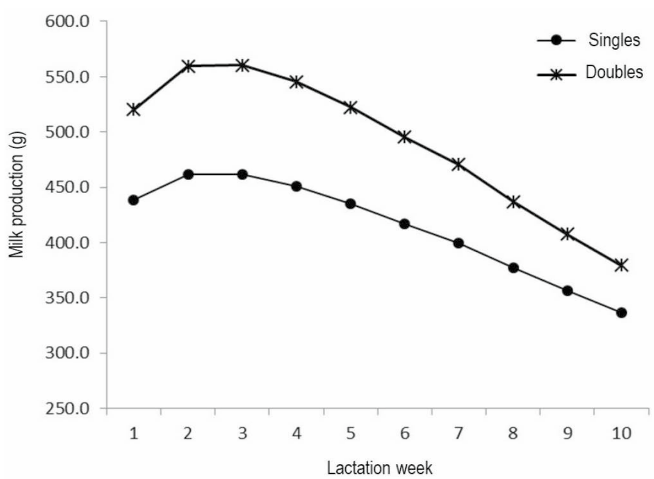

Figure 1. Milk production lactation curve of Pelibuey ewes according to number of lambs suckling.

Table 2 presents the estimated total milk productions for ewes with one and two lambs.

Table 2. Total milk production of Pelibuey ewes (mean ± s.e.), nursing one (n=27) or two (n=18) lambs, total lactation milk production, and daily mean production.

	One lamb	**Two lambs**
Total milk production (liters)	122±1.8a	144±2.2a
Total milk production/ewe (liters)*	131±8	
Mean daily milk production/ewe (g)**	444±24	

*: weighted mean for the number of lambs suckling during the entire lactation (70 days).
**: average for the entire lactation. a: no significant differences (p>0.05).

Table 3 shows the estimators (a, b, c) of the parameters obtained from the lactation curve for ewes with one and two lambs.

Table 3. Parameters (± standard error) of the milk production lactation curve obtained from the Wood model, according to lamb birth type (BT).

Parameter	**a**	**b**	**c**
BT:			
Single	0.44±0.072	0.186±0.021	0.010±0.001
Double	0.53±0.070	0.210±0.022	0.015±0.001

a: milk production at the beginning of lactation, b: limit decline of the curve before the peak of lactation, c: limit decline of the curve after the peak of lactation.

For the entire lactation, the average production per ewe, weighed by the number of lambs suckling, was 131±8 L with an average of 444±24 g d^{-1} (Table 2).

For the whole lactation period, it was found that the ewes that were suckling two lambs produced a similar amount of milk than that produced by ewes that suckled only one lamb (p>0.05, Table 2).

Table 4 shows the PLA values according to the type of birth of the lamb (single, double), of the TPLA, and those of persistence; these did not show significant differences between one another (p>0.05).

Table 4. Lactation peak (LP), time at lactation peak (TLP) and persistency (S), according to ewes of single (n=27) and double (n=18) birth type.

Variable	**LP**	**TLP**	**S**
Birth type:			
Single	409.5a	14.2a	−5.09a
Double	463.4a	16.9a	−5.35a

a: no significant differences (p>0.05).

The weight of the ewe at milking (as covariable) had a significant influence (p<0.01) on the MP; a regression coefficient of $b_{y/x}$=0.026 kg was found, value that indicates that for each kg of live weight gain of the ewe at the time of milking, the MP increased in 26 g.

Finally, Table 5 shows the correlation coefficients between MP and LGR, per week and total.

It can be observed that the correlations were significant, except in the cases of the single birth (week 3), double birth (week 6), and in both types of birth (week 10), this being the last week that corresponds to the date when the ewes were close to drying up. It can also be seen that the magnitude of the correlations shows a tendency to decrease with time, this being more evident in the ewes rearing two lambs.

The average and adjusted lactation curves, both for ewes with one lamb and with those with two lambs, correspond to a "typical" curve, which is characterized by having a gradual increase at the beginning of the lactation until reaching the peak of lactation, followed by a gradual decline until the end of the lactation that corresponds to the type of curve that has been found in other groups of sheep, as in Cuban Pelibuey (Pérez Corría *et al*., 2017) and East Friesian (Ángeles Hernández *et al*., 2018). The time until the peak of lactation in this study agrees with the results obtained by Benson *et al*. (1999) in Suffolk ewes using also the DWM, and with those by Cardellino and Benson (2002) in ewes milked through mechanical milking. However, it differs from the results by Peniche *et al*. (2015), Allah *et al*. (2011), and Peralta-Lailson *et al*. (2005) in terms of the dates of time until the peak of lactation, since in these studies the dates were weeks seven, five and one, respectively. These differences regarding the of type of lactation and date of the time until the peak of lactation is attributed mainly to the effects of the genotype of the ewe and management practices, as found by Aboul-Naga *et al*. (1981) when comparing three sub-tropical non-dairy sheep breeds. Peralta-Lailson *et al*. (2005) in Mexico's Chiapas sheep of the black, white, and brown varieties, concluded that another factor that can influence the lactation curve is the selection effect.

Table 5. Phenotypic correlations between ewe milk production and growth rate of lambs (per week and total), according to lamb birth type (BT).

	BT	
Week	**Single**	**Double**
1	0.68**	0.73**
2	0.53**	0.61**
3	0.32^{ns}	0.58**
4	0.67**	0.62**
5	0.58**	0.47**
6	0.50**	0.31^{ns}
7	0.47**	0.52**
8	0.54**	0.58**
9	0.43**	0.48**
10	0.32^{ns}	0.28^{ns}
Total	0.68**	0.75**

*: p<0.05, **: p<0.01), ^{ns}: non-significant (p>0.05).

Afolayan *et al*. (2002) also found that the parameters *a*, *b*, and *c* were higher in ewes with two lambs, which suggests that the number of lambs suckled by the ewe has an important influence on the MP, which has been found before in other sheep breeds (Snowder and Glimp, 1991). On the other hand, Afolayan *et al*. (2002) mentioned that the parameters *b* and *c* are the ones responsible for shaping the lactation curve. In Mexico's Chiapas sheep, Peralta-Lailson *et al*. (2005) used Wood's model, and they found that Creole Chiapas ewes of the white and brown varieties had atypical lactation curves, which is attributed to the values of parameters *b* and *c*. Some estimators of the parameters of Wood's model that have been estimated in dairy ewes are a=0.979, b=0.071, c=0.009 (Ángeles-Hernández *et al*., 2013), a=1,333, b=0.3, c=0.092 (Miguel *et al*., 2016); in these studies, the magnitude of parameter a standout, which represents milk production at the beginning of the lactation, indicating specialized breeds in milk production.

Estimators of daily averages of MP that have been obtained in hair ewes are: 131 g in Mexico Pelibuey ewes (Castellanos Ruelas and Valencia-Zarazúa, 1982); 1.43 and 1.77 kg in Mexico Pelibuey and Katahdin ewes, respectively (Chay-Canul *et al*., 2019); 123 and 173 g in Blackbelly and St. Croix ewes, respectively (Godfrey *et al*., 1997); 1,200 g in Martinik ewes (Ortega-Jiménez *et al*., 2005); 1,400 g in Santa Inés ewes (Araujo *et al*., 2008). According to Godfrey *et al*. (1997) and Robles-Jiménez *et al*. (2020), the differences in daily milk production can be attributed mainly to the genotype of the ewe and management practices, although Aboul-Naga *et al*. (1981) and Peralta-Lailson *et al*. (2005) also include the selection effect.

Most studies indicate that ewes with two lambs produce more milk than those with only one (Cardellino and Benson, 2002; Morgan *et al*., 2006), and it has been mentioned that the ewes that carry more than one offspring have a higher concentration of serum progesterone and a high volume of the placenta, producing an increase in placental lactogen, thus stimulating the development of the mammary gland during gestation and before lambing, which in turn provokes an increase in MP (Ochoa-Cordero *et al*., 2007; Adegoke *et al*., 2015). Other factors, such as the histo-morphological characteristics of the udder can also affect the MP in ewes (Murawski *et al*., 2019). The lack of differences in MP between ewes with one lamb and ewes with two lambs could be attributed to the size of the sample used in this study.

Heavier ewes generally produce more milk than those of lower body weight (van der Linden *et al*., 2009) and an influence has been found ($p<0.01$) of the ewe weight at the time of birth on the MP (Ángeles Hernández *et al*., 2018), and in genetic improvement programs the body weight of the ewe is used as a selection criterion to increase milk production (Mavrogenis and Papachristoforou, 2000). In the literature, no studies were found where the effect of the ewe weight at the time of milking on the MP has been analyzed. In this study it was decided to measure the ewe weight at milking during the 10 weeks due precisely to its proximity to the moment of milking; however, an inconvenience of this procedure could be the stress and management to which ewes are subjected, whose effect was not quantified in this study.

Godfrey *et al*. (1997) found a correlation of $r=0.37$ ($p<0.0001$) in St. Croix ewes between pre-weaning LWG of the lambs and MP of the ewe measured by the oxytocin method; however, in Blackbelly ewes from the same study the correlation (r=0.17) was not significant (p>0.10). Using the lamb's DWM to measure MP in wool ewes, Snowder and Glimp (1991) and Benson *et al*. (1999) mention positive correlations (p<0.05) between MP of the mother and pre-weaning LWG of the lambs. In the study by Benson *et al*. (1999), the correlation between pre-weaning LWG of the lambs and MP of the mother throughout the lactation (63 days) was r=0.60 (p<0.03), indicating in this study the strong dependence of the lambs on the mother's milk to gain weight and survive, since the lambs did not have access to solid food during the entire lactation. Snowder and Glimp (1991) mentioned in their study that the decreasing value of the correlations as the lactation advanced indicates that in lambs the dependency on milk for their growth decreases.

CONCLUSIONS

Pelibuey ewes show a typical lactation curve, characterized by a gradual increase in milk production until reaching a peak, followed by a gradual decrease until the end of the lactation. Milk production during the entire lactation was 131±8 L, with a daily average of 444±24 g. There were no differences (p>0.05) in milk production between ewes suckling one or two lambs in the whole lactation. The weight of the ewe at milking (as covariable) had an effect (p<0.01) on milk production; for every kg of the ewe's weight increase at milking, the milk production increased in 26 g. For the entire lactation, positive correlations were obtained (p<0.01) between total milk production and growth rate of the lambs.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Defecation rates of white-tailed deer (*Odocoileus virginianus*) based on fiber content in feces

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ABSTRACT

Objective: To develop three models to estimate the defecation rate of white-tailed deer (*Odocoileus virginianus*) according to the season of the year, content of neutral detergent fiber (NDF), and acid detergent fiber (ADF) in their feces.

Design/methodology/approach: Nine captive adult deer were assigned to three levels of dietary fiber. Fecal groups (defecation rate) were counted, forage consumption estimated, and feces were analyzed for their NDF and ADF content. A randomized block design was used, where the effect of the treatments was blocked by season, and a multiple regression analysis was used to define prediction models of the defecation rates.

Results: The defecation rates were different for dietary fiber levels ($P<0.0001$), and for the year season ($P=0.0007$). For spring, the defecation rate model (DR) was $DR=-4.84696-[0.02159\ (NDF)]+[0.58397\ (ADF)]$; for summer $DR=-51.0272+[0.26868\ (NDF)]+[1.61121\ (ADF)]$; and for winter $DR=7.82939-[0.02667\ (NDF)]+[0.17309\ (ADF)]$.

Limitations/implications: Defecation rate or fecal group counting is a useful tool to estimate deer populations. Nevertheless, the definition of an adequate defecation rate represents a hard task, since it depends on multiple factors such as environmental conditions and the components of the deer's diet.

Findings/conclusions: The defecation rate varies depending on the year season and the fiber content in the diet.

Keywords: Wild fauna; deer; fecal groups; intake; fiber; population.

