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CONTENIDO

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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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Productive parameters and carcass yield of rabbits supplemented with *Leucaena leucocephala* (Lam.) de Wit., and *Guazima ulmifolia* Lam. foliage

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ABSTRACT

Objective: To determine the effect of the addition of *Leucaena leucocephala* and *Guazima ulmifolia* foliage on the production parameters and carcass yield of New Zealand rabbits.

Desing/methodology/approach: 30 rabbits (15 females and 15 males) of the New Zealand breed were used, distributed in three treatments (five females and five males), which consisted in feeding 200 g of concentrated food per day + 100 g of fresh *L. leucocephala* or *G. ulmifolia* foliage, and a control group with no supplementation.

Results: The total voluntary intake was not affected by the treatments or gender of the rabbits; an average value of 158.9 g day^{-1} was recorded. Weight gain was 27.2 g day^{-1} on average. The average slaughter weight of the rabbits was 2523 g. The carcass weight was 1,297 g and the average carcass yield was 51.6%. The dissectable fat content was lower in rabbits on supplements (F=6.70, P=0.001) with values of 1.6, 1.8 and 2.11% with fresh foliage of *G. ulmifolia*, *L. leucocephala* and without supplementation, this variable was not affected by gender. The viscera proportion was on average 24.3%. The average meat: bone ratio was 5.6.

Limitations on study/implications: It was not possible to carry out bromatological analyzes of the foliages or their digestibility.

Fingings/conclusions: Supplementation of rabbits with foliage of *G. ulmifolia* and *L. leucocephala* decreases the proportion of dissectable fat and did not affect the production parameters and carcass yield.

Keywords: Weight gain, meat:bone ratio, rabbit breeding, carcass quality.

INTRODUCTION

Livestock is the main source of protein for human populations. It is also an excellent source of nutrients of high biological quality, calcium, iron, zinc, vitamin A availability (Black *et al*., 2008), and easily provides the necessary amount and variety of essential amino acids (Ayala, 2018). It has also been shown

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that manipulating the diet can increase in rabbit meat the presence of functional compounds, such as essential fatty acids, short-chain fatty acids, EPA, DHA, CLA, vitamin E, and selenium (Dalle and Szendrö, 2011). In 2018, the meat production of the main livestock species (cattle, pigs and poultry) was 337.3 million tons (FAO, 2019) with a forecast increase of 13% by 2026 (OECD / FAO, 2017). However, the high consumption of red meat has been directly related to the presence of cardiovascular and degenerative diseases (Pino *et al*., 2009). In this sense, white meats present a dietary option, due to a higher content of essential nutrients and lower fat and sodium content (Cossu and Capra, 2014; Dalle 2002). Rabbit meat is a white meat that despite its excellent biological quality, its consumption has lagged in Mexico, even with government programs to encourage its production and consumption (Olivares *et al*., 2009). It is currently proposed as a promising species to supply high quality meat from sustainable production models, which given the current levels of natural resources deterioration is widely accepted by society (SAGARPA/SENASICA, 2015; Criado-Flórez and Deháquiz-Mejía, 2019). For this species, the foliage of arboreal and shrub species can be used, due to the presence of a caecum that allows them to select and excrete indigestible fiber from their tract, and extract low-quality protein (Mora-Valverde, 2010). This allows a low dependence on grains and other inputs, a reason that explains the acceptance of this activity by small producers in backyard systems (Gutiérrez *et al*., 2017), where the inputs are minimal, with low productivity rates (Olivares *et al*., 2009).

The acceptance of rabbit meat and its by-products in Mexico is still low and is mainly focused on the central region of the country where cultural factors have a high impact on such acceptance (Olivares *et al*., 2009; SADER, 2015). However, in rural areas throughout the different geographical regions of the country, wild rabbits are consumed (Fernández *et al*., 2015) and are preferred over farms raised rabbits because consumers differentiate the products from both (González-Redondo *et al*., 2008). This is due to the genetic differences of rabbits and the way of life (González-Redondo *et al*., 2010) including food. It has been proposed that the organoleptic characteristics of the meat from herbivores are associated or influenced by the number of compounds or metabolites in the foliage they consumed. In this sense, an option to improve the profitability of rabbit production units and the quality and acceptance of their meat is to use shrub and arboreal plant species with forage properties. Therefore, the objective of the present research was to determine the effect of including foliage from *L. leucocephala* and *G. ulmifolia* on the productive parameters and yield of rabbit carcass.

MATERIALS AND METHODS

Location

The research took place at the rabbit area of the Colegio de Postgraduados, Campus Campeche. Located at kilometer 17.5 of the federal highway Haltunchén-Edzná in Champotón municipality, Campeche. Located at 19° 29′ 56.80″ N - 90° 32′ 34.65″ W; 19° 29 ′46.02″ N - 90° 32′ 21.89″ W; 19° 29 ′48.01″ N - 90° 31′ 56.64″ W; 19° 30′ 11.56″ N - 90° 32′ 13.55″ W. The region is dominated by a warm subhumid climate with rains in summer (García, 2004). Annual precipitation varies between 900 and 1200 mm. The site has a mean annual temperature of 25.5 to 26.4 °C and an elevation of 21 m. The slaughter and evaluation of the carcass were carried out in the Meat Workshop of the Instituto Tecnológico de Chiná.

Treatments description

Three treatments were evaluated, treatment 1 (T1) consisted of 200 grams of commercial balanced food+100 grams of fresh *L. leucocephala* foliage. Treatment 2 (T2) consisted of 200 grams of commercial food+100 grams of fresh *G. ulmifolia* foliage and a control treatment (TC) that consisted of 200 g of commercial balanced food with 17% CP. The foliage of the two evaluated species consisted of leaves with tender stems.

Handling of rabbits

Thirty rabbits (15 females and 15 males) of the New Zealand breed were used, weaned at 45 days age with an average initial weight of 275±25 g. Ten animals per treatment (five females and five males) were randomized. They were housed in three metal cages with a capacity of 10 rabbits each, with individual housings of 0.4×0.6×0.9 m. Each cage had an automatic nipple drinker and a hopper-type feeder (Figure 1). At the beginning of the experiment, the animals were dewormed and vitaminized. They were adapted to the experimental diet for one week.

Variables

Voluntary consumption: during the six weeks that the field phase lasted, the rabbits were fed at 8:00 am. Next, the food offered was weighed and left for 24 h. The next day the rejected food was removed and weighed. The values of the fresh weight of the food offered and

Figure 1. Distribution of treatments T1: *Leucaena leucocephala*, T2: *Guazuma umlifolia*, T3: commercial concentrated food.

rejected were converted on a dry basis, using the equation

$$vc = Of - Rf$$

where *vc* = voluntary consumption, *Of* = offered food (g) and *RF* = rejected food (g).

Daily weight gain: rabbits were individually weighed every seven days after a six-hour fast. The weighing was carried out on an electronic scale with a 40 kg capacity. To calculate the daily gain, the following formula was used:

$$DWG = \frac{Fw - Iw}{7}$$

where *Fw* = final weight (g), *Iw* = initial weight (g) and 7 = number of elapsed days. At the end of the field stage, the rabbits were sacrificed based on NOM-033-SAG / ZOO-2014.

Carcass performance: is the percentage relationship between the carcass weight (after removing blood, viscera, skin, head and legs) and the live weight, before slaughter. The performance in fresh carcass was assessed during gutting, then kept for 24 hours in a cold room at 4 °C where the carcass yield in cold was determined. The formula

$$CY(\%) = \left(CW(g) \div LW(g)\right) \times 100$$

was used. Where: *CY* = carcass yield, *CW* = carcass weight and *LW* = live weight.

Meat: bone ratio: after slaughter, the carcasses were left for 24 h in 4 °C refrigeration where the carcasses were weighed. Boning was then carried out, thus obtaining the meat weight and bone weight, for which the following formula was used.

$$M{:}B = \text{Meat weight}/\text{Bone weight}$$

Data Analysis

The data were organized in a random block design, where the levels were male and female. Subsequently, an ANOVA was performed with a GLM model and a test of means comparison via the Tukey test, $P<0.05$, in the Statistica 7.1 statistical software (StatSoft, 2005)

RESULTS AND DISCUSSION

Consumption of concentrated food was not influenced by treatments, sex, or their interaction ($P>0.05$). Consumption of 156.3, 162.4 and 158.2 g were recorded in rabbits supplemented with *L. leucocephala*, *G. ulmifolia* and with no supplementation. Therefore, it is assumed that the usage of the evaluated species of foliage of does not affect balanced feed consumption. Regard gender, average consumption of 145.6 and 172.3 g was observed for males and females respectively. The total consumptions observed in this study were higher than those reported by Deshmukh *et al*. (1993), who reported a total of 68.5 g DM day^{-1} from *Morus alba*.

The treatments did not influence the daily weight gain ($P>0.05$), registering averages of 24.5, 28.4 and 28.7 g in rabbits supplemented with *L. leucocephala*, *G. ulmifolia* and without supplementation. The values observed here are higher than those reported by Villa-Ramírez and Hurtado-Villegas (2016). They report daily weight gains of 5.3 g in rabbits fed with silo grasses of *Axonopus scoparius* and *Tithonia diversifolia* (Hemsl.) and *Morus alba* foliage fodder, and 5.2 g day^{-1} with silos of the same grass and *Boehmeria nivea* foliage. For their part, Nieves *et al*. (2009) reported weight gains of 29.49 g day^{-1} in New Zealand rabbits fed with *L. leucocephala* foliage, these values are similar to those reported here. Male and female rabbits increased their weight by 27.5 and 27.2 g day^{-1}, each, with no statistical differences

(P>0.05). The interaction of the supplementation type and the gender had no statistical effect. Also, Castaño and Cardona (2015) reported higher daily weight gains than those presented here, in male and female rabbits, with diets based on concentrated food plus *Tithonia diversifolia*, *Arachis pintoi* and *Trichanthera gigantea* foliage, with averages of 47, 44 and 42 g day^{-1}.

The treatments affected the weight at sacrifice after a six weeks experimental period (F=5.377, P=0.021), with average weights of 2.399; 2.574 and 2.597 g for the rabbits supplemented with *L. leucocephala*, *G. ulmifolia* and with no supplements, respectively. The gender of the rabbits had no effect on the live weight at the time of sacrifice and averages of 2.498 and 2.548 g for males and females. Regard the interaction between treatment and gender, no differences were observed (P>0.05) (Table 1). The slaughter weight was higher than that reported by Nieves *et al*. (2009), who obtained a slaughter weight of 1.810 g on rabbits supplemented with arboreal species foliage; and that reported by Cornejo-Espinoza *et al*. (2016) with 2.050 g average in rabbits with different *ante mortem* fasting periods.

The carcass weight had no changes due to the study factors (P>0.05), with average weights of 1.354, 1.220 and 1.319 g for rabbits supplemented with fresh *L. leucocephala*, *G. ulmifolia* foliage and no supplementation, respectively. The carcass weight by gender of the analyzed rabbits had a 1.261 and 1.334 g average for males and females. In the food × sex interaction, no differences were observed (P>0.05) (Table 1). Lower carcass weights were reported by Martinez *et al*. (2010) in rabbits with *Hibiscus rosa-sinensis* L. or *Brosimum alicastrum* Sw. restricted foliage supplementation and values of 790.5 and 822.0 g, while with free access 933.5 and 951.3 g.

The treatments did not affect carcass yield (P>0.05) with mean values of 51.9, 51.7 and 51.3% in rabbits supplemented with *G. ulmifolia*, *L. leucocephala* fresh foliage and with no supplements. In this sense, the gender of the rabbit did not affect the carcass yield (P>0.05), with observed values of 51.5 and 51.7% for males and females. The supplementation × sex interaction had no statistical difference (F=12.72, P=0.001). The highest value was in females supplemented with *G. ulmifolia* foliage with 53.6%, while the lowest was in male rabbits supplemented with *G. ulmifolia* foliage (Figure 2). The carcass yields in the present study are lower than those reported by Cornejo-Espinoza *et al*. (2016) who obtained average yields of 56.1% in rabbits fed with concentrated feed under commercial conditions. Yet, higher than those reported by Martinez *et al*. (2010) of 48.9 and 48.2% in rabbits supplemented with *H. rosa-sinensis* L. or *B. alicastrum* Sw. foliage.

The dissectable fat content (scapular and perirenal) in the carcass was influenced by the treatments (F=6.70, P=0.001) 1.6, 1.8 and 2.11%, for rabbits supplemented with fresh *G. ulmifolia*, *L. leucocephala* foliage and without supplementation. Likewise, a greater dissectable fat accumulation was observed in male rabbits compared to female rabbits with averages of 2.1 and 1.5% respectively (F=10.31, P=0.001). In the interaction supplementation and rabbit gender, no effect was observed on the fat accumulation in the rabbit carcass (P>0.05) (Table 1). The dissectable fat contents were higher than those reported by Martinez *et al*. (2010) in rabbits with restricted *H. rosa-sinensis* L. or *B. alicastrum* Sw. foliage supplementation and values of 0.27 and 0.26%, while with foliage free access values of 0.96 and 1.48%.

No effect of treatment, gender and their interaction was observed (P>0.05) concerning the weight of the

Table 1. Characteristics of the carcass of rabbits supplemented with fresh *L. leucocephala* and *G. ulmifolia* foliage.

Treatment	Sex	Weight (g)	PFC (g)	Viscera (%)	Fat (%)	R. C:H
Leucaena leucocephala	M	2589±13	1352±68	20.9±1.00	1.9±0.25^{a}	5.6±0.9
	H	2560±52	1315±44	25.1±1.32	1.7±0.12^{ab}	5.1±0.2
Guazuma ulmifolia	M	2411±14	1215±151	25.8±4.21	2.1±0.51^{a}	5.6±0.1
	H	2386±48	1288±45	24.1±0.73	1.1±0.05^{b}	5.5±1.2
Commercial concentred food	M	2494±185	1302±122	25.0±5.67	2.4±0.41^{a}	6.5±0.2
	H	2699±86	1368±104	24.9±1.02	1.9±0.34^{ab}	5.4±0.3

^{ab} Different literals in the same column indicate significant difference (P<0.05). PFC=Cold carcass weight. R. C:H: Relationship meat: bone.

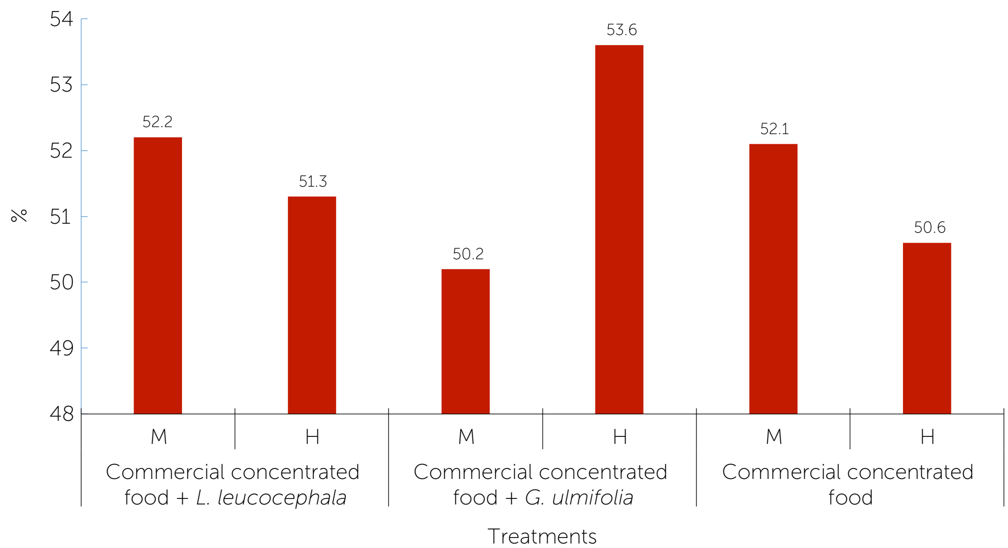

Figure 2. Carcass yield on rabbits supplemented with of *L. leucocephala* and *G. ulmifolia* foliage.

viscera. Values of 23.0, 24.9 and 25.0% were observed in the rabbits supplemented with *L. leucocephala*, and *G. ulmifolia* foliage and no supplements. In females and males, the weight of the viscera was 23.9 and 24.7% of the live weight of the animals. Values of 22% in the proportion of the weight of the viscera with respect to the live weight at the time of sacrifice of rabbits fed with concentrated food were reported by Cornejo-Espinoza *et al*. (2016), which relates to the fact that fibrous foods consumption can affect the development of the digestive tract site in which it is digested (Abad *et al*., 2012).

The meat: bone relation shows no significant difference in the study factors or their interaction (P>0.05). Mean values of 5.35, 5.57 and 5.92 were observed; in rabbits supplemented with *L. leucaena*, *G. ulmifolia* foliage and with no supplementation; and 5.30 and 5.94 for females and males. The total average of this variable in the experiment was 5.6 (Table 1), with consistent values, except for male rabbits fed with concentrated food and no supplements. But they coincide with that reported by Pascual *et al*. (2005) from 5.48 in rabbits in a synthetic R line. Lower values were reported by Capra (2014) in rabbits supplemented with alfalfa and without supplementation of alfalfa (3.32 and 3.57) and as in the present work, the lowest relation was found in animals that received green foliage supplements.

CONCLUSIONS

The foliage of *G. ulmifolia* and *L. leucocephala* used as supplementary food in rabbits fed with concentrated feed had no effect on the total consumption and weight gain of the rabbits. Carcass performance and the meat : bone ratio were similar in rabbits with foliage supplements from both species and rabbits with no supplement. The inclusion of fresh foliage of the two species had a significant effect on the reduction of dissectable fat (scapular and perirenal) in the rabbits after six weeks of fattening. The proportion of the weight of the viscera did not increase with the addition of foliage as a supplement in the rabbit's diet.

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Use of Renewable Energy as a Strategic Behaviour for Companies in the Agricultural Sector

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ABSTRACT

Objective: To describe the use of renewable energies in firms in the agricultural sector in order to associate their use to competitiveness variables and to determine if their incorporation has an impact on the competitive performance of the firms.

Design/Methodology/Approach: An instrument was designed aimed at managers and owners of companies in the agricultural sector based on the theory of industrial organization and competitiveness. The information was coded, and association tests as well as comparative cluster analysis were performed.

Results: The use of renewable energy by the firms addresses economic and commercial strategies. Of the twelve competitiveness variables used to compare firms, nine were linked to the use of renewable energies. The firms using renewable energy demonstrated superior results in competitiveness.

Study Limitations/Implications: The results are applicable to firms in the agricultural sector within the region analyzed. Financial and energy consumption variables should be considered if the method of analysis is to be replicated.

Findings/Conclusions: The use of renewable energy is a strategic behavior that allows companies to improve their market position. Companies that use renewable energy as a strategic behavior are more competitive.

Key words: Agriculture, competitiveness, energy, industrial organization.

INTRODUCTION

Firms in the agricultural sector are often regarded as being linked to competitive market structures, also known as perfect competition structures. This is due to their products being categorized as commodities, and because the companies that participate in this type of market are price takers. However, authors such as Cabral (2017); Reimer and Stiegart (2006); Sexton *et al*. (2007); Vettas (2010), argue that this is not necessarily so, since competitive firms in the agricultural sector meet market requirements and make use of strategies typical of oligopoly markets.