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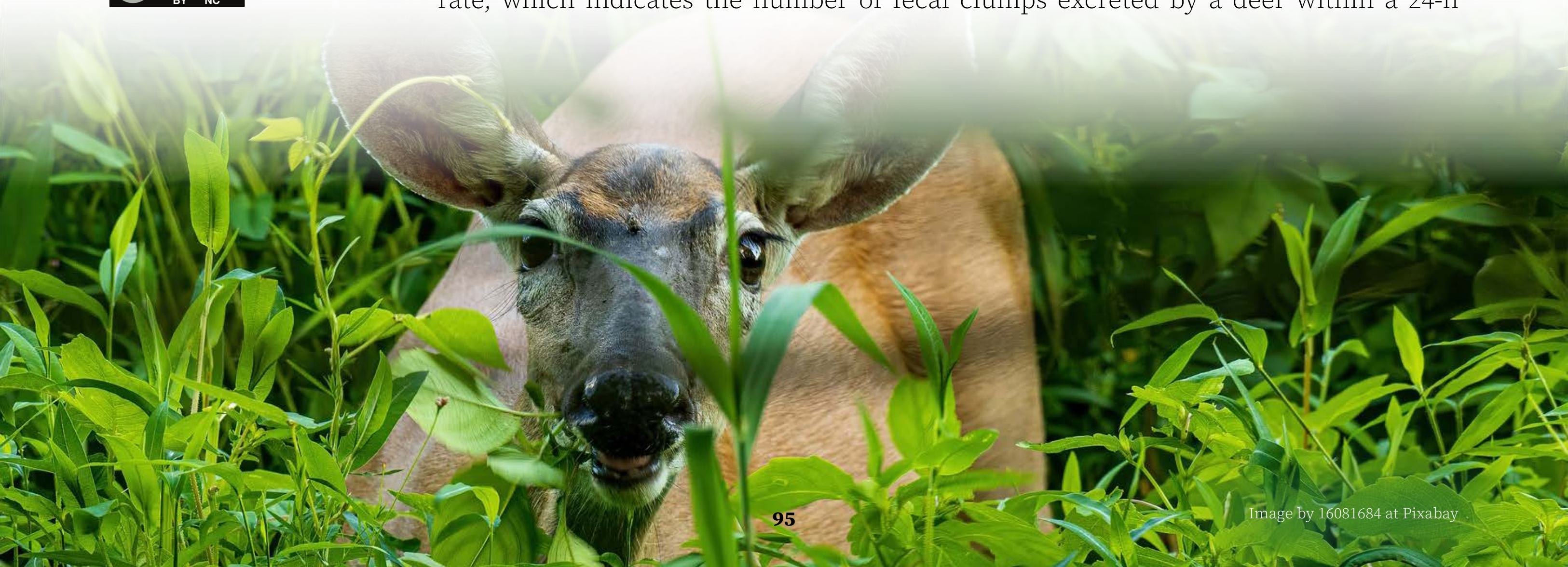
INTRODUCTION

Fecal clump counting is a component of a method frequently used to estimate deer populations in temperate and tropical forests. This method involves using defecation rate, which indicates the number of fecal clumps excreted by a deer within a 24-h



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period (Bennett *et al.*, 1940; Forsyth *et al.*, 2005; Portillo *et al.*, 2010). Usually, defecation rates are applied to similar vegetation types where a deer population is to be estimated (Mandujano and Gallina, 1995; Beltrán-Vera and Díaz de la Vega, 2010). However, there is a large reported variation of the defecation rates which could be used (Van Etten and Bennett, 1965; Ryel, 1971; Rogers, 1987; Fuller, 1991; Härkönen and Heikkilä, 1999). The incorrect selection of a defecation rate may lead to erroneous estimates of the population density and is consequently a misleading factor in a management strategy.

Cellulose is the main polysaccharide in the cell wall of forages, and lignin is an integral component. The undigested fiber portion passes through the digestive tract and contributes to rumen filling (Moore and Jung, 2001). Van Soest *et al.* (1991) developed analytical methods to determine neutral detergent fiber (NDF), which is only partially digestible. Acid detergent fiber (ADF) residues include hemicellulose, protein, lignin and nitrogen combined with silica and pectins (Church *et al.*, 2001). The NDF and ADF determination in forage and feces is useful since both are highly correlated with digestibility and defecation rates (McDonald *et al.*, 2006). The objective of this research was to estimate defecation rates of white-tailed deer for their fecal NDF and ADF content, by developing models for different seasons of the year. This is a pioneering study given there are no publications on using diet components and their consumption across seasons in estimating defecation rates. The published research on defecation rates only refers to counting the number of fecal groups that a deer defecates in a 24-hour period, which is what motivated the development of the present study, involving factors specific to the feed that explain the variation and definition of defecation rates.

MATERIALS AND METHODS

The research took place in the Altiplano Potosino, Mexico, 22° 34’ 53.9” N and 103° 38’ 41.3” W, with an annual rainfall of 400 to 500 mm. The research was conducted in the Experimental Station “La Huerta” of the Colegio de Postgraduados, Campus San Luis Potosí, from December (winter) to September (summer). Nine white-tailed deer adults (one male and two females per treatment) born in captivity, were confined in individual pens (20 m × 10 m each), pre-adapted to three different diets, used as treatments (low fiber, medium fiber, and high fiber content). Three white-tailed deer (*Odocoileus virginianus*) were randomly assigned to each treatment (Table 1).

The assessed variables in diets as well as in the deer feces were the dry matter consumption, number of fecal groups, dry matter (DM), NDF, ADF, crude protein (CP), organic matter (OM) and lignin content.

Dry matter consumption. Forage was weighed and accessible *ad libitum* to each deer; the food rejected was weighed 24 hours after it was offered. Once a month, the consumption was calculated by the weight difference. The daily consumption of dry matter was estimated based on the DM content in the diet, according to the result of the chemical analysis of the diet.

Table 1. Ingredients, chemical composition and fiber content of three diets used as treatments to test the effect on consumption and defecation rates in white-tailed deer.

Treatments	Ingredients in diet	Chemical composition					
		DM %	Ashes %	CP %	NDF %	ADF %	Lignin %
Low fiber level	100% commercial food (Trophy Maker®)	92.25	6.21	20.51	33.11	10.84	2.82
Midium fiber level	70% commercial food (Trophy Maker®) and 30% ground alfalfa	98.47	7.06	19.78	42.13	17.11	6.26
High fiber level	30% commercial food (Trophy Maker®) and 70% ground alfalfa	98.18	9.12	18.65	48.39	24.93	5.05

DM=dry matter; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber.

Defecation rate. Each deer was under direct observation once a week for a continuous 24-hour period from December to September. All the times a deer defecated were recorded. At the end of 24 hours, all fecal groups were collected to verify that the total was equal to the number of fecal groups obtained by direct observation. Verification was possible because individual pens were cleaned removing all accumulated fecal groups before the continuous 24 hours of observation. All the collected fecal groups were dried in a forced-air oven at 55 °C and ground in a Wiley mill with a 1 mm mesh for their chemical analysis.

Chemical analysis. From the total fecal groups collected, a sample (n = 200) was used for laboratory analysis, as well as another similar sample for the analysis of the diets. In the laboratory, The DM, OM, CP and ash content were determined in the laboratory, following the procedures of the AOAC (2005). The NDF, ADF and lignin contents were analyzed following the procedures described by Van Soest *et al*. (1991).

Statistical analysis. To assess the effect of the fiber level on food intake and the defecation rate during spring, summer and winter, an ANOVA was carried out under a randomized complete block design, where the treatments corresponded to the three fiber levels in diets, blocked by the three seasons considered in this research. Once the season and fiber level were determined to be factors that defined forage intake and defecation rate, defecation rate models were constructed using multiple regression analysis for both NDF and ADF in feces and its corresponding rate of defecation. The statistical analyses were performed using the SAS statistical software (v. 9.0).

RESULTS AND DISCUSSION

Daily DM intake ranged from 0.37 to 2.14 kg per deer. Feed intake was affected ($P=0.0006$) by the dietary fiber level and by the season ($P<0.0001$). The lowest DM intake occurred in winter (0.37 kg), the highest in summer (2.14 kg). Deer consuming the low-fiber diet averaged 1.01 kg (±0.41) of DM intake, while the medium-fiber diet averaged 1.09 kg (±0.28), the high-fiber diet averaged 0.85 kg (±0.21). The range of feed intake reported by Short *et al*. (1969) was 0.47 to 0.98 kg, while Ruggiero and James

(1976) reported daily intakes of 1.03 kg (±0.14) and 1.78 kg (±0.37) for males. Holter *et al*. (1977) reported the season effect on food intake and body weight in white-tailed deer, and detected a reduction in forage intake during winter, increasing in spring and summer. Differences in food intake throughout the year are determined by behavioral mechanisms and morphological and physiological changes related to photoperiod at varying endocrine levels (Bailey and Brown, 2011), as well as other factors such as digestive disorders, feeding frequency, forage processing, diet-associated effects, environmental factors, and the ability of different species to digest a particular forage, especially high-fiber forage (Church *et al*., 2001).

The effect of dietary fiber level on the defecation rate showed a difference ($P<0.0001$), as well as between seasons ($P=0.0007$). The average daily defecation rate for deer consuming low fiber was 10 fecal clumps (±3.48), while for deer consuming a medium fiber diet it was 16 clumps (±4.70), and for the high fiber diet, the defecation rate was 15 (±4.18). At the end of summer, vegetation begins to decrease in its nutritional quality (Clemente *et al*., 2005; Dostaler *et al*., 2011). Then, deer show changes in DM intake as the amount of dietary fiber varies, because, as forage matures, its digestibility, protein, mineral, and soluble carbohydrate content decreases, while cell wall constituents increase (Vangilder *et al*., 1982). Johnson *et al*. (1998) found a linear reduction in protein and OM as well as NDF and ADF as the diet increased. Similar information in other grazing ruminants has been reported, where NDF and DM also increased as the season progressed, and because shrubs are more lignified in winter, defecation rates and feed passage significantly decreased (Rogers, 1987). Our results show that during spring the defecation rate was 14 (±4.82), in summer 15 (±4.26) and 12 (±4.85) in winter.

Results to determine the relationship between fiber content and defecation rate showed that the NDF percentage in feces ranged from 47.01% to 70.22%, ($\bar{}$=55.91%) (±4.02). Neutral detergent fiber in feces increased ($p<0.0001$) as dietary fiber level increased. Neutral detergent fiber found in the feces with low fiber diet was 54.11% (±3.50), while for medium fiber diet, 57.51% (±4.15) and 57.40% (±2.92) for high fiber diet. Acid detergent fiber also showed differences ($P<0.0001$) according to the dietary fiber levels. Acid detergent fiber in fecal groups with low fiber diet averaged 27.42% (±2.02), while with medium fiber diet 33.86% (±3.17) and 36.51% (±1.92) for high fiber diet. The forage intake level affects the defecation rate in deer, and the type of forage affects forage intake (Smith, 1964). Showers *et al*. (2006) reported that in white-tailed deer with high fiber digestibility levels, feed intake decreases, and with low digestibility, DM intake increases. The negative relationship between NDF and feed intake indicates that at low forage intake in the digestive tract, the filling capacity has been reached (Gray and Sarvello, 1995). This is confirmed in this study, because as fiber increased in the diet, feed intake decreased, confirming significant changes in the seasonal defecation rate. Rogers (1987) found a defecation rate increase in white-tailed deer during spring and summer seasons, and lower values during winter. In this regard, Van Etten and Bennett (1965) observed differences in the total number of deer fecal groups collected in different seasons, reporting 869 fecal groups in spring and 682 groups in autumn. Sawyer *et al*. (1990) estimated an average defecation rate of 12 fecal groups, which increased to 34 in the fall. In other studies, Perez *et al*. (2006) found a high coefficient of variation in the number of fecal groups for white-tailed deer; daily fecal groups ranged from 8 to 25 and from 5 to 28.

In this research we found that fiber and season were the main factors affecting the defecation rate. To estimate the defecation rate (DR), multiple regression analysis provided three prediction models. For spring the model was DR=−4.84696−[0.02159 (NDF)]+[0.58397 (ADF)]; for summer, the model was DR=−51.0272+[0.26868 (NDF)]+[1.61121 (ADF)]; and for winter the model was DR=7.82939−[0.02667 (NDF)]+[0.17309 (ADF)] (Table 2).

Table 2. Prediction equations of defecation rates (DR) of white-tailed deer, from the contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) in feces.

Prediction equation	r^2	Season of the year
DR=−4.84696−[0.02159 (NDF)]+[0.58397 (ADF)]	0.91	Spring
DR=−51.0272+[0.26868 (NDF)]+[1.61121 (ADF)]	0.89	Summer
DR=7.82939−[0.02667 (NDF)]+[0.17309 (ADF)]	0.87	Winter

DR=defecation rate; NDF=percentage of neutral detergent fiber in feces; ADF=percent of acid detergent fiber in feces.

The models developed in this study can be applied by wildlife managers in other study areas under different ecological conditions since changes in defecation rates directly relates to dietary fiber contents, which are affected by changes in the botanical composition of the intake and by different environmental conditions in the ecosystems. Therefore, our results support the hypothesis that the defecation rate of white-tailed deer differs according to the season of recollection of fecal groups and their fiber contents. Season and rainfall are indirect factors affecting the defecation rate. The physiological state of a plant is highly correlated with its fiber content, and it determines the consumption level and, therefore, the rate of defecation.

CONCLUSIONS

Food intake in white-tailed deer seasonally varies according to dietary fiber content, due to the dietary variation resulting from changes in the climatic conditions, leading to changes in defecation rate. The defecation rate of white-tailed deer in winter significantly decreases due to lower forage intake. Defecation rate can be predicted for a particular season in areas where fresh fecal clumps are collected based on NDF and ADF content, regardless of habitat type. The models for predicting defecation rate in white-tailed deer obtained in this research are a tool to reduce error in estimating wild population densities.