Hence the relevance of using the industrial organization theory (IOT) as a reference, particularly strategic behaviors (SBs), and the competitiveness approach to analyze the use of renewable energies by agricultural sector firms (ASF).

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SBs are part of an oligopoly market structure and according to Ramírez and Unger (1997), they are defined as strategies that allow firms to maintain or improve their position in the market in which they compete. This study is preceded by research that addresses the SBs of agricultural sector firms in the region of Northeastern Mexico. Authors such as Taddei-Bringas and Robles (2002); Taddei and Preciado (2008), identify and analyze the strategic behaviors used by food industry firms to adapt to changes in the market. Velderrain-Benitez *et al*. (2019) focus on companies that produce grapes in this region and seek to prove that the market structure under which they compete is an oligopoly.

Concerning studies about renewable energies, none were found that approached the subject with this theoretical framework. In this regard, research in Mexico is aimed more toward productivity potential and energy transition (Martinez, 2020). The objective was to describe the use of renewable energies in companies in the agricultural sector in order to associate their use with competitiveness variables, and to determine if their incorporation has an impact on the competitive performance of the companies.

MATERIALS AND METHODS

This study was carried out with 32 agricultural sector firms (ASF) in the municipalities of Hermosillo, Carbo and San Miguel de Horcasitas, in Sonora, Mexico, in the period between March and December, 2019. Of these, 14 firms used renewable energy (FRE), particularly photovoltaic solar energy, and 18 operated without this technology (FWRE). An instrument divided into five dimensions was designed: strategic behavior and renewable energy; market scope; vertical and horizontal integration; profitability and market positioning; and product differentiation. Based on the field work conducted, the information obtained was then coded and a database was developed. A Chi-square test was performed to identify the association between the use of renewable energy and competitiveness variables followed by a hierarchical cluster analysis, using Rstudio software version 1.21335.

RESULTS AND DISCUSSION

The results of the study indicate that the use of renewable energies comprises a strategic behavior (SB) that allows companies to maintain or improve their market position by enabling cost reduction, improve the image within their market, as well as anticipate their market needs and the possibility of obtaining institutional benefits and price incentives.

The primary areas where this technology is used are: cold storage, packaging, drying process and product separation areas, offices, irrigation systems, and housing and sports facilities for workers.

Of the 14 companies that used renewable energy, 11 of them received financial support from the government (Shared-Risk Trust Fund, Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food; and Agriculture-related Trust Funds). Once this was identified, the data obtained were coded corresponding to the different sections of the methodology applied, and association tests were performed between competitiveness variables and the use of renewable energies. Once the Chi-square test (Table 1) was performed, the companies were grouped so that they could be compared.

Table 1. Competitiveness variables associated with the use of renewable energies.

Variables	Significance level (p-value)
Market reach	
Level of exported products	0.1031
Level of export markets (LEM)	0.04762
Harvest fields level (HFL)	0.03437
Number of export strategies (NEE)	0.04447
Profitability and market position	
Investment level (IL)	0.04032
Investment amount level (AmountL)	0.02448
Number of problems to satisfy demand (NPSD)	0.05634
Vertical integration and horizontal integration	
Vertical integration level (VIL)	0.02814
Horizontal integration level (HIL)	0.01486
Differentiated products	
Product differentiation level (PDL)	0.02216
Certification level	0.8826
Green labels level	0.2156

Source: Prepared by the authors based on Chi-square test.

The use of renewable energy represents a strategy used by companies to form the clusters. However, different behaviors that have allowed the companies to remain in the market were also considered important, which were obtained within the dimension of strategic behaviors and renewable energies (Table 2).

Subsequently, the means of competitiveness variables were compared between the clusters and the type of company. In figures 1-5, the mean is represented by a thick line and the data per company by points. Group one shows FRE (right side of the graphics) and group two FWRE (left side).

One of the first findings of the cluster analysis is that FRE have a higher field level than FWRE (Figure 1), which shows a greater installed capacity for production; FRE were also proven to have more harvest fields in municipalities and states other than the ones being evaluated.

The LEM variable for the three clusters shows that the FRE have the highest means, which indicates that they have access to a higher number of export destinations (Figure 2). The theory signals that companies which export to a greater number of markets tend to stabilize their sales faster, especially when there are price drops and fluctuations in product demand (Hirsch and Lev, 1971).

Table 2. Main Characteristics of the clusters

Clusters	Characteristics
Commercial cluster (COC)	- Marketing company integrated to the firm - Three firms use renewable energies - Two firms don't use renewable energies
Quality Cluster (QC)	- Quality product strategies - Six firms have renewable energies - Eleven firms don't use renewable energies
Adaptation and innovation cluster (AIC)	- Strategies of adaptation to market conditions, innovation, and research - Five firms use renewable energies - Five firms don't use renewable energies

Source: Prepared by the authors based on hierarchy analysis.

In this regard, 10 of the FWRE have the United States as their sole destination market. Also within that scenario is the only company that does not export, which would indicate a limited capacity to respond to adverse situations.

In a study conducted for other industries, Denis and Depelteau (1985) argue that firms with greater market information are better positioned in international markets and do not depend on public institutions or private companies to export their products.

In this case, it was found that there are FWRE that depend on FRE to export their products. In regards to NEE, only in the COC did CRE demonstrate a higher average than CWER: in the remaining clusters the results were equal.

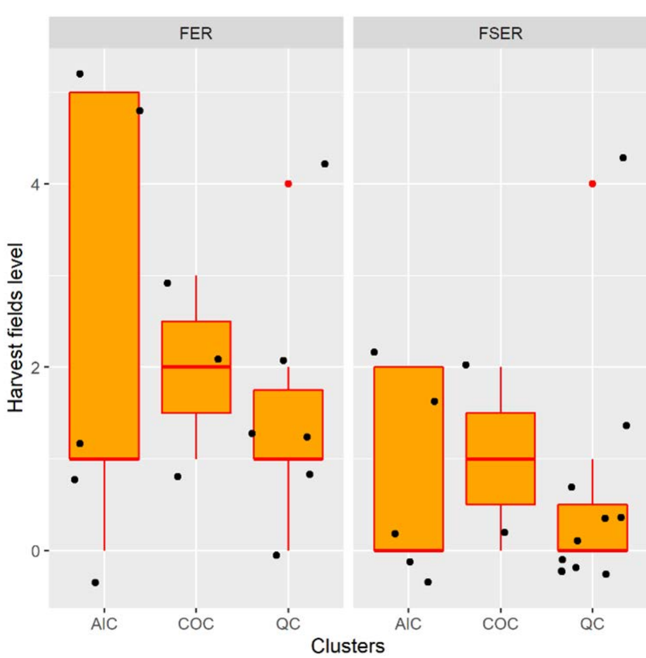

Figure 1. Comparison between CRE (FER) and CWRE (FSER) firms on harvest fields level.

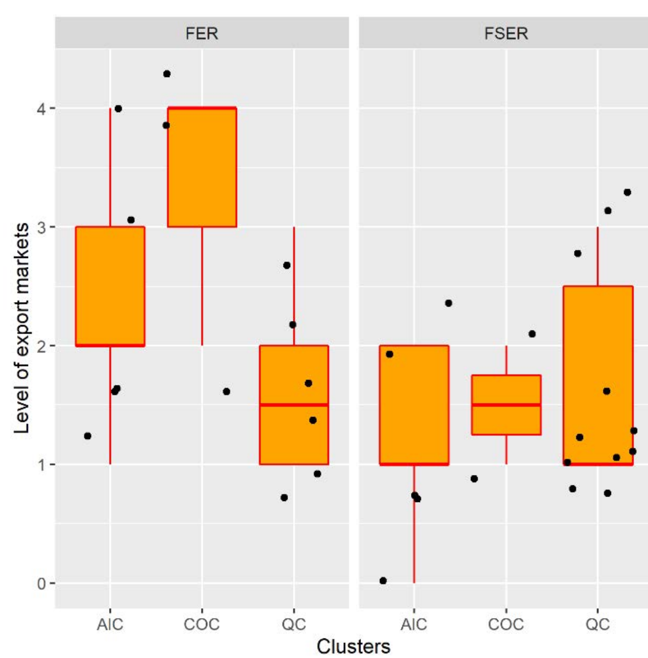

Figure 2. Comparison between CRE (FER) and CWRE (FSER) firms on export markets level.

The principal strategies used by COC firms are related to compliance with international export standards. Xiong and Beghin (2014) argue that when firms comply with these export standards, a demand for their products in the international market is incentivized.

The number of investments and the amount in Mexican pesos of the investments made in the past five years were used to determine the IL and the AmountL. For the IL variable, CRE firms in the COC and AIC clusters were found to have a higher average than CWRE; in the QC cluster, findings show equal mean values. For the AmountL variable (Figure 3), CRE have a higher average than CWRE.

The profitability of a firm allows observing its performance in the market (Boccard, 2010). Likewise, the investment amounts represent the capacity a firm has to maintain economic activity and identify market opportunities (Arslan-Ayaydin *et al*., 2014).

To determine the VIL, the integration of goods production, packaging, product transport to the final client and trading company were considered (Figure 4). The results indicate that the AIC and COC of CRE show more vertical integration than CWRE; however, in the QC, both types of firms have equal averages.

Authors such as Lin *et al*. (2014) point out that in markets where the demand is dominant, it becomes more attractive to integrate vertically going forward, and in this sense the trading companies are the ones that set the standard in terms of product specifications and packaging. In this regard, all the CRE have two integrated activities moving forward: packaging and product transportation.

According to Shepherd and Shepherd (2004) and Tarziján and Paredes (2006), this type of integration is directed at the efficiency in the organization, use of resources, and control of processes.

The above is consistent with the strategies of some CRE as they integrate packaging facilities and product transportation, to reduce the risks and uncertainty caused by hiring third parties to carry out these activities and reduce costs.

For HIL, activities of the firms in the same or different sector were considered, as well as the number of alliances that the companies have (Figure 5). In the three clusters identified, CRE demonstrated better results than CWRE, which would indicate that they are more horizontally integrated.

Concerning alliances, Pawlewicz (2014) points out that the firms in the agricultural sector that are associated with other firms have higher possibilities of gaining access or cooperating with clients that demand a higher volume of products. In that regard, the CRE interviewees indicated that they had alliances with small-scale producers, which allowed them to meet the production volume

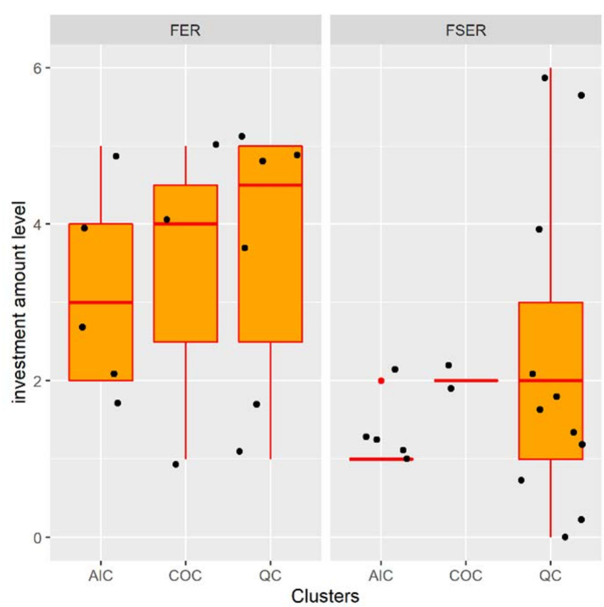

Figure 3. Comparison between CRE (FER) and CWRE (FSER) firms on investment amount level.

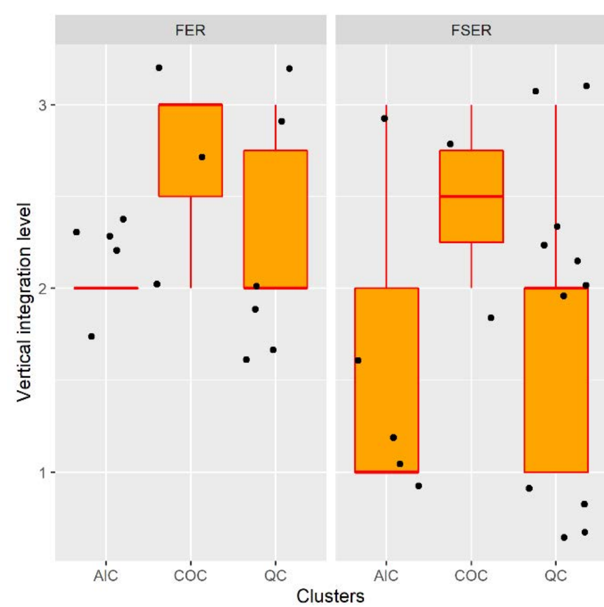

Figure 4. Comparison between CRE (FER) and CWRE (FSER) firms on vertical integration level.

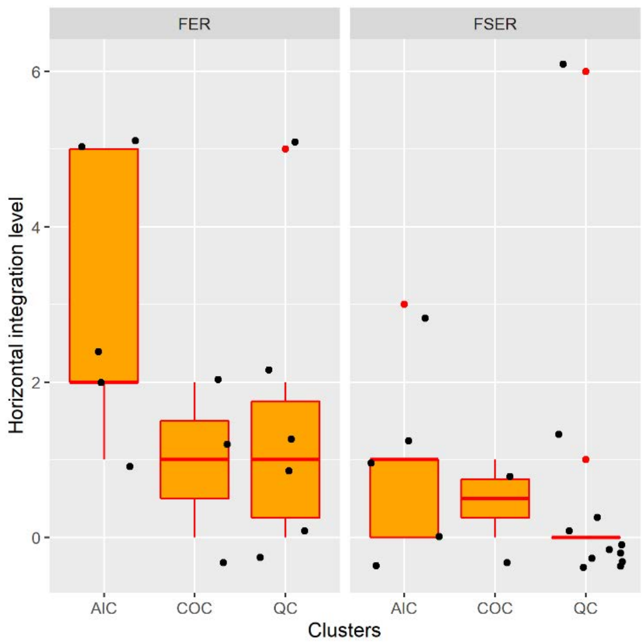

Figure 5. Comparison between CRE (FER) and CWRE (FSER) firms on horizontal integration level.

demands imposed by the trading companies; some even make alliances with trading companies in order to have greater market security and sell at more competitive prices. Concerning activities within the same market or in a different one, Ullah and Shivakoti (2014) mention that firms in the agricultural sector decide to carry out other activities within the same sector in order to better manage the market risks. When they are carried out in a different market, these activities are supported by high profits.

Using the theoretical elements of horizontal integration of the firms described by Boccard (2010); Coloma (2002); Tarziján and Paredes (2006), it is possible to assert that the CRE with their alliances, associations and collaborations could gain greater market power, increase their production capacity or reach a greater number of clients.

In product differentiation, certifications, green labelling and differentiated products were taken into account. Concerning the variables related to green labelling and certifications, no association was found with the use of renewable energies. The firms showed scarce evidence of the use of green labels. Regarding the certifications, there is no real difference between companies since they all have the same certifications: Primus GF, Global Gap, Fair Trade, among others. Although initially the assumption was made that the use of renewable energies would allow them to differentiate themselves, it was found that in the case of certifications or green labelling, these were not acquired due to the incorporation of this technology. When it comes to differentiated products, CRE have a higher level, since they have a greater variety of products such as varieties of grapes, chili pepper or squash.

Finally, although evidence was found of association with the NPSD variable, the problems signaled by the firms are related more to natural factors that endanger agricultural activities. The results show that CRE show above average levels in competitiveness variables, indicating better competitive performance in CRE companies.

CONCLUSIONS

The study developed shows that the use of renewable energies as a strategic behavior generates favorable impacts in firms in the agricultural sector, as was expressed by 71% of the CRE interview respondents. In the analyzed firms, findings show that the use of renewable energies as a strategic behavior by agricultural sector firms is aimed at meeting economic and commercial needs. The association found between different competitiveness variables and the use of renewable energies allows stating that there is a convergence. In this sense, the study carried out results in substantial findings, particularly in the comparative exercise between clusters and firms types; the CRE demonstrated better competitiveness indicators than their counterparts, which would indicate that they are more competitive. For future studies, adding variables of a financial character, of energy consumption and energy production, is suggested, which in this case were considered confidential by the interview respondents.

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AGRO PRODUCTIVIDAD

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Construction of Social Sustainability in Milk Production Systems in Central Mexico

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ABSTRACT

Objective: To build mathematical models to evaluate the social sustainability of small-scale milk production systems.

Design/Methodology/Approach: Thirty small-scale cowsheds were analyzed. Two models were built using multivariate regression, estimated with ordinary least squares and considering the factors that producers perceive as important for social sustainability.

Results: The first model (ER) included tangible variables and the second intangible variables (SR). Both models explained more than 80% of the variables associated with social sustainability.

Study Limitations/Implications: The results represent an effort to link the statistical analysis with qualitative data that is difficult to quantify.

Conclusions: The ER and SR models represent a proposal for counting immaterial indicators so they can be incorporated into the sustainability analysis. Both models could be a methodological proposal to connect statistical data with purely qualitative data such as perception.

Keywords: Livestock production, mathematical models, ethnography, social structures.

INTRODUCTION

Sustainable development began to become popular since 1988 when the World Commission on Environment and Development published the Brundtland Report, and sustainability was defined as that which can satisfy the needs of the present generation without compromising the ability of future generations to satisfy their own needs (WCED, 1987). This definition has been taken up again frequently in the studies of resource use and environmental problems, and although it involves the economic and social spheres, these are only relevant if they are compatible with the environmental quandary (Janker *et al.*, 2019).

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During the first years of the 21st century, studies such as Pretty's (2000) began to analyze certain productive activities under the notions of sustainability, giving rise to a series of studies on sustainable agriculture (Maxey, 2006; Graymore *et al*., 2008) and livestock production (Bigras-Poulin *et al*., 2004; Rojas-Downing *et al*., 2017).

Sustainability in its social conceptualization has been described as a multifunctional concept (De Wit *et al*., 1995) and has been analyzed from diverse perspectives. From the agricultural point of view, Janker *et al*. (2019) propose the analysis of the social dimension of sustainability through a working framework that contemplates the identification of local elements of the agricultural system. Saifi and Drake (2008), for their part, consider that sustainable agriculture is constructed by thinking about municipalities as socio ecological systems capable of reducing the national and global interconnection regarding the main agricultural inputs. Veldhuizen *et al*. (2015) consider that the studies on social sustainability ought to consult different groups of the parties interested in order to obtain a balanced view about the problems of productive systems.

Due to the multi-functionality of the concept of social structures, there has been scarce consensus about what social sustainability is and ought to include, particularly for rural studies; however, authors such as Karami and Mansoorabadi (2008), Vallance *et al*. (2011), and Dlouhá *et al*. (2013), have preferred to root social sustainability through the categories of tangible needs (water, food, shelter) and intangible needs (culture, human values, social networks, equity and justice). Authors like Janker *et al*. (2019) propose that for the empirical application of the social sustainability framework in rural areas (sustainable agricultural systems) it is required to identify local elements of the productive system and for actors to identify their needs with regards to the system and their working conditions.