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AP AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Andrological characteristics of tropical milking criollo Bulls

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ABSTRACT

Objective: To assess the testicular and semen characteristics of Tropical Milking Criollo (CLT) bulls in the subhumid Mexican tropics.

Design/methodology/approach: Eight bulls were evaluated and distributed in two groups: G1 (n=5): young bulls and G2 (n=3): adult bulls. All bulls were managed under grazing and evaluated throughout a year. From each bull, the following measurements were taken once a month: live weight, body condition score, scrotal circumference, and testicular width, length and volume. Semen was obtained every 3 months via an artificial vagina. The evaluated semen variables were: aspect, volume, mass and individual motility, and sperm concentration and morphology.

Results: Live weight and testicular measurements linearly increased during the study in bulls from both groups. All bulls had a scrotal circumference larger than the minimum threshold value for cattle and high-quality semen.

Study limitations/implications: The low availability of CLT bulls prevented the inclusion of a larger number of animals in the research. This low animal availability makes it necessary to establish standard values for testicular measurements and semen characteristics in the CLT breed in order to select the best individuals as sires and contribute to its conservation.

Findings/conclusions: The CLT bulls had good scrotal circumference and semen quality from a young age and into adulthood. These traits make CLT bulls an important alternative for livestock breeding in the tropics.

Keywords: Semen quality, scrotal circumference, semen.

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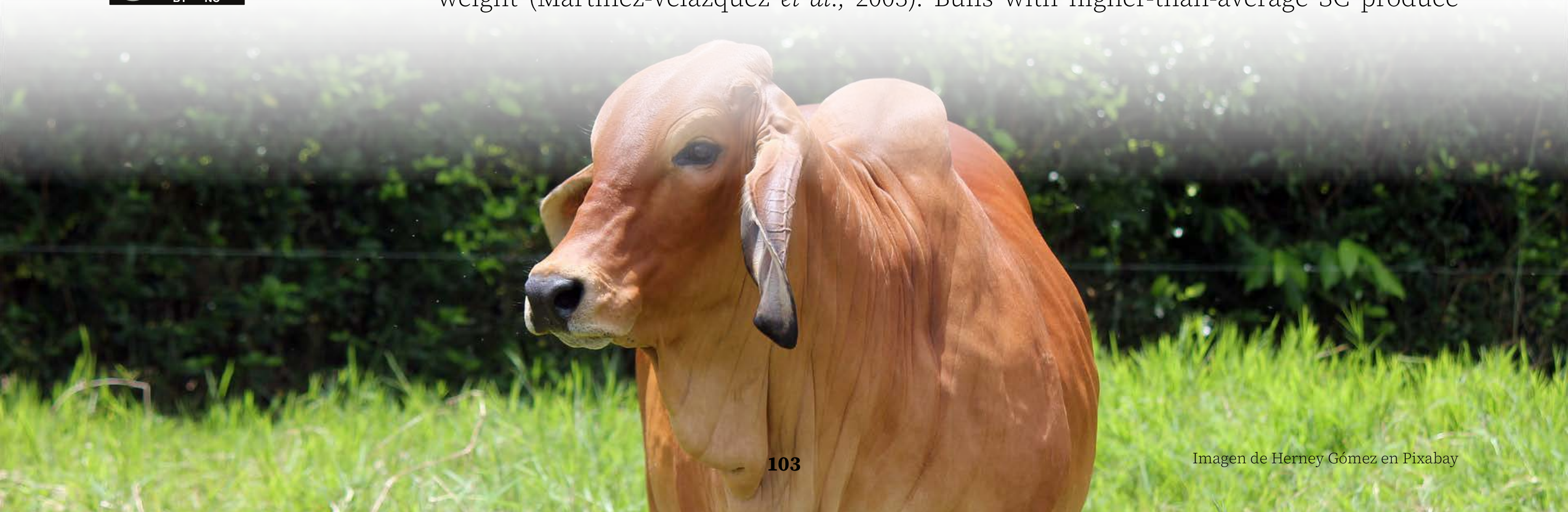
INTRODUCTION

The testicular measurements and semen quality evaluation are essential in the assessment of the fertility of bulls. Out of the testicular measurements, the scrotal circumference (SC) is the most used, given its easy measurement, high repeatability, and high correlation with sperm concentration, semen quality, testicular size, and body weight (Martínez-Velazquez *et al.*, 2003). Bulls with higher-than-average SC produce



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more semen, of better quality and reach puberty earlier (Silva *et al.*, 2012). The live weight of the animal is positively correlated to the testicular weight, which in turn, has a high correlation with the amount of spermatic tissue and with the SC, so the SC is the basis for estimating the testicular size and selecting sires (Silva *et al.*, 2012).

The populations of Tropical Milking Criollo cattle (CLT; *Bos taurus taurus*) are scarce and distributed only in certain tropical regions of Mexico (De Alba, 2011; Parra-Cortés and Magaña-Magaña, 2019). This breed is characterized by its precocity, high fertility, ease of calving, survival, resistance to diseases and ectoparasites, and longevity (De Alba, 2011; Rosendo-Ponce and Becerril-Pérez, 2015). However, little has been documented on the andrological characteristics of males in warm climate conditions; this is necessary to select specimens to increase their population or for crossbreeding schemes with European or Zebu breeds in the tropics, which would improve their profitability and the sustainability of the cattle herds in these regions (Parra-Cortés and Magaña-Magaña, 2019).

Although reproductive traits have been characterized in males from *B. taurus taurus* breeds in the Latin American tropics (Palmieri *et al.*, 2004; Madrid-Bury *et al.*, 2011), there is no information on the CLT breed, despite its importance as a dairy genotype adapted to the tropics. Therefore, the objective of this research was to assess the testicular and seminal characteristics of CLT males in the subhumid Mexican tropics.

MATERIALS AND METHODS

Geographical location and characteristics of the study

The research was conducted in a CLT cattle herd owned by the Colegio de Postgraduados, Campus Veracruz, located in the state of Veracruz, Mexico, on the central coast of the Gulf of Mexico, at latitude 19° 16’ N and longitude 96° 16’ W, at 20 m altitude, with a warm sub-humid climate, mean annual temperature of 26.5 °C and annual precipitation of 1 230 mm. The study was conducted over one year and included four periods: 1=September 22 to December 20, 2=December 21 to March 19, 3=March 20 to June 20, and 4=June 21 to September 21.

Experimental animals and management

Eight bulls were selected from a group of 14 CLT males, which had no sight, limbs, or reproductive problems that could affect the results of the study. The bulls were distributed in two groups according to their age: G1 (n=5): young males that at the beginning of the study were 19.3±0.4 months old, weighed 260±9 kg (live weight, LW) and had body condition (BC) from 2.5 to 3.0 on a scale of 1 to 5 (1=emaciated and 5=obese; Wildman *et al.*, 1982); and G2 (n=3): adult males at 30.5±3.1 months old, weighing 371±29 kg LW and with BC similar to G1. The animals grazed in paddocks of *Megathyrsus maximum*, *Brachiaria mutica*, *Cynodon nlemfluensis*, and *Paspalum* spp., at a stocking rate of 2 AU ha^{-1}, and did not receive feed or mineral supplementation. All males were kept together, and none had been used as sire.

Live weight and body condition

The LW of each animal was recorded at the beginning of the study and subsequently every 30 d for one year. The weighing was done on a commercial cattle scale, and the BC was visually evaluated by the same technician, using the scale from 1 to 5 described above.

Testicular characteristics

The scrotal circumference (SC), testicular width (TW), testicular length (TL), testicular volume (TV) and testicular consistency (TC) were measured in all animals at the beginning of the study and every 30 d thereafter. Scrotal circumference was measured with a scrotal tape measure; TW and TL were measured in each testicle using a vernier; and TV was calculated with the TW and TL measurements using the equation $TV = 0.5236\ (TW)\ (TL)^2$ (Bailey *et al.*, 1996). The TC was assessed by palpation of each testis, which were graded as firm or soft, and testicular tone was graded as elastic, flaccid or rigid.

Seminal characteristics

Every three months, a semen sample was collected from each animal with an artificial vagina. For semen collection, the bull was placed with a cow previously synchronized with $PGF_2\alpha$ (20 mg dose of Lutalyse®, Lab. Zoetis, USA) during the same days of the evaluation of testicular characteristics. Immediately after collection, semen volume was determined by direct observation in the collection tube, and mass (MM) and individual (IM) sperm motility were determined. To establish MM, a 10 μL semen drop was placed on a slide pre-warmed to 37 °C, observed under a phase-contrast microscope (10x and 40x) and assigned a value from 0 to 100%. To determine the IM, a 10 μL drop of semen was placed between a prewarmed slide and coverslip at 37 °C, observed for progressive rectilinear motility with phase-contrast microscopy (10x and 40x) and assigned a value from 0 to 100%. The spermatozoa concentration (SC) in the ejaculate was determined with a hemocytometer, for which 10 μL of semen were diluted in 2 mL of formol saline solution; then, two chambers of the hemocytometer were filled and the number of spermatozoa present in five large squares in each chamber was counted using a phase-contrast microscope (40x); the total number of cells counted was multiplied by 10^6 to obtain the number of spermatozoa per milliliter of semen. To determine sperm morphology, 20 μL of semen were diluted in 1 mL of formalin-saline solution and analyzed following the criteria by Blom (1973), using a phase-contrast microscope (1000x); 400 cells were evaluated, and the percentage of abnormal cells recorded.

Statistical analysis

Descriptive statistics were used to characterize the evaluated variables. For testicular (SC and VT) and seminal characteristics (volume, MM, IM, SC and abnormal spermatozoa) descriptive statistics were performed and mean comparisons were made using Tukey's tests when significant F tests were detected ($P < 0.05$).

RESULTS AND DISCUSSION

Changes in body weight and body condition

Weight increased in both groups of bulls and all maintained body condition from 2.0 to 2.5 (Table 1). At the end of the study, G1 bulls weighed 362.8±13.4 kg and G2 bulls weighed 451.3±22.2 kg; during the study, G1 bulls gained 103.1 kg and G2 bulls 80.2 kg.

The weight changes observed in the G2 bulls suggest a stabilization of the growth and weight of the CLT bulls between 36- and 42-months age, as suggested for other breeds, depending on their management (Vásquez and Arango, 2002). This will be necessary to verify in future studies with a larger number of animals.

Table 1. Age, live weight, and body condition of young (G1) and mature (G2) Tropical Milking Criollo bulls throughout the seasons.

Group	Time periods			
	1	2	3	4
Age (months)*				
G1	19.3±0.4	21.6±0.2	24.8±0.4	27.8±0.4
G2	30.5±3.1	33.3±3.1	36.5±3.1	39.2±3.1
Live weight (kg)*				
G1	260±9	266±9	285±16	363±13
G2	371±29	365±45	377±67	450±42
Body condition				
G1	2.5	2.5	2.0	2.5
G2	2.5	2.5	2.5	2.5

*Mean ± standard deviation. 1=September 22 to December 20, 2=December 21 to March 19, 3=March 20 to June 20, 4=July 21 to September 21.

Testicular characteristics

Upon palpation, all bulls had testes of firm consistency and elastic tone in all evaluations, indicating good testicular consistency. The SC linearly increased during the study in both groups, which can be attributed to weight gain and age (Table 2). An increase in SC has been reported as age advances in Zebu (Torres-Junior and Henry, 2005) and European breeds (Jiménez-Severiano, 2002).

It was also observed that at 24.8±0.4 months of age, the G1 bulls had a SC of 31.5±0.5 cm, slightly lower than the 32 cm suggested as a minimum for bulls of criollo breeds at the age of 24 m (Irons *et al*., 2007). In this regard, it is worth mentioning that the bulls used in this study are genetically small in body size, and their diet was based on low nutritional quality grass without supplement, which probably affected the SC.

The SC of the evaluated bulls at different ages was comparable to that of the horned Costeño, Romosinuano (Palmieri *et al*., 2004) and Guzerat (Torres-Junior and Henry, 2005) bulls, the latter with greater weight than the CLT and the Criollo Limonero (Ocanto *et al*., 1991; Madrid *et al*., 1995). However, the SC in CLT bulls was lower than that of *Bos taurus indicus* × *Bos taurus taurus* bulls (Prieto *et al*., 2007), with higher body weight than the CLT.

Table 2. Testicle measures of young (G1) and mature (G2) Tropical Milking Criollo bulls, throughout the seasons.