Despite the efforts to build evaluation tools for social sustainability, there are still no pre-established social criteria used as variables, so that at the methodological level the concept continues to be vague (Olakitan, 2019). This study attempts to contribute to decrease this methodological gap and combines ethnographic and statistical approaches for the determination of variables defined by the social actors involved, which are necessary for the satisfaction of tangible and intangible needs. Milk production systems, both in Mexico and in other global economies, have been positioned within the five agro-productive systems of greatest importance (FAO, 2016). However, attaining productive increments constitutes a challenge, since the dairy farms have constantly had to face changes in economic and technical scenarios, causing their profitability to be affected (Calsamiglia *et al*., 2018). Based on this, the objective of this study was to develop mathematical models to evaluate social sustainability in small-scale milk production systems in Central Mexico.

MATERIALS AND METHODS

The research was carried out in two localities of the municipality of Aculco, Estado de México, Mexico, with great reputation as milk producer given that it produces close to 3% of the state total, that is, more than 17 thousand tons of milk (SEDAGRO, 2013).

The localities selected were: El Tixhiñú (99° 52′ 31″ W and 20° 06′ 54″ N), with altitude of 2,438 m, and La Concepción Ejido (99° 52′ 23″ W and 20° 07′ 59″ N) with altitude of 2,399 m. Both localities are considered in the cultural imaginary of the zone as the most important in terms of milk production.

Sample of Producers

The study was done with n=30 productive units, 17 in Tixhinú and 13 in Concepción Ejido. The sample represented 14.70% of the total production units present in the study zone and in agreement with Palella and Martins (2012), a sample of 10, 20 or 40% can be representative and valid as long as the characteristics of the study subjects are universal for the population. These production units were selected through a snowball non-probabilistic sample. Selection criteria for the sample were specified (Otzen and Manterola, 2017), among which the following stand out: a) small-scale production, that is, size of the herd between two and thirty milking cow plus replacements; b) milk production was their main source of income, although it was possible for some member of the family to have a paid job; c) the main feeding input of the livestock are local fodders, and d) predominately make use of family workforce. Work was also carried out with key informants, a municipal delegate from each locality, an ejido commissioner and a canal worker in charge of both localities.

The data were collected through ethnographies carried out within the productive units (PUs) and qualitative field work techniques, especially in-depth interviews with each member of the PUs in the sample. These interviews were led as informal conversations, so that the interviewee could respond without pressure and spontaneously (Espinoza-Guzmán *et al*., 2018).

The interview was divided into two stages: a) the first was focused on obtaining general information about the PU and sociodemographic characteristics of the producers; and b) the second stage sought to obtain the perception of the producers about what it implied to be a milk producer and how to achieve sustainable productive systems, that is, they were asked about the elements that they considered part of the economic (tangible) and social (intangible) structures of production. The field work period was from January 2014 to July 2015. In order to have correspondence with the objective of the study, only the general results of the characteristics of the PUs are presented, and the models' results are presented in their developed form.

Building Mathematical Models

According to Karami and Mansoorabadi (2008), social sustainability should be measured in terms of satisfaction of basic needs, which for Vallance *et al*. (2011) are classified into tangible (employment, income, infrastructure) and intangible (culture, social networks, generational transference). Following these proposals and with the aim of being able to quantify the factors which, from the perception of producers, have influence on social sustainability of small-scale milk production, two models were built from multiple regression, estimated with the ordinary least squares method (OLS) (Wooldrige, 2015).

It should be mentioned that all the indicators in the models were selected according to recommendations by Janker *et al*. (2019), through the identification of local elements of the productive system.

The first model, ER, analyzed the perceptions that producers associate with the economic structures that intervene in milk production, that is, the tangible aspects of production. Meanwhile, the second model, SR, was focused on the social structures, that is, the intangible aspects such as traditional knowledge and social networks. The equations applied were:

$$ER_i = \beta_0 + \beta_j X_{ji} + \varepsilon_i, \quad j > 1, \quad i = 1,\ldots,30$$

(1.1) $1<=j<=5$

$$SR_i = \beta_0 + \beta_j X_{ji} + D_{1i} + \varepsilon_i, \quad j > 1, \quad i = 1,\ldots,30$$

(1.2) $j=3$

D_{1i} is a dummy variable, ε_i represents the error.

For the construction of the response variable in both models, the PUs were asked for the indicators that they considered an essential part for the satisfaction of tangible (ER) and intangible (SR) needs.

ER was built considering the total number of hectares with cultivated pastures, total of hectares sown with maize, and total number of milking cows.

On the other hand, SR was built considering the average of the following variables: number of people with whom irrigation water is shared, number of people from the family who work in the farm, number of permanent employees, and number of temporal workers. All of these were recorded in the same metric measurement unit.

It is important to emphasize that the variables shown in Table 1, which fed both models, were selected through the declarations from producers about what they perceive as tangible and intangible aspects of social sustainability (Janker *et al*., 2019). Thus, for the purpose of this study, social sustainability was defined in terms of the categories of needs, tangible for ER and intangible for SR. All the variables were considered numerical in the same way that Wooldridge (2011) considers the years of education and the experience to explain the average of profit per hour.

Finally, for both models, ER and SR, two results were obtained. The first belongs to the complete model, that is, it includes all the variables that are directly related, based on the perception of producers, while the second only includes the variables that were statistically significant. The software used for the analyses was IBM SPSS Statistics version 20 and Gretl Statistics (Gnu Regression, Econometrics and Time-series Library).

RESULTS AND DISCUSSION

General Characteristics of the Production Units

The productive units (PUs) have on average four members of the family, of which at least two work daily in milk production, the mean age of the producers is 53 years, with average schooling of finished primary

Table 1. Variables used in ER and SR.

Variable	Definition
DC	Total milking cows
CP	Total of hectares
MA	Total of maize hectares
SW	Total number of people whom the producer organizes to pay the water quota
MWF	Total family members that contribute to productive activities
NPE	Total number of permanent employees, who are hired when family labor is not available, work directly with the animal herd, do not have a contract termination date and their salary is received per week
NTP	Employees hired for short periods of time, can be days, weeks and / or specific jobs on agricultural land; their salary is received daily or, at harvest time, they usually receive their income per bag of harvested corn
PLM	Price of a liter of milk ($USD)*
SJ	Total of family members with a salary out or in the study area
AGE	Producer age at the moment of the interview
TL	Total of milk yield at the moment of the interview
CA	Milking calves (0 to 6 month of age)
IFS	Farm technology**
TBA	Total of backyard animals
DR	Refers to farms which had social relations outside the study area via salary jobs***

*1 USD=18,15 MXN (October 2017, Banco de México)
** Types of facilities: 1) farms that do not have a defined space for the livestock; 2) farms that only have a space called cowshed, used as dormitory and trough of milking cows; 3) farms that have a cowshed with pen in a totally demarcated single space; and 4) those farms that have cowshed and pen that are completely separate, where the pen is the demarcated place for the livestock to wander during most of the day.
*** if at least one member of the family has a paid job outside the farm.

(six years of elementary school). There are no speakers of indigenous languages in the study zone and the predominant religion is Catholic. The dairy herd has on average 11 milking cows with a production of 170 L of milk per day. Two milking events are carried out per day and in 90% of the cases it is done manually. Concerning the backyard animals, there are on average five sheep, six rabbits, one pig and 27 fowl for each PU.

On average, 1.6 ha is destined for the cultivation of pastures, and 4.0 ha for the cultivation of maize and other local fodders, particularly oats. It should be mentioned that the PU with greatest land ownership has an ejido property regime. There is qualified hired labor inside the PUs analyzed, and on average two temporal employees are hired for the sowing and harvesting times. In the study zones there are both property in Tixhiñú and ejido in La Concepción.

Model for the Analysis of Tangible Economic Structures (ER)

Table 2 presents the two results from the analysis developed for the model of the economic or tangible structures of social sustainability in the PUs registered; that is, ER1 corresponds to the analysis with the totality of the variables expressed by producers and ER2 expresses only the statistically significant variables. It should be mentioned that when comparing ER1 and ER2, the variation percentage of the response variable (ER) was very similar, so these models explain 54% of the rate of variables which, in the perception of small-scale milk producers, represent the necessary economic aspects for the satisfaction of tangible needs and thus achieve for dairy farms to be sustainable.

The MWF and NPE variables were the ones of greatest significance, followed by PLM. The high significance of variable MWF agrees with the observations by García *et al*. (2003), who suggest that the farms with smaller herds and which depend 100% of family labor have higher competitiveness of the system in comparison with the larger farms that are not so dependent on family labor. For Posadas-Domínguez *et al*. (2014), family labor provides profitability and competitiveness to small-scale milk production, and represents a source of social capital. In addition, it has an impact on the direct production costs and the increase of income (Cabrera *et al*., 2010; Zhou *et al*., 2013).

Table 2. Results of the Multivariate Regression for the ER Model (n=30).

Variable	R^2	Standard coefficient	Standard error
ER1	0,55		
Constant		−0,357*	0,205
MWF		0,010***	0,003
PLM		0,989*	0,576
NPE		0,014***	0,004
SJ		−0,002	0,003
NTE		0,001	0,002
ER2	0,54		
Constant		−0,357*	0,199
MWF		0,011***	0,003
PLM		0,988*	0,558
NPE		0,012***	0,003

*** p<0.01, ** p<0.05, * p<0.1

With regards to the variable PLM, it would be logical to think that milk sales are carried out seeking the highest price; however, ethnographic data indicated that there are social factors that have influence on the decisions about who to sell to.

In the study zone, all producers deliver their milk to boteros or stockpiling agents, who transform it into cheese, so the price is established by them. It was observed that the bonds of trust, friendship and camaraderie influence directly on the decisions of who to sell the product to and the PUs do not necessarily seek a better price, which agrees with Oddone (2012) who shows that friendship and camaraderie networks are a cultural and symbolic practice that allows the individual to maintain or improve his level of material, physical and emotional wellbeing through various practices.

Through the ER model, it was detected that, as mentioned by Rao and Qaim (2013), hiring agricultural employees has a positive effect on rural zones. According to Dupraz and Latruffe (2015), family and hired labor can be substituted one with the other, as long as it is about the technical operations of the farm; however, these hires can be affected directly by the changes of non-agricultural salaries (Yang-Ming *et al*., 2012), reason why the NTE variable was not significant, since there is not an exact programming or control of the paid laborers per day or per harvest.

Contrary to what was established by Meert *et al*. (2005), for whom paid work constitutes a strategy for the survival of farms, the SJ variable was not statistically significant; however, the ethnographic data confirm that the income obtained outside the farm contributes to stabilizing the finances of households that would otherwise be strongly influenced by the fluctuations of prices and seasonal cycles, which belong to the business cycles of agricultural and livestock products.

Model for the Analysis of Intangible Social Structures (SR)

Table 3 presents the results from the SR Model. The immaterial structures are difficult to count because they depend directly on the limits established by social actors on environments and interests perceived individually (Stewart *et al*., 2010); this explains the variability in the data. However, these immaterial components, such as social networks, are critical components for the safety and wellbeing of households, especially in rural zones (Baird and Gray, 2014).

The power relations and social hierarchy represented by the IFS variable were positive and significant both statistically and ethnographically, since as is shown in the testimonies, the producers constantly seek to improve the facilities of the PU, which agrees with what is suggested by Jacoby and Mansuri (2015) who express that the social hierarchy exerts a deep effect on the accumulation of capital in rural zones.

The positive coefficient associated to the DR variable represented a strategy of family PUs to build a complex

Table 3. Results of the Multivariate Regression for the SR Model (n=30).

Variable	R^2	Standard coefficient	Standard error
SR1	0,37		
Constant		8,571**	3,237
AGE		−0,091*	0,049
TL		−0,014**	0,006
CA		−0,408*	0,226
IFS		1,482*	0,738
DR		2,508*	1,334
TBA		0,004	0,018
SR2	0,36		
Constant		8,669**	3,148
AGE		−0,090*	0,049
TL		−0,014**	0,006
CA		−0,391*	0,210
IFS		1,466*	0,720
DR		2,528*	1,305

*** p<0.01, ** p<0.05, * p<0.1

social network that allowed sustaining unforeseen agricultural and family events through work loans, savings plans, group savings schemes (informal financial strategy that can be weekly, biweekly or monthly), among others. Authors like Verswijvel *et al*. (2018) mention that friendship networks depend on trust and can provide the opportunity to expand social circles and create social capital.

The variable associated to age (AGE) had a negative influence on the SR model, because when ageing, the social interactions of the producer decrease given that they no longer have to widen their network since the farm is consolidated, although it is also because the phenomenon of generational transition (material and immaterial) takes place as the producer ages. The socio-productive relationships that were part of an extensive social interweaving begin to change, and the trust that there was in each of the parts of the former network is not transferred in its totality, losing nodes of social relationships, and forcing the new successor to add new actors to the network. It should be mentioned that when the transition is made, the father only conserves the symbolic ownership of the cowshed so that although the son becomes the administrator, he only receives total social recognition after the father's death.

The CA variable had a negative influence on the SR model because, according to field data, the milk production systems sell only male calves and keep the females as replacements for the dairy herd. Considering that the birth rate between sexes is 50/50%, the producers only create social relationships for half the births.

It is important to mention that for the TBA variable, based on the perception of small-scale milk producers, it is necessary for the creation of camaraderie and friendship networks that allow exchanges through reciprocity, so this contributes to the social sustainability of the system; however, in the statistical analysis its coefficient was not significant. The reason for this was that people only share a small number of backyard animals and on special occasions the rest is used for auto-consumption of the domestic group whether in feeding or in programmed and extraordinary economic expenses, as Stroebel *et al*. (2011) describe. For Kariuki *et al*. (2013), backyard livestock production plays an important role for the families since the animals and the products can be exchanged or sold to purchase food, especially in times of scarcity, in addition to being a conservation space for agrobiodiversity (Rodríguez and Meza, 2014).

According to Vargas-Hernández (2010), the creation of social capital is one of the greatest foundations of sustainability since because it's based on elements of trust and reciprocity, coordinated actions can be eased in favor of environmental protection; therefore, it is suggested to place special emphasis on the variables related to the SR model, which can generate links between producers to act as platforms for plans and programs in favor of the region's sustainable development.

CONCLUSIONS

The hybrid methodologies used allowed contributing evidence where the inclusion of traditional knowledge and social participation have not been incorporated into sustainability analyses, because the indicators of these variables are located in the immaterial context and the socio-cultural category. Likewise, the ER and SR models fulfill the purpose of counting these immaterial indicators to be able to incorporate them into the sustainability analyses, so they constitute a methodological proposal that combines ethnographic data and statistical analyses. ER and SR together explain slightly over 80% of the variance rate of the variables considered for the evaluation of sustainability in small-scale milk production systems. For the case of the category that included the satisfaction of tangible needs (ER), the variables with highest influence are price of a liter of milk, number of permanent employees, and members of the family that work in the farm. In the case of the category of satisfaction of intangible needs (SR), the variables that contribute most to the model due to their significance are domestic roles and infrastructure. The methodological proposal developed in this study represents an effort to connect the statistical analyses with purely qualitative data and difficult to materialize, such as perceptions.

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Cattle Grazing Exclusion Increases Basal, Crown and Mulch Cover in the Sierra de Órganos National Park, Sombrerete, Zacatecas, Mexico

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ABSTRACT
Objective: To estimate the effects of cattle grazing exclusion on soil and vegetation conditions in grasslands of Sierra de Órganos National Park (SONP), Sombrerete, Zacatecas, Mexico.

Design/Methodology/Approach: Four transects with cattle grazing exclusion were strategically established in SONP grasslands. In each transect the basal, crown and organic mulch cover, soil cover, bare soil, and the form of the autumn plant were measured from 2008, 2010, 2012 and 2014.

Results: Cattle grazing exclusion caused an increase in basal, crown and organic mulch cover, soil cover, as well as over-rested plants and deteriorated plants; bare soil cover and the percentage of normal plants decreased.

Study Limitations/Implications: Increase of organic mulch cover implies the accumulation of combustible material that represents a potential risk of fire occurring in the SONP.

Findings/Conclusions: Increase of organic mulch, over-rested plants and deteriorated plants shows that SONP grasslands are transiting to a less stable ecological state.

Keywords: plant cover, bare soil, degraded grassland.

INTRODUCTION

The Sierra de Órganos National Park (SONP) is an important ecotourism zone due to the scenic beauty produced by a number of steep elevations and rock formations. The SONP also stands out for social, economic, environmental, and scientific values that represent the large biodiversity present in ecosystems that comprise it (SEMARNAT, 2013) In the SONP land, cattle grazed continuously during the whole year for a long time. The animal load exceeded the forage capacity, therefore causing vegetation and soil deterioration (Márquez *et al*., 2006). On November 27th, 2000, the SONP was declared (DOF, 2000), but it was not until the second semester of 2008

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that bovine and equine grazing was excluded. Grazing exclusion is an efficient management strategy to restore degraded grasslands worldwide (Li *et al*., 2018; Bi *et al*., 2018). Grazing exclusion can improve characteristics of the plant community, and the physicochemical and biotic properties of the soil in degraded grassland areas. Therefore, it can serve as an efficient way to rejuvenate the grasslands (Wang *et al*., 2018). Grazing exclusion also increases leaf litter accumulation (organic mulch), which may lead to light limitation and increase growth points of plants that are then more susceptible to damage (Vermeire *et al*., 2018); in the long term this could negatively influence the renovation and productivity of species (Jing *et al*., 2013). Likewise, the structure and function of the plant community has been altered significantly in some regions due to the excess of mulch accumulation, particularly in pastures of tufted grasses and rhizome grasses (Hou *et al*., 2019). Physical interference from mulch reduces grassland diversity and modifies the composition of species within diverse grassland communities.

Knowledge of the effects of grazing exclusion on the soil and vegetation can be important and timely for the SONP managers. Managers are able to know if the objectives of the SONP management program are being achieved; mainly the one related to protection, which implies "safeguarding the permanence and conservation of biological diversity and representative geological formations, through the establishment and promotion of a set of policies and measures to improve the environment and control the deterioration of ecosystems" (SEMARNAT, 2013). This type of information may be useful to cattle breeders with production systems with grazing conditions similar to those found in the SONP. For these reasons, the effects of cattle grazing exclusion on soil and vegetation conditions of the Sierra de Órganos National Park, in Sombrerete, Zacatecas, Mexico, were estimated.

METHODS AND MATERIALS

Description of Study Area

The study was carried out in the Sierra de Órganos National Park (SONP) located in northwest of the municipal township of Sombrerete, Zacatecas, Mexico; the SONP covers an area of 1,124.65 hectares of ejido property and has an altitudinal range of 2,120 to 2,560 meters. The SONP is located within the extreme geographic coordinates: 23° 46′ 54.31″ N and 103° 46′ 37″ W, 23° 48′ 06.39″ N and 103° 49′ 08.66″ W, 23° 46′ 07.71″ N and 103° 47′ 01.26″ W and 23° 48′ 28.80″ N and 103° 48′ 57.93″ W (SEMARNAT, 2013). The climate in the SONP is temperate sub-humid (C (w0) (w) to (e)), with summer rains (UNAM, 1970). The physiography is low sierra of volcanic rock with escarpments, ridges and small valleys (UACH, 2002). The soil types in the SONP are Fluvisol, Xerosol and Eutric Lithosol associated with Eutric Cambisol. In the SONP, the vegetation types present are: Pine forest, Oak forest, Natural grassland, Scrubland, Riparian vegetation, and Aquatic and underwater vegetation (UACH, 2002). In addition, Enríquez *et al*. (2003) identified 406 species, 254 genera and 75 families of vascular flora.