Group	Time periods			
	1	2	3	4
Scrotal circumference (mm)*				
G1	29.1±0.7^{d}	30.5±0.2^{c}	31.5±0.5^{b}	32.9±0.2^{a}
G2	32.0±1.0^{d}	32.8±0.7^{c}	33.2±0.7^{b}	34.9±0.5^{a}
Scrotal width (cm)*				
G1	6.1±0.3	6.7±0.2	7.1±0.2	7.5±0.2
G2	7.2±0.2	7.6±0.6	7.8±0.4	8.0±0.4
Scrotal length (cm)*				
G1	9.7±0.4	9.9±0.4	10.3±0.3	10.2±0.4
G2	10.5±0.7	11.1±0.5	11.3±0.5	11.5±0.4
Testicle volume (cm^3)*				
G1	373±22^{b}	426±17^{b}	529±26^{a}	567±34^{a}
G2	585±44^{b}	685±43^{a}	708±37^{a}	724±31^{a}

^{a,b,c,d} Means having different superscript letter within a row differed ($p<0.05$).
*Mean ± Standard deviation. 1=September 22 to December 20, 2=December 21 to March 19, 3=March 20 to June 20, 4=July 21 to September 21.

Racial differences have been noted that cause some *Bos taurus taurus* breeds to reach puberty at a younger age, lower weight and smaller SC than others. It has been proposed that males should be evaluated according to a minimum SC standard for the breed and not according to the one established by the Society for Theriogenology (Coulter *et al.*, 1987). This could be applied to this study, that is, to establish a SC standard for the CLT breed in particular, because they are smaller in size and weight less than most *B. taurus taurus* breeds.

Like the SC, TW and TL also increased linearly throughout the evaluation in all animals (Table 2). The TW was higher in comparison to Guzerat bulls (Torres-Junior and Henry, 2005); TL was higher than that of Guzerat bulls (Torres-Junior and Henry, 2005) and lower than that of *B. taurus indicus* × *B. taurus taurus* bulls (Prieto *et al.*, 2007). The TV was lower in comparison to Guzerat bulls (Torres-Junior and Henry, 2005).

Seminal characteristics

Ejaculate volume and seminal concentration significantly increased until the last evaluation (Table 3), which was when the bulls were one year older. The greatest ejaculate volume (EV) observed in both groups of bulls was similar to that of Holstein bulls in temperate climates (Brockettt *et al.*, 1994) and *B. taurus indicus* × *B. taurus taurus* bulls (Prieto *et al.*, 2007), and was higher than that of Criollo Limonero (Madrid *et al.*, 1995), horned Costeño, and Romosinuano (Palmieri *et al.*, 2004) bulls.

Spermatozoa concentration in CLT bulls was similar to that of Holstein bulls in a temperate climate (Brockettt *et al.*, 1994) and Criollo Limonero bulls (Madrid *et al.*, 1995) in a tropical climate, although it was lower than that of horned Costeño and

Romosinuano (Palmieri *et al.*, 2004) bulls, also in a tropical climate. Although the semen appearance coincided with that of this last study, the highest concentration of spermatozoa obtained in CLT bulls was around 1 billion mL^{-1}, while in horned Costeño and Romosinuano (Palmieri *et al.*, 2004) it was 1600 million mL^{-1}.

Table 3. Semen characteristics of young (G1) and mature (G2) Tropical Milking Criollo bulls during the study.

Group	Time periods			
	1	2	3	4
Semen volume (mL)*				
G1	3.4 ± 0.2^{b}	3.8 ± 0.4^{b}	3.3 ± 0.4^{b}	4.7 ± 0.6^{a}
G2	3.8 ± 0.6^{b}	4.0 ± 0.1^{b}	5.5 ± 0.8^{a}	6.5 ± 1.4^{a}
Total sperm count ($x10^{6}$ mL^{-1})*				
G1	560 ± 112^{b}	586 ± 103^{b}	714 ± 56^{b}	974 ± 110^{a}
G2	667 ± 16^{b}	667 ± 167^{b}	747 ± 167^{b}	$1\,000\pm312^{a}$
Mass motility (%)*				
G1	88±2	88±2	88±2	84±4
G2	80±2	80±2	80±2	70±10
Individual motility (%)*				
G1	88±2	88±2	88±2	84±4
G2	80±2	80±2	80±2	70±10
Abnormal sperm (%)*				
G1	-	12.0 ± 1.2^{a}	13.4 ± 0.9^{a}	6.6 ± 0.7^{b}
G2	-	13.3 ± 1.7^{a}	16.3 ± 0.9^{a}	3.7 ± 0.3^{b}

a,b Means having different superscript letter within a row differed ($p<0.05$). * Mean ± Standard deviation. 1=September 22 to December 20, 2=December 21 to March 19, 3=March 20 to June 20, 4=July 21 to September 21.

The MM and IM were high in CLT bulls from 19.3±0.4 months of age, contrary to reports that indicate that progressive motility gradually increases with age (Torres-Júnior and Henry, 2005). The results indicate that CLT bulls show high MM and IM since a young age, which are maintained at least until 39.2±3.1 months of age. In CLT bulls IM was higher than that reported in Criollo Limonero (Madrid *et al.*, 1995), horned Costeño, Romosinuano (Palmieri *et al.*, 2004), Guzerat (Torres-Júnior and Henry, 2005), and *B. taurus indicus* × *B. taurus taurus* (Prieto *et al.*, 2007) bulls.

The AE percentage in both groups of CLT bulls was less than 30 %, a value established as a minimum by the Society of Theriogenology. The AE percentage decreases as age increases (Torres-Júnior and Henry, 2005). The percentage of AE in young CLT bulls at 19.3±0.4 months of age was similar to that obtained at similar ages in Criollo Limonero (Madrid *et al.*, 1995), and lower than that of horned Costeño, Romosinuano (Palmieri *et al.*, 2004), and *B. taurus indicus* × *B. taurus taurus* (Prieto *et al.*, 2007) bulls.

It is important to know the reproductive characteristics of the criollo breeds, in particular the CLT, in order to select the best specimens to be used to improve and increase the number of individuals of their breed, or in crossbreeding schemes with

European or Zebu breeds in the tropics, to increase the profitability of the cattle herds in these regions and preserve this breed (Parra-Cortés and Magaña-Magaña, 2019).

CONCLUSIONS

The CLT bulls had good scrotal circumference and seminal quality from a young age through adulthood. The smaller scrotal circumference of the CLT breed, with respect to other breeds, does not affect its seminal quality and is in proportion to the smaller body size of these animals. The CLT bulls have similarities and differences with other breeds, for this reason, it is important to have specific information about this breed.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Productive achievements in backyard poultry projects funded by the strategic program for food security at Tepecoacuilco, Guerrero, Mexico

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ABSTRACT

Objective: To identify the socioeconomic factors in Tepecoacuilco, Guerrero that favored food production and family income that improves their food security via backyard poultry projects.

Methodology: 31 families with backyard poultry projects for chicken meat and egg production were surveyed and their information complemented with two participatory workshops.

Results: The average backyard area per family was 48.27 m^2, of which 25.3 m^2 were destined to the projects supported by the program. Only 16.1% of the assessed projects are in operation and families with active projects improved their diet by increasing their consumption of eggs and healthy meats. Regarding egg production, an annual average of 187.2 kg was obtained in operating projects.

Limitations: Local violence conditions in the study area limited interviewing all beneficiaries selected in the sample.

Conclusions: Beneficiaries improved their family diets with the financed projects; however, the results indicate that family needs are still not fully fulfilled, because the beneficiaries continue to buy eggs essential for their diets. The projects achieved little or no contribution to their household income.

Keywords: families, production, food security, backyards.

INTRODUCTION

The backyard is considered an agrosystem in rural households, where families produce food of animal and vegetable origin, medicinal and ornamental crops, fruits and shade trees. Raising minor species of domestic animals in backyards is a survival

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strategy of poor rural families that, by selling these, allow them to have cash income (Olvera-Hernández, 2017) to cover emergency or unexpected expenses. Among the commonly kept minor species by rural households are poultry, with Creole hens (*Gallus gallus* L.) and "guajolotes" (*Meleagris gallopavo* L.) standing out (Vargas-López, 2018). The Mexican government has promoted the Strategic Program for Food Security (PESA), where the developed projects included a backyard component to strengthen poor families. In 2007, the first PESA allocation (636.2 million Mexican pesos) was included in the Federal Expenditure Budget Decree (DPEF), year after year its budget amount increased, and it was only in 2016 and 2017 when it decreased (Torres-Oregón & Rendón-Rojas, 2017) (Figure 1).

The PESA operated in Mexico to benefit more than a quarter of a million people considered among the poorest in rural areas (Torres-Oregón & Rondón-Rojas, 2017) (Table 1).

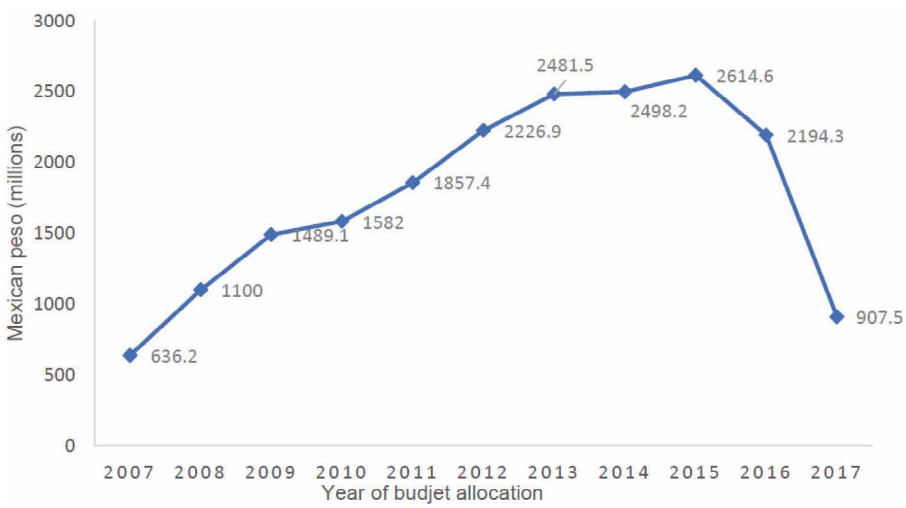

Figure 1. Budget of the Strategic Food Security Program (2007-2017). Source: Torres-Oregón & Rendón-Rojas (2017).

In the state of Guerrero, the projects that predominated with the operation of the PESA were backyard projects, mainly the production of laying hens. The objective of this study was to identify the socioeconomic factors that favored improvements in the backyard production of families participating in the PESA, thus contributing to their food security.

MATERIALS AND METHODS

An *ad hoc* questionnaire was designed to record information from 31 interviews, conducted in August 2019, to the heads of households in the communities of Tierra Colorada, Lázaro Cárdenas, Acayahualco, Maxela and Xalitla, Municipality of Tepecoacuilco, state of Guerrero, which were listed as beneficiaries of the PESA backyard projects (Figures 2 and 3).

Table 1. Coverage of the 2017 Strategic Food Security Program.

State	Municipalities	Communities	Families
Chihuahua	17	261	2,924
Durango	13	274	8,203
Zacatecas	43	304	10,747
Nayarit	11	142	5,103
San Luis Potosí	24	488	17,163
Tamaulipas	5	50	1,813
Jalisco	5	48	1,270
Guanajuato	3	77	1,266
Querétaro	21	231	1,917
Hidalgo	62	431	13,837
Colima	10	50	949
Michoacán	21	408	11,512
Estado de México	15	240	4,996
Tlaxcala	36	106	3,774
Puebla	70	626	27,241
Veracruz	2	0	0
Morelos	23	115	7,944
Guerrero	109	1,310	61,615
Oaxaca	310	1,050	37,312
Chiapas	82	953	48,281
Tabasco	3	75	1,836
Campeche	8	122	5,817
Yucatán	12	45	953
Quintana Roo	5	62	1,844
Total	910	7,468	264,480

Source: Torres-Oregón & Rendón-Rojas (2017).

Figure 2. Operating bird gallery from the Strategic Food Security Program at Lázaro Cárdenas, Guerrero, Mexico.

Figure 3. Non-operating bird gallery from the Strategic Food Safety Program at Tierra Colorada, Guerrero, Mexico.

The sample size was determined by criterion (arbitrary) considering the social and economic situations of the region, so it was not a probability sampling. The selection consisted of interviewees enlisted as beneficiaries who had been participating in the program for at least three years to assess the impact of PESA support. The surveyed data was complemented with other information obtained from two participatory workshops.

An exploratory visit to the region was conducted in November 2018 with the support of the technical staff of the Rural Development Agency following up on the projects in the studied communities. The surveys were applied, and the participatory workshops were held during August 2019.