Within SONP biodiversity, there are 36 mammal species (Rodríguez-Maturino *et al*., 2013); 19 reptile species (Rodríguez *et al*., 2018); 97 bird species (Rodríguez *et al*., 2018); 43 diurnal butterfly species, (Álvarez-García *et al*., 2017). Of these species, 17 are within some category of risk and eight are endemic, according to the NOM-059-SEMARNAT-2010 (SEMARNAT, 2010).

Sampling Procedure

Four transects (I, II, III and IV) were established in the SONP grasslands. One hundred observation points were randomly selected in transects I, II and IV; and 66 points were selected in transect III. Four measurements of the variables basal, canopy and organic mulch cover, soil cover, bare soil and plant form were made in each transect. The first measurement was made in 2008, when cattle grazing exclusion began; then, the remaining three measurements were made in 2010, 2012 and 2014. The results are presented in the results section as zero (0), two (2), four (4), and six (6) years of grazing exclusion, respectively. The data were obtained at the beginning of autumn in each of the above-mentioned years using the Early Warning Biological Monitoring -Rangelands and Grasslands method (ASCHM, 1999). The plant species identified in the grassland were grouped into three functional plant groups (Vega *et al*., 2019).

Description of Estimated Attributes

Basal cover: is the vertical projection of plant material toward the surface when viewed from above.
Canopy or crown cover: is the perimeter of the plant's foliage in its widest horizontal plane.
Organic mulch: is the layer of residue on the soil surface composed of leaves, stems and manure; also, organic mulch includes material that is decomposing and being incorporated into the soil.

Soil cover: is the proportion of soil area covered by some type of protective material such as mulch, gravel, stones and standing plant material.

Bare soil cover: is the proportion of soil surface area devoid of some type of protective material.

Plant form includes three categories: a) Normal plants are vigorous plants, with presence of stems, leaves and seed production and where no old growth is observed. b) Over-rested plants are those plants that have been esceedingly rested for several seasons; the grasses show rusty leaves and stems of two or more years, which impede growth, and the hollows in the plant's center may contain remnants of that ungrazed material. c) Deteriorated plants are plants with evidence of overgrazing or over-resting, but the plants are dying.

Statistical Analysis

Basal and crown cover, organic mulch cover, soil cover, bare soil, and plant form were the response variables as a result of maintaining the pasture with grazing exclusion for several years. In the variance analysis, the source of variation was the years with grazing excluded. The variance analysis was carried out for each response attribute by considering a completely randomized design. When significant effects were evident in any variable, the comparison was made with Tukey's multiple range test at α=0.05 (Stell *et al*., 1997). The statistical analyses were performed using the Minitab 16 software, through the 'General Linear Model' statistical procedure.

RESULTS AND DISCUSSION

The basic statistical estimators of soil and vegetation attributes measured at baseline (0 years) and at 2, 4 and 6 years after grazing exclusion are shown in Table 1. Extremely large means and coefficients of variation (>30%) and variance analysis results (not shown) suggest that differences between the year of initiation (0) and 6 of grazing exclusion tend to be significant in all eight attributes involved. Therefore, the comparison results are presented below.

Differences ($p<0.01$) were associated to the grazing exclusion time factor in the following attributes of the SONP grassland: basal cover, crown cover, organic mulch cover, soil cover, bare soil cover, normal plants, over-rested plants and deteriorated plants. The mean basal cover of plants in the exclusion period increased 19.94 percentage points, from 9.02% to 28.96% (Table 1). In the first two years of exclusion, the increase in cover was not significant, but between years four and six the increase was very significant (Figure 1). Poaceae (formerly grasses) contributed 92.35% to 95.35% of the basal cover identified in the exclusion period; herbaceous plants contributed 1.34% to 6.28%; and trees and shrubs contributed 1.37% to 3.36% (Figure 2). Only herbaceous plants had a significant increase in year four of the exclusion; changes were not significant during the exclusion period in the other functional plant groups.

The mean crown cover of vegetation during the exclusion period increased 79.24 percentage points, from 13.93% to 93.17% (Table 1). The largest increases occurred during the first two years of exclusion and then from the fourth to the sixth year; during the interim period of exclusion, a slight decrease took place (Figure 3). The mean organic mulch cover during the exclusion period increased 124.61%, by changing from 17.76% to 39.34% (Table 1). During the first two years of exclusion, mulch increase was significant, but between the fourth and sixth year, the increase was not significant (Table 1). During the exclusion period the mean soil cover, integrated by basal cover of plants and organic mulch, was increased in 41.53 percentage points, by changing from 26.78% to 68.31% (Table 1). The largest increases belong to the first two years of the exclusion and from the fourth to the sixth; growth was moderate during the third year (Figure 1).

Mean cover of bare soil decreased during the exclusion period 41.53 percentage points, from 73.22% to 31.69% (Table 1). The largest decreases corresponded to the first two years of exclusion, and to the fourth, fifth and sixth; the decrease was moderate in the third year (Figure 1).

The percentage of normal plants during the exclusion period decreased 53.55 percentage points, from 99.45% to 45.90% (Table 1). The largest decrease was in the last two years of the exclusion, from the second to the fourth year the decrease was moderate, and in the first two years the decrease was small (Figure 3).

The percentage of over-rested plants increased by 17.21 percentage points during the exclusion period, from 0.55% to 17.76% (Table 1). The highest increases were observed from the second to the fourth year, and from the fourth to the sixth; in the first two years of exclusion the increase was small (Figure 3). The percentage of deteriorated plants in the exclusion period increased

Table 1. Basic statistical estimators of vegetation and soil surface attributes in Sierra de Órganos National Park grasslands, in cases of 0, 2, 4 and 6 years of cattle grazing exclusion.

Variable (%)	Years of exclusion	N	Mean	Standard error	Standard deviation	Coefficient of variation
Basal cover	0	366	9.02	1.50	28.68	318.10
	2	298	16.44	2.15	37.13	225.80
	4	366	16.67	1.95	37.32	223.91
	6	366	28.96	2.37	45.42	156.83
Crown cover	0	366	13.93	1.81	34.68	248.87
	2	298	34.90	2.77	47.75	136.81
	4	366	27.87	2.35	44.90	161.10
	6	366	93.17	1.32	25.26	27.11
Organic mulch cover	0	366	17.76	2.00	38.27	215.49
	2	298	36.24	2.79	48.15	132.86
	4	366	39.89	2.56	49.03	122.92
	6	366	39.34	2.56	48.92	124.33
Soil cover	0	366	26.78	2.32	44.34	165.60
	2	298	52.68	2.90	50.01	94.93
	4	366	56.56	2.59	49.64	87.76
	6	366	68.31	2.44	46.59	68.21
Bare soil cover	0	366	73.22	2.32	44.34	60.55
	2	298	47.32	2.90	50.01	105.70
	4	366	43.44	2.59	49.64	114.26
	6	366	31.69	2.44	46.59	147.01
Normal plants	0	366	99.45	0.38	7.38	7.42
	2	298	98.99	0.57	10.00	10.10
	4	366	91.26	1.48	28.29	31.00
	6	366	45.90	2.61	49.90	108.71
Over-rested plants	0	366	00.55	0.39	7.38	1350.92
	2	298	01.01	0.58	10.00	993.30
	4	366	08.74	1.48	28.29	323.51
	6	366	17.76	2.00	38.27	215.49
Deteriorated plants	0	366	0.00	0.00	0.00	0.00
	2	298	0.00	0.00	0.00	0.00
	4	366	0.00	0.00	0.00	0.00
	6	366	36.34	2.52	48.16	132.54

36.34 percentage points, from 0.00% to 36.34% (Table 1). Deteriorated plants occurred in the last two years of exclusion (Figure 3).

The increase in basal cover during the exclusion period is congruent with the results of other experiments (Li *et al*., 2018; Bi *et al*., 2018; Wang *et al*., 2018). It is possible that rainfall influenced the behavior of the basal cover. In fact, a very small increase (0.23%) was associated with basal cover from the second to the fourth year of exclusion; notably, the increase was greater from the fourth to the sixth year (Table 1). Likewise, the volume of precipitation was 24% lower than the mean in the fourth year of exclusion, while precipitation in the sixth year was 21% higher than the annual mean (526 mm). In this context, Strand *et al*. (2014) point out that precipitation is a key element influencing basal cover behavior.

The dynamics of canopy cover changes were similar to those of basal cover during the exclusion period;

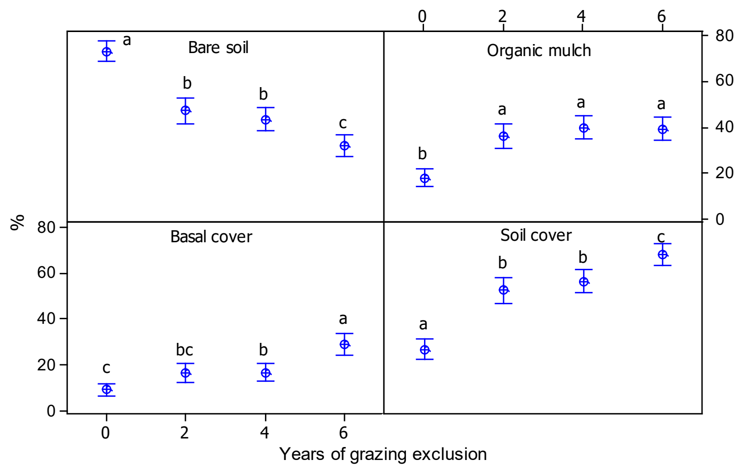

Figure 1. Percentages of mean basal cover, organic mulch, bare soil and soil cover in the SONP grassland during six years of exclusion. Means with different letters are different according to Tukey's test ($p<0.01$). Bars represent the mean ±1 standard error.