Tepecoacuilco municipality is located in the northern area of the state of Guerrero. It has a territorial extension of 984 km^2, representing 1.54% of the total state area. It is located between 17° 54' and 18° 22' north latitude and 99° 41' west longitude (INEGI, 2010). The 2010 Population and Housing census reported a total population of 30,470 inhabitants in the municipality, of which 14,612 (47.96%) were men and 15,858 (52.04%) women (INEGI, 2010). The municipality's main economic activity is agriculture followed by livestock activities. With data from the recent 2015 poverty assessment conducted by the Consejo Nacional de Evaluación de la Política de Desarrollo Social (National Council for the Evaluation of Social Development Policy, CONEVAL, 2015), in the municipality of Tepecoacuilco, 26,108 individuals were in poverty, from which 20,186 (77.32%) lived in moderate and 5,922 (22.68%) in extreme poverty.

RESULTS AND DISCUSSION

The surveyed beneficiaries of the program were on average 49.4 years old and had 6 years of schooling (sixth grade of elementary school). In the state of Guerrero as age increases, the illiteracy rate also increases, being higher among women (INEGI, 2015), thereby indicating that the female population in poverty was denied the right to education. This coincides with the results found in this research. The highest age percentage of the female respondents was found in the range of 55 and 64 years (32.40%), who had a schooling level of the third year of elementary school. The interviewees stated that before being beneficiaries of the program they were engaged in multiple activities, including open corn production (80.00%), egg production and poultry breeding (53.30%), cattle, goat and pig breeding (6.70%), and open vegetable production (3.30%).

The predominant type of land ownership was mostly private (53.57%) and "ejido" (14.29%). The rest of the beneficiaries stated that they did not have a property for staple crops planting but rented (21.43%) or borrowed it (10.71%). Of the total area owned by the assessed families, 86.36% corresponded to rainfed agriculture and 13.64% to irrigated agriculture.

It was found that among the families in the surveyed communities, it is common to carry out productive activities in their backyards, although without appropriate infrastructure. The average surface area of the backyards per family was 48.27 m^2. The average surface area destined for the projects installed by the program was 25.3 m^2 (52.00%).

Before participating, the families already had birds in their backyards and experience in their management and care. For them, small species such as poultry, play an important role in the production of eggs and meat, foods that contribute to their diet. For this reason, most PESA beneficiaries chose poultry projects.

All PESA beneficiary families indicated that the program did contribute to improving their diets. However, the PESA projects did not achieve their objective, because only 16.12% were still operating, although with problems to maintain the flock, basically due to lack of inputs on their feed. Projects with low production represented 41.94% and 41.94% of the projects were no longer operating.

The main reasons for which the projects where no longer operational were: lack of time to attend to the project (31.60%); health problems of the families attending the birds (26.30%); the project was not adapted to their needs (21.10%); the beneficiaries were too old to attend to their project (10.40%); the project was located in an inadequate site (5.30%), and predators killed the flock (5.30%).

The projects in operation had a deficient production due to the lack of resources to purchase inputs for diets (33.30%), local inputs for the diets (30.60%), locally available vaccines (22.20%), resources for the purchase of the vaccines (8.30%) and practical vaccines application training (2.80%).

Fifty-one-point zero four percent of the interviewed families with projects still in operation mentioned that the project increased their monthly egg consumption by 16.20%, although their production was not sufficient to meet their families' consumption needs. Therefore, all the interviewed people (100%) mentioned that they bought eggs and chicken meat to supplement their consumption; in other words, the families were not able to produce enough food from their project to fully satisfy their consumption needs. This is consistent with what Verduzco *et al.* (2016) referred about that the poultry projects promoted by the PESA, in the state of Oaxaca were semi-intensive dual-purpose systems, with a 12 birds average flock size in reproductive age and poor productive and reproductive parameters, so they contributed scarcely to their food security or did not represent an income source for the beneficiaries.

In this same sense, in evaluations carried out by the United Nations Food and Agriculture Organization (FAO), the Ministry of Agriculture, Livestock, Fisheries and Food (SAGARPA) and the Economic Commission for Latin America and the Caribbean (CEPAL) reported that the PESA program contributed with generated income equivalent to 4.60% of the value of the daily *per capita* consumption of basic food basket products in rural communities (Mohar-Ponce, 2011). The Economic Commission for Latin America and the Caribbean also reported that the contribution was 1.20% (Sema-Hidalgo *et al*., 2011). Similarly, the Centre for Scientific Studies (CECS-UACh, 2013) reported that the indicator eggs/hens/week did not represent an increase throughout the program's operation, but rather a declining production.

The above contrasts with the study conducted by Montes de Oca *et al*. (2017), which reported that in the backyard poultry projects of the PESA program in the state of Morelos, 47.20% of the beneficiaries did obtain income, although it was of little or no contribution in the area for housing improvement, food, clothing, transportation, medical expenses, savings, entertainment and the creation of contingency funds, since they only made small-scale sales of surplus with their neighbours in the same locality, selling it mostly by piece. This was also the case in the present research.

Similarly, Trujano-Ramos (2017), in a research conducted in the state of Hidalgo, noted that PESA beneficiaries increased their production level, moving from self-consumption to placing their products in local markets, taking advantage of their local resources, without representing a significant income for the families.

According to the goals set by the Rural Development Agency for the area of this study, backyard projects had to reach a production of 144 kg of eggs during a project cycle for newly installed projects and 169 kg per cycle in projects that were already operating.

In the present study, an average annual production of 187.2 kg was recorded in projects that were in operation, which indicates that the established goal was exceeded. However, according to the consumption needs of the families, this goal was not sufficient because the program beneficiaries were still buying eggs for family food; in other words, the PESA program helped little, so it is necessary to rethink their goals, in order to meet the food needs of the participating families. According to the obtained data, the main destination of their production was self-consumption with 72.73%.

CONCLUSIONS

The beneficiaries of the poultry projects supported by the PESA program improved their family diet with the consumption of eggs and meat and had greater availability of food for the basic food basket, although it was not enough for families to meet their consumption needs. In the projects that are still working, the families had difficulties in their operation. There was a downward trend in production due to inadequate management of the projects, due to the lack of inputs to support them, such as feed, vaccines, and replacements for the flocks.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Advances and Perspectives in Research on Buffalo Milk Production and Mozzarella Cheese

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ABSTRACT

Objective: To conduct a bibliographic review of the inventory and distribution of the buffalo herd, leading dairy buffalo breeds, and to map the main research topics for dairy buffaloes, emphasizing feeding methods and their effects on milk and mozzarella cheese quality.

Design/Methodology/Approach: Analysis of the main research topics on dairy buffalo, through a wide review of specialized journals.

Results: The production and processing of buffalo milk has gained relevance in recent years along different latitudes thanks to its nutritional qualities and the international regard for products such as mozzarella cheese. The main studies are carried out in Asia, Italy, and Brazil, emphasizing that diets are a determining factor in yield and quality of milk and its derivatives, but that genetics, environment, and animal management are what in the end model these characteristics.

Study Limitations/Implications: To conduct further research on dairy buffalo, especially in Mexico, where it has important development opportunities.

Findings/Conclusions: The bibliographic body of work presents practical restrictions, advances are recognized, and also the need to further research topics such as reproduction and animal welfare, management and valuation of buffalo milk and its derivatives, with the opportunity to explore organic production.

Keywords: Buffalo milk, mozzarella cheese, research, review.

INTRODUCTION

Milk as a research topic maintains a privileged position globally, given its relevance to the diet of millions of people and because it is one of the most complete sources of nutrition available. This attention has been focused on dairy cattle, which contributes

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81% of global milk production. In recent years, however, buffalo milk has aroused great interest, as it contributes around 15% of global production and, especially, due to its nutritional qualities that are superior to those of other mammals.

The relevance of the water buffalo can be seen in the notable growth of the global inventory, of 11% between 2008 and 2018, with India and Pakistan standing out, where more than 70% of the world's buffalo milk is produced (Khedkar *et al.*, 2016). It is used in a range of dairy products, and due to its high nutritional value, is beneficial to the health of consumers (Napolitano *et al.*, 2019). In Italy, it is processed into mozzarella cheese with a Protected Designation of Origin (PDO), and is highly valued internationally (Gulzar *et al.*, 2019).

The properties and quality of buffalo milk and its derivatives are influenced by various factors such as the feeding regime and the health of the cows, environmental conditions and, in general, by the production system (Shelke *et al.*, 2012; Bertoni *et al.*, 2019a, b, c; De la Torre *et al.*, 2019; Mota-Rojas *et al.*, 2019a,b; Sabia *et al.*, 2020). In response, a wide variety of studies have been carried out (Guerrero-Legarreta *et al.*, 2019), thus this article sought to bring to light and discuss recent and relevant scientific findings on the dairy water buffalo cow and on mozzarella cheese, highlighting the main advances and topics that require further exploration. To this end, a vast bibliographic selection and review was carried out, prioritizing specialized journals.

GLOBAL BUFFALO INVENTORY

Statistics on the inventory of buffalos in the world are still not consolidated, but those by FAO (2018) provide a good start. In 2018, the buffalo population reached more than 206 million heads in the world, concentrated in Asia with 97.4% of the total and an average annual growth rate (AAGR) of 1.01% between 2008 and 2018, above the global average of 0.97% (Table 1). The three countries that stand out for their inventory in that continent are India, China, and Pakistan. Asia is followed by Africa, with 1.70% of the global inventory, with a negative AAGR of 1.4% in the same time span. In the Americas and Europe, a marginal part of this inventory has been accounted for, with 0.70 and 0.20%, respectively, but with a relatively high AAGR of 1.75 and 2.55%, respectively. The statistics for the Americas are scarce, but it has been estimated that the countries with the highest number of water buffalo are: Brazil with three million heads, Venezuela with 960 thousand, Argentina with 120,000, and in fourth place, Mexico with 45,000 (Patiño *et al.*, 2016).

Table 1 shows the summary of the number of water buffalo heads in the world and by continent from 2008 to 2018.

The principal dairy breeds of water buffalo in the world

The functional morphology of the cow is a key aspect for milk production which, according to the Italian National Buffalo Species Farmers' Association (ANASB), comprises a correctly aligned backbone, good rump development, a harmonious conformation of bone structure (body width and depth), adequate formation of hocks and hooves, as well as a developed mammary system. Of special importance is the adequate development of the hind quarters, where 60% of total milk is extracted (Zava and Sansinena, 2017).

Table 1. Number of buffaloes in the world, 2008-2018 (thousands of head).

Buffaloes	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	TCMA
Africa	4052.7	3838.7	3818.3	3983.2	4165.0	3915.3	3949.3	3701.6	3436.8	3432.6	3506.1	−1.31
America	1153.1	1141.9	1191.1	1284.7	1268.6	1339.1	1326.5	1377.6	1377.9	1382.1	1397.1	1.76
Asia	180202.4	188785.8	188634.1	189533.6	190602.8	191095.9	192399.1	194247.7	197382.9	199016.9	201258.2	1.01
Europe	332.9	368.5	390.7	379.6	373.2	426.3	395.6	404.8	415.5	432.7	439.0	2.55
Oceania	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	2.35
World	185741.3	194135.2	194034.4	195181.4	196409.9	196776.8	198070.7	199732.0	202613.4	204264.6	206600.7	0.97

Source: FAO, 2018.

Based on these characteristics, certain breeds have been prioritized depending on each context. In Asian countries, particularly in India, the Murrah, Nili-Ravi, Surti and Jaffabaradi breeds have been preferred and catalogued as the most productive after a long, non-systematic selection process. In particular, the global dominant breed, Indian Murrah, shows a milk yield of between 1,500 and 5,000 liters, depending on the ecosystem in which it develops, and frequently reaches an average butyric fat content of 7.5% (Zava and Sansinena, 2017); females reach average weight of 550 kg and males exceed 600 kg (Almaguer, 2007). In Europe, the Mediterranean buffalo cows are preferred, and in lactation periods of 270 days, they register an average of 2,462 kg, with 8.07% and 4.65% fat and protein content, respectively, with a high yield for products such as mozzarella cheese (AIA, 2018).

To illustrate the performance of certain buffalo breeds, Zhou *et al.* (2018) compared milk yields per day (Figure 1), as well as fat and protein content in the Murrah, Nili-Ravi, mixed, and Mediterranean breeds. This last one stood out with the highest yield and fat content (a little more than 8%), although in protein it remained close to the average of the other breeds. In contrast, the Murrah breed showed the lowest yield, but a significant value in fat and protein.

As to the breeds' characteristics, Murrah stands out with its jet-black color, soft and fine skin, curved horns, slight head and neck, short extremities, wide hips, and well-developed udder and teats, these being black, long, and robust (Mingala *et al.*, 2017). The Nili-Ravi breed possesses similar characteristics to the Murrah, but is distinguished principally by the white marks present on its extremities, as well as the less-curled horns (Moioli and Borghese, 2005). The Jaffarabadi breed is characterized by wide horns that reach either side of its neck, a long body with a wide and deep chest, and an udder with very prominent veins and long teats (Mingala *et al.*, 2017).

The European Mediterranean breed is characterized by long horns that point backwards and slightly outwards, a wide and deep chest, a wide but short rump, and a medium-sized udder with cylindrical teats (Borghese and Mazzi, 2005). In addition, the udder presents optimal traits for machine milking (Mingala *et al.*, 2017).

Concerning the Americas, both Brazil and Argentina have prioritized the Murrah, Mediterranean, and Jaffarabadi breeds, as well as crosses between them (Borghese and Mazzi, 2005).

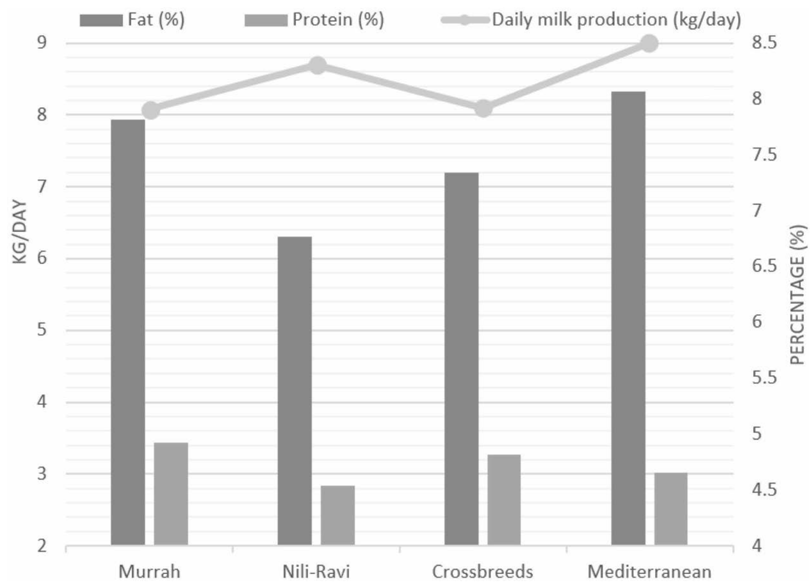

Figure 1. Daily milk production and percentage of fat and protein of four buffalo breeds. Source: Adapted from Zhou *et al*. (2018).

Although the same breeds are used, milk yield during lactation varies substantially between different countries, as in the case of the Nili-Ravi breed, which in prior years reported a yield of 1,820 kg/cow/year in India, while in China it was 2,262 kg/cow/year (Borghese and Mazzi, 2005); this is due to the influence of the environment, and more generally, to the management of each production system.

MAIN RESEARCHED TOPICS ON DAIRY BUFFALO COWS

A great number of studies have been recorded that center on the dairy buffalo cow (Guerrero-Legarreta *et al*., 2019). They have focused on four main topics: health and reproductive aspects of the females, as well as quality of the milk and the mozzarella cheese. Figure 2 summarizes the most relevant scientific findings.

The following paragraphs delve further into the topics related to the production and quality of buffalo milk as well as the effects on mozzarella cheese quality, in order to form an initial assessment on advances and opportunities in this body of research.

Relation between production and quality of buffalo milk

The diet of the buffalo cows has a special influence on milk quality; in India, Shelke *et al*. (2012) evaluated this among 19 Murrah buffaloes divided into two groups: the control group was fed maize forage, a mix of concentrate and wheat hay, while the treatment group was fed the same diet plus 25% fat and a concentrate supplement of mustard and peanut oil. The buffaloes were fed twice a day for 90 days and milk samples were collected during lactation to evaluate content of fat, protein, non-fat solids, and lactose using a milk caliber. The results revealed that the treatment group displayed greater milk production than the control group once the supplement was withdrawn, as well as a higher percentage of fat; in contrast, the percentage of protein, lactose, and non-fat solids were similar in both groups. This innovation is justified from the zootechnical perspective; however, its profitability would still need to be evaluated.

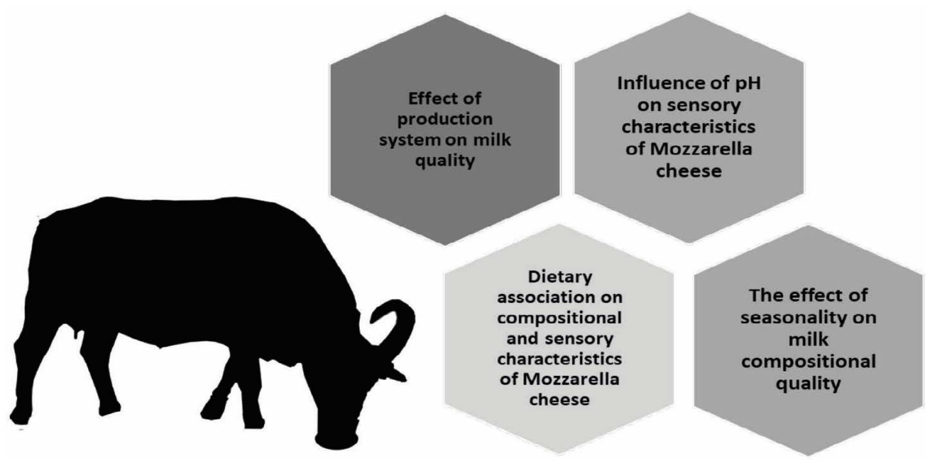

Figure 2. Themes and areas of knowledge recently identified in water buffaloes on milk and Mozzarella cheese quality.

For their part, Patel *et al*. (2020) prepared pumpkin-flavored buffalo milk to define the sensory properties and storage characteristics, and to analyze its nutritional profile. They added pumpkin flesh and sugar in different proportions and conducted three evaluations: the sensory properties (taste, color and appearance) were evaluated by a panel; the nutritional analysis was carried out using chemical methods; microbial and nutritional characteristics were assessed on sterilized milk stored under ambient conditions for 180 days. The authors observed that the milk prepared with pumpkin flesh favors consumption due to its flavor and the sweetness from the added sugar, but increases the levels of carbohydrates and slightly decreases protein levels. Regarding storage, colonies of certain fungi were detected, induced by the conditions and ingredients with which the milk was processed.

In Brazil's Amazon region, the effects of two production systems (PS) on buffalo milk yield were studied (Barbosa *et al*., 2007). In PS1, pasture-fed animals were raised using *Brachiaria humidicola* and *Pueraria phaseoloids*, among others; during the dry season, they grazed on *Pennisetum purpureum*. The animals were given minerals ad libitum and were milked manually once a day. In PS2, the calves were separated at birth; cows were supplemented with a concentrated diet consisting of 60% maize and 40% rice bran, with one kg of concentrate per 3 kg of produced milk. The average milk yield of PS1 and PS2 was 3.2 ± 1.29 and 4.31 ± 1.86 kg/day, respectively. For PS1, the most productive animals were from the 7/8 Murrah genetic group, while for PS2, it was those from the 3/4 Murrah group. The differences in milk production suggested a genetic-environmental interaction in both production systems.

Productive conditions for mozzarella cheese

Most research on this subject has been recorded in Italy, given the large proportion of milk that is processed into this type of cheese (Pauciullo and Lannuzzi, 2017). Sabia *et al*. (2020) evaluated the effect of two diets, the first based on ryegrass hay and the second on ryegrass silage, on the volatile organic compounds of mozzarella cheese. The results showed that the compositional characteristics of the cheese, such as the cheese texture and aroma, varied depending on the diet. Cheese derived from buffalo cows fed with silage presented a higher percentage of fat, protein, and dry content. In terms of the cheese's texture, higher levels of viscosity and elasticity were detected in the mozzarella cheese from the buffalo cows fed with hay, which could be associated to a lower percentage of fat. Concerning the aromatic profile, it was found that terpenes such as linalool and aldehydes, as well as nonanal, were more abundant in cheese derived from animals fed with hay, both volatile components responsible for the citric aroma and characteristic taste of mozzarella. This coincides with the detection of a lower intensity of the herbaceous aroma of cheese derived from buffalo cows fed with hay. In addition, five compounds were identified that allowed for the distinction of cheeses based on the diet, which allows associating them with a specific geographic zone and confirming the identity of the cheese with respect to its Protected Designation of Origin label.

Other ingredients have also been administered in the buffalo cows' diets, such as in the case of Taticchi *et al*. (2017), who fed dried pitted olive marc (DPOM) to Mediterranean lactating buffaloes to measure yield and dietary-sensory characteristics of mozzarella cheese. The results revealed that there was no significant difference between the control group and the one that was administered DPOM in performance or body condition of the females, nor in the characteristics of the milk. However, the cheese produced from the milk of buffalo cows in the treatment group fed with DPOM showed a greater percentage of fat (26.1 *vs* 25.2%), as well as a lower level of saturated fatty acids (77.7 *vs* 71.6%), and a greater percentage of unsaturated and monounsaturated fatty acids (28.4 *vs* 22.3%; 24.6 *vs* 18.8%), which agrees with the lowest atherogenic and thrombogenic indexes (3.68 *vs* 4.95; 3.14 *vs* 3.68). In the sensory evaluation, both groups had a positive score (white pearly color, smooth surface, good compaction, lactic aroma, soft texture, and sweet tase), demonstrating that the addition of DPOM did not cause negative effects on the sensory properties of the cheese and that it even improves it, since low atherogenic and thrombogenic indexes are correlated with a lower risk of coronary heart disease.

In another study, Uzun *et al*. (2018) analyzed the effect of including fresh fodder (sorghum) in the diet of lactating buffalo cows on the properties of mozzarella cheese. They did not find a difference in the profile of fatty acids in cheese produced from the milk of the control group compared to the group that was administered 10 kg of fresh sorghum; however, the cheese from the group that was administered 20 kg of fresh sorghum exhibited higher levels of mono and polyunsaturated fatty acids, low levels of saturated fatty acids, and a better atherogenic index score; in addition, this cheese was softer and moister. Therefore, this last diet reduced costs, improved the properties of mozzarella cheese, and favored acceptance from consumers.

Likewise, Ranucci *et al*. (2016) evaluated in Italy the seasonal effect (summer vs winter) on the composition and quality of mozzarella cheese from Mediterranean buffalo milk. They reported significant differences in the color: the cheese produced in the winter was darker and less yellow, which is attributed to the milk's higher water content. This quality influenced the sensorial evaluation, since consumers opted for these cheeses.

In Pakistan, Gulzar *et al*. (2019) studied the influence of the pH of milled curds, the effect of storage on quality (color, texture, and appearance), and the fatty acid profile of mozzarella cheese. They reported that whiteness decreased significantly as time in storage was prolonged, as did the pH of milled curds (5.2 to 4.9). Regarding texture, firmness decreased as pH went down, due to the dissociation of the casein micelle. In contrast, the authors reported that the pH of milled curds had a low influence on the fatty acid profile, while the time in storage had a significant influence, since the use of packaging with a weaker barrier against air and light could favor the oxidation of the cheese, which in turn could have a harmful effect on health, and therefore result in rejection from consumers.

CONCLUSIONS

Ever since the buffalo has come to be valued as a productive option globally, a more thorough inventory of animals in several countries has been achieved, corroborating that Asia is leading in both milk production and number of animals, while remarkable growth rates have been registered in the Americas and Europe. Likewise, dairy breeds are increasingly the object of planned selection processes.

The qualities of buffalo milk have been widely recognized for their high content in total solids and elevated cheese yield. Additionally, buffaloes have endured what are usually adverse climates for the majority of domesticated species, such as hot and humid conditions, in which buffaloes have shown an outstanding performance.

Regarding mozzarella cheese, more studies still need to be conducted to comprehend all the factors involved in its nutritional and bacteriological qualities. Specifically, changes in the diet and the use of natural additives tend to improve the nutritional levels and to favor a pleasant taste, and simultaneously, they can boost consumption among a wider public. Similarly, packaging that is effective for preserving characteristics such as softness and moistness and increase the shelf-life may promote the acquisition of larger markets.

This brief review showcased advances, but above all pointed to many areas that need to be addressed or at least expanded on, especially in countries like Mexico and its tropical regions, where there are high expectations for buffalo products. To this end, more must be explored, from the identification of good management practices, to aspects concerning milking and hygiene. In addition, further exploration is necessary regarding marketing tools to be used to increase milk production and dairy product yields, open new commercialization avenues and contribute to the development of local producers and marginal areas.

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AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Agronomic Evaluation and Physiological Quality in Triticale, under Two Production Systems in the Laguna Region

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ABSTRACT

Objective: To evaluate ten triticale genotypes to assess the quality of the seeds under two production systems, with cut and without cut, in the municipalities of Matamoros (L1) and Francisco I. Madero (L2), Coahuila, Mexico.

Design/Methodology/Approach: The agronomic variables evaluated were: Grain yield (GY), number of seeds per spike (NSS), spike length (SL), number of spikelets per spike (SS) and plant height (PH). Variables in the laboratory were: normal seedlings (NS), abnormal seedlings (AS), seeds without germinating (SWG), dry seedling weight (DW), plumule length (PL) and radicle length (RL). Statistical analysis was performed with the PROC ANOVA procedure, of the SAS software.

Results: A higher grain yield was found for Matamoros (L1) compared to Francisco I. Madero (L2); however, for the variable number of seeds per spike it was higher in the latter (L2). For the physiological quality of seeds in L2, the highest values were in the variables normal seedlings and radicle length. In the comparison of production systems, the best response was for the system without cut in both locations; therefore, good quality triticale seed can be produced with acceptable grain yield.

Study Limitations/Implications: It is necessary to describe the performance of triticale in the spring-summer agricultural cycle in the central region of the country.

Findings/Conclusions: The productive performance of triticale genotypes was variable depending on the production system, and there was also a different effect on the physiological quality of the harvested seed.

Keywords: Triticale, seeds, quality, systems.

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INTRODUCTION

Triticale (X *Triticum secale* Wittmack) is a cereal product of breeding between wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.). Its name has been formed with half of the name of each of the genera of its parents (CIMMYT, 1976). Currently, this crop represents an option as a fodder crop since it has characteristics such as high productivity, adequate resistance to diseases and pests, tolerance to stress, high capacity for nutrient absorption, superior nutritional quality, and fast establishment in comparison to traditional crops such as oats, wheat or rye (Guinta *et al.*, 2015; Velázquez, 2018), making it a good alternative to decrease the deficit of fodders for animal diets.

In Mexico, during 2019, according to the Service for Agrifood and Fishing Information (*Servicio de Información Agroalimentaria y Pesquera*, SIAP), 24,604.24 hectares of triticale were harvested for fodder, grain and seed. In the Comarca Lagunera that includes the states of Coahuila and Durango, SIAP 2019 reported on the triticale crop for fodder use, a surface of 1,345.9 hectares harvested with a production volume of 49,387.6 t, with an average yield per hectare of 36.28 tons. According to the SNICS 2020 (National Service of Inspection and Certification of Seeds, *Servicio Nacional de Inspección y Certificación de Semillas*), three hectares of the AN-184 variety were harvested for the production of qualified triticale seed.

Triticale cultivation represents a valuable alternative due to its acceptable biomass production and grain yield, for animal feed (Estrada *et al*., 2012; Bassu *et al*., 2013); it exceeds wheat in biomass production, and has greater resistance to leaf diseases and to marginal production conditions (Ammar, 2013). Presently, in northeastern Mexico it represents an alternative as fodder plant, due to its good capacity for regrowth, allowing several cuts and being more competitive than ryegrass, barley or oats (Ammar, 2013), in addition to having a greater content of nutrients. Currently, this crop is gaining presence because of the productive reconversion in some fodder and grain producing zones of the country, substituting some traditional crops. The use of this cereal in Mexico is predominantly for fodder production (plant), and its grain as supplement to diets for animal consumption, mainly monogastric; also, for human diet, as bread grain flour mixed with wheats.

The generation of fodder varieties with an adequate production and seed quality is sought today; this aspect is lacking updated information with regard to the new varieties of this crop, which is a limitation for the production and liberation of new commercial varieties that comply with the demands of the seed market. Therefore, the objective of this study was to evaluate the triticale seed harvested in two production systems (with cut and without cut), as well as their effect on the physiological quality at the laboratory level.

MATERIALS AND METHODS

Experimental site

This study was carried out during the 2018-2019 fall-winter agricultural cycle in two localities of the Comarca Lagunera Region in the state of Coahuila, Mexico. The first locality was Rancho El Campanario in the municipality of Matamoros, located between 25° 30’ 01.6” Latitude N and 103° 09’ 20.9” Longitude W, with an altitude of 1,120 masl. The mean maximum temperature is 31.5 °C, the mean minimum temperature is 12.9 °C, and the mean temperature is 22.9 °C. The mean annual rainfall is 176.1 mm (SMN, 2019). The predominant soil type is Xerosol. The climate is very dry semi-warm (100%) (INEGI, 2009). The second locality was Establo Lanchares in the municipality of Francisco I. Madero, located between the coordinates 25° 54’ 24” Latitude N and 103° 17’ 45” Longitude W, with an altitude of 1,100 masl. The mean maximum temperature is 28.2 °C, the mean minimum temperature is 11.2 °C and the mean temperature is 19.7 °C. The mean annual rainfall is 189.6 mm (SMN, 2019). The predominant soil type is Xerosol and Leptosol. The type of climate is dry semi-warm (86%) and dry very warm and warm (14%) (INEGI, 2009).

Triticale germplasm

Ten genotypes of triticale from the Cereals Program of the Plant Breeding Department of Universidad Autónoma Agraria Antonio Narro were used, as well as a commercial variety, for sowing in both localities. The names of the genotypes used are the following: F2-1, F3-23, F13-17, F14-9, F3-13, F6-23, F16-12, F6-14, AN-184, and Bicentenario. For cultivation, the tasks carried out were: terrain preparation for sowing cereals in the region, plowing, dragging, leveling and furrowing. Sowing in Matamoros, Coahuila, was done on December 3, 2018, and in the locality of Francisco I. Madero, it was on December 5, 2018. They were both done manually, by seed drilling in the bottom of the furrow. A sowing density of 110 kg/ha was used, adjusting to the size of the plot. Each experimental unit was six furrows with 0.30 m of spacing by 10 m of length, with a surface per plot of 18 m^2. Gravity fed irrigation was applied to the experiments immediately after sowing. Then, four helping irrigations were applied on the stages of tillering, setting, flowering and grain filling; however, irrigation was added for the triticale with cut after cutting in both localities. Regarding weed control, Triasulfuron was applied (10 g/ha) during the stage of tillering. In the experiment with cut, it was done at 75 days after sowing in both localities, cutting the totality of the plot with a mechanical reaper, at an approximate cutting height of 4-5 cm.

Threshing and seed conditioning

Threshing was carried out in the building of the Cereals Program of the Plant Breeding Department, with a stationary threshing machine for small grain cereals. The seed obtained as a result of the threshing process was transferred to the Seed Conditioning Laboratory in the Training and Development Center in Seed Technology of the UAAAN, where the process of conditioning was applied through an air-sieve machine (Clipper®) for the laboratory, and that is where the seed was cleaned of impurities (stubbles) and the seeds with mechanical damage were eliminated.

Variables evaluated at the field and laboratory level

At the field level, the agronomic variables evaluated were: plant height (PH), which was measured with a measuring tape from the base of the plant to the distal end of the spike, in each experimental unit and in each sampling, recorded in cm. For the variable yield (GY), the threshed seed from each experimental unit was weighed in an electronic scale and recorded in kg. For this variable, the following formula was used: yield estimation =(kg harvested) (surface of experimental unit)/10,000 m^2. Likewise, the following variables were measured: spike length (SL), where 10 spikes were selected that were measured from the tip to the base with a millimetric sheet and expressed in cm; number of spikelets per spike (SS), where the number of spikelets in each spike of the 10 selected spikes were counted; and number of seeds per spike (NSS), where from each experimental unit the spikes were selected randomly in plants with full competence, threshed manually, and the number of seeds from ten spikes counted.

In the post-harvest stage at the laboratory level, to determine the physiological quality of the triticale seed, normal seedlings (NS) were evaluated, which were assessed eight days after sowing and consisted in the total count of normal seedlings, and the result expressed in percentage (%). Abnormal Seedlings (AS): all the seedlings with damaged primary roots, deformities, negative geotropism, without secondary roots, and with low limited vigor limiting their optimal development, were considered as abnormal seedlings, and the result expressed in percentage (%). Seeds without germinating (SWG): the seeds that did not present any sign of radicle emergence were counted and the result was expressed in percentage (%). Length of plumule and of radicle (PL) and (RL): these variables were measured in normal plants, considering those that did not present any abnormality, and measuring each of the structures was carried out using a table with a graduated millimetric sheet in scale of cm. Dry seedling weight (DW): after the previous variables were determined, measuring this variable consisted in depositing all the normal seedlings (NS) by repetition in perforated brown paper bags and identified with the number of repetition and treatment, and then they were placed in a dry stove brand (SHEL LAB®), at a temperature of 72 °C during a lapse of 24 h. After such time the samples were placed in a desiccator with the aim of avoiding them becoming moistened from the environment, and not affecting data taking. Later, the samples of each repetition were weighed in an analytic scale (OHAUS®), to determine the value of the dry weight and it was represented in mg/seedling.

Experimental design and statistical analysis

The experimental design used in the field was complete random blocks with factorial arrangement (2 localities × 2 production systems × 10 genotypes) with three repetitions.

In the linear model the following factors were considered: Localities (Locality 1 Matamoros and Locality 2 Francisco I. Madero), Production Systems (without cut and with cut) and Varieties (10 triticale genotypes).

The statistical analysis was performed considering the genotypes evaluated in the two localities, with their corresponding means comparison tests (Tukey, $P \leq 0.05$) using the SAS statistical package version 9.0 (SAS Institute, Caray, NC, USA, 2004). The statistical model of the variables evaluated in the laboratory was performed according to a completely random experimental design with factorial arrangement (2 localities × 2 production systems × 10 genotypes).

RESULTS AND DISCUSSION

The variable (GY) showed a highly significant difference ($P \leq 0.01$) in localities, systems and in the interactions localities by systems and systems by variety (Table 1).

For varieties and the triple interaction, there was significant difference (P≤0.05). For the variable (NSS) there was a highly significant difference (P≤0.01) for localities and systems, between variables there was a significance difference (P≤0.05). For the variable (SL) a highly significant difference was found (P≤0.01) in varieties and in the interaction systems by varieties. For varieties there was a significant difference for localities and systems. For the variable (SS) a highly significant difference was found (P≤0.01) in localities and varieties. For systems and the interactions localities by varieties and localities by systems by varieties there was significant difference. For the variable (PH) a highly significant difference was found (P≤0.01) for localities, varieties, and the interaction systems by varieties. A significant difference was seen for systems and the interaction of localities by systems by varieties. Next, Table 2 shows the means comparison test (Tukey ≥0.05) of the variables evaluated in the field.

Table 1. Analysis of variance for agronomic variables in triticale genotypes.

Source of variation	DF	Grain yield (GY; t ha^{-1})	NSS	SL (cm)	SS	PH (cm)
BLOCK	2	12.22	11.78	1.02	4.07	118.76
LOC	1	10.77**	1725.20**	3.65 *	2.16**	3162.13**
SYS	1	8.23**	4212.67**	3.46*	29.00*	634.08*
VAR	9	1.32*	216.95*	4.24**	76.21**	4143.51**
LOC*SYS	1	5.54**	3.67	8.64	6.07	5.20
LOC*VAR	9	0.60	142.63	2.18	23.32*	206.32
SYS*VAR	9	2.79**	130.98	3.76**	12.69	759.87**
LOC*SYS*VAR	9	1.16*	154.61	1.05	17.38*	312.64*
ERROR	78	330.08	66.78	0.60	7.10	92.48
MEAN		1.66	43.25	12.47	27.32	97.6
C.V. %		34.93	18.69	6.27	9.7	9.88

** Significant at the (P≤0.01) probability level; Significant at the * (P≤0.05) probability level; D. F: degrees of freedom; LOC=location; SYS=systems; VAR=varieties; C. V: coefficient of variation. Grain yield/t ha^{-1} (GY)=Grain yield per hectare; NSS=Number of seeds per spike; SL= Spike length; SS= Number of spikelets per spike; PH= Plant height.

For (GY) in the case of L1, there was a higher yield in comparison than in L2, which had an influence on the agronomic management that it was given because in L2 irrigation was not applied at the time when the crop demanded it, so the yield decreased in comparison to L1. The difference in relation between systems was that a higher yield was found without cut compared to where cutting was done, because the cut interrupted the vegetative cycle, and therefore, the plant reduced its capacity for regrowth and seed production. For the case of varieties, the one with higher yield was variety 1 with an average yield of 2.12 tons per hectare, due to its precocity exceeding the control (Bicentenario). However, according to Mendoza *et al.* (2011) there were values that ranged between 6.61 and 1.4 tons per hectare. For (NSS) in the case of L1 there was a lower number of seeds than in L2, because the plants in L2 presented higher stress due to the environmental conditions, in addition to the agronomic management which impacted the yield. Between the systems without cut and with cut there was a higher number of seeds in the system without cut because the crop was kept without the fodder cut, and with the cut performed there was lower regrowth and therefore the plant was only able to produce spikes, but with lower vigor, which generated a lower number of seeds per spike. Within the varieties, the values presented a similar trend, although variety 7 of late habit was the one that presented the highest average value of 54 seeds per ear, which is why this is directly linked to the number of spikelets per spike, according to Velasco *et al*. (2020) who obtained higher results fluctuating between 73 and 59 (NSS). However, Paccapelo *et al*. (2017) reported values that ranged between 39 and 28 seeds per spike. According to the results reported by Beji (2016), for the number of seeds per spike, it reports values of 34 to 20 seeds per spike in triticale.

Table 2. Comparison test of means for agronomic variables in triticale genotypes.

	Source of variation	Grain yield (GY; t ha^{-1})	NSS	SL (cm)	SS	PH (cm)
LOC	Matamoros	1.96 a	39.46 b	12.64 a	29 a	92.47 b
	Fco. I. Madero	1.36 b	47.05 a	12.29 b	26 b	102.74 a
	MSD	210.96	2.93	0.28	0.96	3.50
SYS	Without cut	2.49 a	49.18 a	12.64 a	28 a	99.90 a
	With cut	0.83 b	37.33 b	12.30 b	27 b	95.30 b
	MSD	210.16	2.93	0.28	0.96	3.50
VAR	F2-1	2.12 a	37.08 b	11.56 d	23 c	117.37 a
	F3-23	1.71 abc	44.08 ab	12.86 abc	28 ab	84.70 b
	F13-17	1.33 bc	43.41 ab	12.20 bcd	26 bc	112.58 a
	F14-9	1.15 c	42.75 b	12.59 abcd	28 ab	80.20 b
	Bicentenario	2.02 ab	42.33 b	11.83 cd	24 c	116.18 a
	F3-13	1.49 abc	42.75 b	12.47 abcd	29 ab	82.45 a
	F6-23	1.79 abc	54.08 a	11.97 cd	30 a	114.54 a
	F16-12	1.98 ab	42.66 b	13.47 a	30 a	79.25 b
	F6-14	1.72 abc	41.41 b	12.95 ab	29 ab	114.41 a
	AN-184	1.28 bc	42 b	12.86 abc	28 ab	74.33 b
	MSD	771.46	10.74	1.04	3.52	12.82

LOC=location; SYS=systems; VAR=varieties; MSD=Minimum significant difference; Grain yield/ton ha^{-1} (GY)=Grain yield per hectare; NSS=Number of seeds per spike; SL=Spike length; SS=Number of spikelets per spike; PH=Plant height. Within columns, means followed by the same letter are not significantly different according to Tukey ($P \leq 0.05$).

In the means comparison test for the variable spike length (SL) for the case of the localities, in L1 there was a length of 12.64 cm which was the highest and in L2 a length of 12.29 cm. For the case of the systems, the system without cut had the longest length of 12.64 cm and the system with cut a length of 12.30 cm, very similar values to those of the localities. For the varieties, variety 8 was the one that presented the highest value with a longitude of 13.47 cm, with the other varieties ranging between 11 and 13 cm, similar to what was reported by Velasco *et al*. (2020). In the means comparison test for the variable number of spikelets per spike (SS) in the case of localities, L1 presented the highest value with 29 spikelets per spike and L2 with a value of 26 spikelets per spike. In the case of the production systems, the system without cut had the highest value with 28 spikelets per spike and the system with cut a value of 27 spikelets per spike. In the case of the varieties, varieties 7 and 8 shared the same letter with the highest value of 30 spikelets per spike, values similar to those mentioned by Velasco *et al*. (2020). It is important for this variable to be related to (NSS) since that is where it is related to the fertility of the spikelet and which is directly related to grain production. In the means comparison test for the variable (PH) in the case of the localities, L2 presented higher height with a value of 102.74 cm and L1 with a value of 92.47 cm. In the case of the production systems, the system without cut with a value of 99.90 cm and the system with cut with a value of 95.30 cm. For the case of varieties, five behaved with the same letter with the following values: variety 1 with 117.37 cm, variety 5 with 116.18 cm, variety 7 with 114.54 cm, variety 9 with 114.41 cm and lastly, variety 3 with 112.58 cm; likewise, the values reported by Mendoza et al. (2014) were exceeded. Next, Table 3 presents the analysis of variance with the attributes of physiological quality in triticale seeds.

Table 3. Analysis of variance for physiological quality in triticale seeds, evaluated at the laboratory.

Source of variation	DF	NS (%)	AS (%)	SWG (%)	DW (mg/ seedling)	PL (cm)	RL (cm)
LOC	1	1114.82	2110.44**	433.50	366.93 **	103.61	713.74**
SYS	1	40987.56 **	46510.15**	27.21	55.64	3.07	62.67
VAR	9	1765.26**	1330.55**	95.07	45.91 **	102.83	70.07 **
LOC*SYS	1	17941.76**	13417.31**	643.34 **	8.15	92.66	13.26
LOC*VAR	9	617.17 **	1076.70	40.58	13.38	77.13	45.85
SYS*VAR	9	1325.26 **	1495.49 **	22.75	43.25 **	82.40	46.16
LOC*SYS*VAR	9	1172.41**	897.83*	35.84	16.30	44.78	21.85
ERROR	384	301.33	322.62	36.24	10.52	47.36	18.14
MEAN		62.11	33.55	5.21	12.15	12.46	13.91
C.V.%		27.94	53.52	115.34	26.68	55.22	30.6

** Significant at the ($P \leq 0.01$) probability level; Significant at the * ($P \leq 0.05$) probability level; D. F: degrees of freedom; LOC=location; SYS=systems; VAR=varieties; C.V: coefficient of variation. NS=Normal seedlings; AS=Anormal seedlings; SWG=Seeds without germinating; DW=Dry seedling weight; PL=Plumule length; RL=Radicle length.

For normal seedlings (NS) there was a highly significant difference ($P \leq 0.01$) in systems, variety and in the interactions localities by systems, localities by varieties, systems by varieties, and localities by systems by varieties. For abnormal seedlings (AS) there was a highly significant difference ($P \leq 0.01$) in localities, systems, varieties and in the interactions localities by systems, and systems by varieties. In addition, there was significant difference ($P \leq 0.05$) for the interaction localities by systems by varieties. For the variable seeds without germinating (SWG) there was highly significant difference ($P \leq 0.01$) for localities by systems. For the variable dry weight (DW) there was highly significant difference (P≤0.01) for localities, varieties and the interaction systems by varieties. For the variable plumule length (PL) there was no significant difference in the treatments. For the variable radicle length (RL) there was highly significant difference (P≤0.01) for localities and varieties.

Table 4. Comparison test of means for physiological quality in triticale seeds, evaluated at the laboratory.

Source of variation		NS (%)	AS (%)	SWG (%)	DW (mg/ seedling)	PL (cm)	RL (cm)
LOC	Matamoros	61.00 b	35.00 a	4.00 b	11.29 b	12.00 a	12.73 b
	Fco. I. Madero	64.00 a	31.00 b	6.00 a	13.18 a	13.01 a	15.36 a
MSD		3.35	3.44	1.16	0.629	1.33	0.82
SYS	Without cut	72.00 a	23.00 b	5.00 a	12.54 a	12.38 a	14.34 a
	With cut	52.22 b	44.00 a	5.00 a	11.76 b	12.53 a	13.49 b
MSD		3.34	3.43	1.15	0.629	1.32	0.82
VAR	F2-1	46.50 c	45.75 a	7.12 ab	12.76 abc	8.62 b	12.46 b
	F3-23	69.44 a	26.89 c	3.66 bc	10.87 c	13.43 ab	13.33 b
	F13-17	57.50 abc	37.10 abc	5.40 abc	12.45 abc	11.99 ab	16.63 a
	F14-9	68.40 a	28.80 c	2.80 c	12.62 abc	11.21 ab	14.85 ab
	Bicentenario	54.00 bc	41.44 ab	8.00 a	14.04 a	13.54 a	14.84 ab
	F3-13	62.75 ab	36.16 abc	4.26 abc	10.99 c	12.85 ab	12.12 b
	F6-23	67.83 a	26.88 c	5.00 abc	13.57 ab	13.18 ab	14.23 ab
	F16-12	62.97 b	32.91 bc	5.66 abc	11.39 bc	12.13 ab	13.36 b
	F6-14	57.95 abc	36.16 abc	6.66 abc	11.79 abc	11.76 ab	13.57 b
	AN-184	68.25 b	27.33 c	4.25 abc	11.51 bc	14.84 a	13.84 ab
MSD		12.22	12.54	4.22	2.29	4.84	3.00

LOC=location; SYS=systems; VAR=varieties; MSD=Minimum significant difference; NS=Normal seedlings; AS=Anormal seedlings; SWG=Seeds without germinating; DW=Dry seedling weight; PL=Plumule length; RL=Radicle length. Within columns, means followed by the same letter are not significantly different according to Tukey (P≤0.05).

In the means comparison test for normal seedlings (NS) in the localities, there was a difference between letters positioning L2 with 64.0% of germination and L1 with 61.0% of germination; this is linked to the fertility of the spikes, which was reflected in the number of seeds per ear which was higher than in L2, due to hydric stress and because of the agronomic management in this locality, which in the end had a positive effect on the seed's germination. In the case of systems, for the means comparison for the system without cut there was 72.0% of germination, compared to the system with cut with 52.22% of germination; the variation is directly related since due to the cut the plant had lower fertility that was reflected in a lower number of seeds per ear that and number of spikelets per spike. For the case of varieties the one with higher percentage of germination was variety 2 with 69.44% and variety 7 with 67.83%. However, Mendoza *et al*. (2011) report values that fluctuate between 81.0 and 94.25% of germination. In the means comparison test for abnormal seedlings (AS) for localities, abnormal seedlings in L1 was higher, 35.0%, and in L2 it was 31.10%. In the case of the systems the highest percentage of abnormal seedlings was for the system with cut of 44.0% and in the system without cut of 23.0%. For varieties the one that presented 45.75% of seedlings was variety 1. For the means comparison test for seeds without germinating (SWG) in the case of the localities, it was L2 with 6.0% and L1 with 4.0%. For both production systems there was similar percentage of 5.0% of seeds without germinating.

In the means comparison test for the variable dry weight (DW) for the localities, L2 had higher weight with 13.18 mg/seedling in relation to locality 1 with 11.29 mg/seedling. In the case of production systems for the system without cut 12.54 mg/seedling, and the system with cut 11.76 mg/seedling. Within the varieties the one that obtained the highest value in this variable was variety 5 (Bicentenario) with 14.04 mg/seedling. However, (Fernández *et al.*, 2015) report that in wheats the varieties with high vigor in favorable environments have a positive repercussion in the dry weight per seedling, since vigorous seedlings and with high emergence speed increase the dry weight.

For the variable plumule length (PL) for the case of localities, in the means comparison with the same letter it behaved in L2 with a value of 13.01 cm and in L1 with a value of 12.0 cm. For the case of the production systems there was no difference in the means test since the letter was similar for the two systems; for the system with cut the value was 12.53 cm and for the system without cut it was 12.38 cm. In this same variable for the means comparison test for varieties, two resulted with the same letter, variety 10 (AN-184) with a value of 14.84 cm and variety 5 (Bicentenario) with a value of 13.54 cm. Fernández *et al.*, 2015 mention for wheat that plumule length is favored by the variety, production environment, and agronomic management. Likewise, varieties with high germination vigor impact positively in the emergence speed, and in addition in environments with favorable conditions there is an acceptable growth and development of seedlings in their diverse phenological stages, which has an impact in higher yield.

For the results of the variable radicle length (RL) in the localities, Francisco I. Madero presented a higher value with 15.36 cm in relation to Matamoros with a value of 12.73 cm. For the case of the production systems, the system without cut with a length of 14.34 cm and the system with cut with a length of 13.49 cm. For the varieties, genotype F13-17 presented the highest value, of 16.63 cm, which is directly related to the vigor of the seed and its capacity to be established in the field.

CONCLUSIONS

In this study the locality of Matamoros showed higher grain yield in the genotypes evaluated, because they were given better conditions of agronomic management for the production, compared to the location of Francisco I. Madero. In the seed production systems, the one that showed better yield was the system without cut, since when doing a fodder cut the phenology of the crop was delayed, as well as an effect on the regrowth of stems and the number of spikelets, which influences its fertility and is directly related to the number of grains per spike. For the seed production systems, the system without cut stood out in the variables plant height, spike length, number of spikelets per spike, and number of seeds per ear. In the analysis results of physiological quality, a higher percentage of germination and higher dry weight of the seedling and radicle length was found, in the seed harvested in the locality of Francisco I. Madero. In the locality of Matamoros, a higher percentage of abnormal seedlings was found, with this being an indicator of the deterioration of the seed, related to a lower physiological quality. In terms of the seeds production systems, the system without cut presented high values in percentage of germination, dry weight of the seedling and radicle length. Therefore, it is concluded that for the production of triticale seeds, the production systems do affect the yield and the physiological quality of the seeds, so this study finds that the seed production system without cut was the ideal.

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