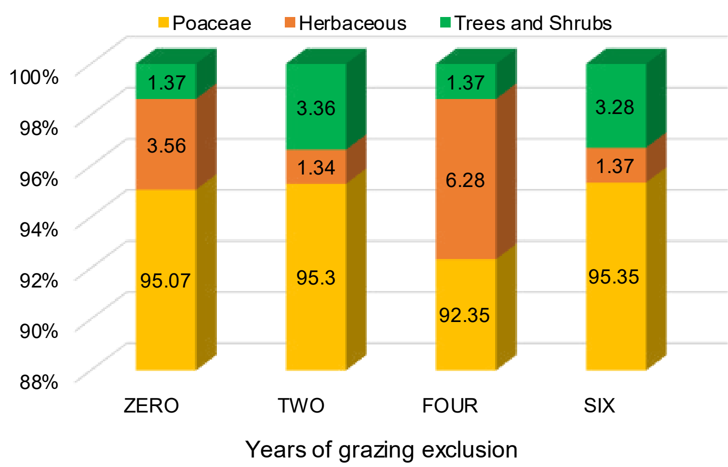

Figure 2. Percentage of functional plant groups in SONP grassland during six years of exclusion.

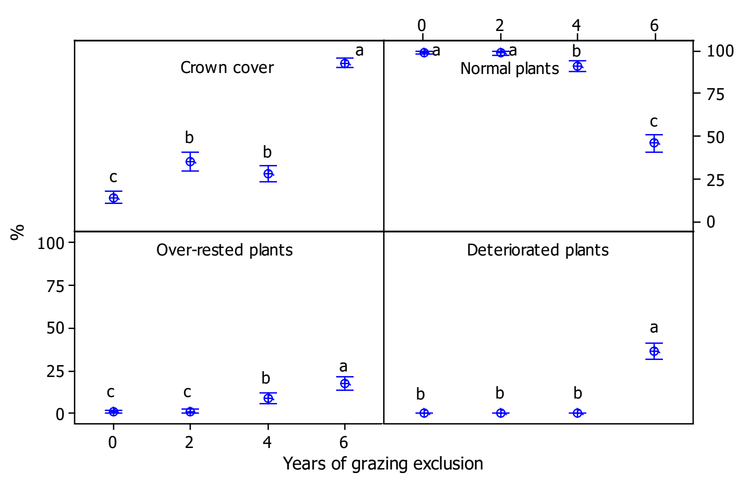

Figure 3. Percentages of crown cover of normal, over-rested and deteriorated plants in the SONP grassland during six years of exclusion. Means with different letters are different according to Tukey's test ($p<0.01$). Bars represent the mean ±1 standard error.

possibly, rainfall also influenced it. In addition, increasing crown cover increases the shaded area and decreases light toward Poaceae growing points, conditions that can inhibit plant growth (Li *et al*., 2018).

Poaceae make up the most prominent functional plant group in the exclusion area (Figure 2) because it is a grassland ecosystem. In addition, Poaceae, trees and shrubs changed non-significantly during the six years of exclusion. This result agrees with that observed by Molinar *et al*. (2011) in their study on grazing exclusion.

Increasing organic mulch is consistent with results from other studies on grazing exclusion (Zou *et al*. 2016; BI *et al*. 2018; Li *et al*. 2018; Hou *et al*. 2019). It is known that the increase in organic mulch originates from the accumulation of large quantities of plant material, which is not consumed by herbivores due to grazing exclusion. The accumulation of mulch damages Poaceae that have their growth shoots on the bottom of the plant, and these shoots may remain shaded and physically impeded from growing (Savory 2005). When mulch remains on the plant until the next growing season, almost all perennial grass species are weakened and, in fact, if the accumulation of dead matter persists for several years, the plant may die (Savory 2005).

Soil cover increased 155.08% during the grazing exclusion period due to the increase in basal and organic mulch cover. Organic mulch was the attribute that contributed most to the soil cover (Table 1). However, the basal cover should be the main component of the soil cover, due to the unfavorable effects caused by organic mulch when it accumulates for a long time.

Bare soil cover decreased throughout the exclusion time (Table 1). This result agrees with that observed by Jeo (2005), who identified that the amount of bare soil decreased with the exclusion of grazing. Also, Vermire *et al*. (2018) found less bare soil in exclusions than in areas grazed at 75% utilization.

The percentage of normal plants decreased because these organisms changed to over-rested plants and, in turn, these changed to deteriorated plants during the exclusion time. This trend was more noticeable after the second year of exclusion (Table 1). The change dynamics of plant form observed in this study agrees with those reported by Savory (2005), who states that over-rested plants contribute old plant material to the mulch and, in turn, change to deteriorated plants due to the effect of the mulch accumulated over several years, which prevents the growth of reproductive shoots.

Grazing exclusion after the second year began to be detrimental for the SONP grassland. In this regard, Weber and Horst (2011) report that some Poaceae in semi-arid areas have evolved with large herbivores. In addition, Poaceae and soil surface require small disturbances to maintain the health of their biotic communities, thus increasing soil organic matter (Savory 2005, Weber and Horst 2011), providing soil-covering mulch, and improving rainfall efficiency (Savory 2005).

CONCLUSIONS

Exclusion of grazing for six years in the SONP grassland increased basal cover, crown cover, organic mulch cover, soil cover, as well as the percentage of over-rested plants and deteriorated plants; also, grazing exclusion decreased bare soil cover and the percentage of normal plants. The increase in organic mulch cover, percentage of over-rested plants and deteriorated plants over six years demonstrates that the SONP grassland is transitioning into a less stable ecological state. The increase in organic mulch cover over six years implies the accumulation of combustible material and represents a potential risk for fires to occur in the SONP grassland.

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Supply Chain and Economic Viability of *Vanilla planifolia* Andrew Production: A Case Study

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ABSTRACT

Objectives: To characterize the supply chain of vanilla (*Vanilla planifolia* Andrew) in order to detect areas which could be improved and to determine the economic viability of its production.

Design/Methodology/Approach: The information was compiled through semi-structured interviews in a vanilla company. The Value Stream Mapping technique was used to describe the supply chain. Additional databases were consulted in order to obtain information on the production and commercialization of vanilla. The economic viability of vanilla production was analyzed with IRR.

Results: This case study had five phases in its supply chain. The IRR of cash flow in the traditional and technological production systems were positive, although the IRR of the traditional system was greater even though it had lower production volumes.

Study Limitations/Implications: It was observed that vanilla requires between 3 and 4 years for its first harvest, independently of the production system, traditional or technological, which means that there are negative cash flow numbers during the first two years in both systems, despite a positive IRR.

Findings/Conclusions: The critical stage in the supply chain of the company studied was the production. The cash flow for the technological system was superior when compared to the traditional system. However, the IRR for the technological system was lower, since the investment in shade cloth was not compensated by the discounted cash flows that could otherwise be obtained.

Keywords: value chain, IRR, vanilla.

INTRODUCTION

Vanilla (*Vanilla planifolia* Andrew) is native to Mexico, which was the sole producer during several centuries. Mexico benefited from the global monopoly of vanilla during colonial times. However, once the production was taken up in other countries thanks to the technique of manual pollination, described by Edmon Albius in 1836, and the principal component of its flavor and aroma was isolated by Nicolas-Theodore Gobley in 1958, the country started losing its international presence.

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Vanilla was primarily cultivated in the Papantla region, in the north of the state of Veracruz. Currently it is also cultivated in Chiapas, Oaxaca, Puebla, and San Luis Potosí. Vanilla is one of the most expensive species worldwide, and could cost up to $500 USD per kilogram. However, vanilla production in Mexico has decreased in recent years and was surpassed in production by Madagascar and Indonesia, which are the principal producers worldwide; nevertheless, there are ample opportunities for commercialization at a national and international level.

Some of the factors which have limited the expansion of Mexico's vanilla production are: the price of artificial substitutes, climate change, insecurity and product theft, and the damage caused by *Fusarium oxysporum* which causes mortality and limits the useful life of the areas cultivated. For Chopra and Peter (2008), the supply chain is integrated by all of the parties involved, either directly or indirectly, in order to satisfy the needs of clients. The agrifood supply chain, AFSC or FSC (Agri Food Supply Chain or Food Supply Chain) is responsible for the production and distribution of plant and animal products. This includes activities such as sowing and harvesting, processing, quality control, packaging, storage, transportation, distribution and commercialization (Granillo *et al*., 2012).

Van Der Vorst (2006) mentions that there are two primary food chains: that of fresh products and that of processed products. Additionally, Jeffee *et al*. (2010) propose that modern agrifood supply chains are networks that integrate the flow of physical and financial products, as well as information. When characterizing the agrifood supply chain, the following studies stand out: Ariadna *et al*. (2009), Castro and Colmenares (2011), Vargas Canales *et al*. (2015), and Bermúdez Avendaño (2016); these studies used surveys as methodology. Similarly, authors such as Cáceres and Escobar (2006) and Hernández-Mogollón *et al*. (2011) reference the Supply Chain Operational Reference Model (SCOR) for the characterization of the chain. In addition, other researchers such as Beshara *et al*. (2012) use a simulation technique. Based on the aforementioned, the objective was to characterize the supply chain of vanilla (*Vanilla planifolia* A.), to detect areas which could be improved and to determine the economic viability of its production in order to boost the sowing and harvesting process in Mexico.

MATERIALS AND METHODS

The methodology included two parts. In the first part the tools used to describe the supply chain were established, and in the second the techniques used to analyze the economic viability of its production.

Once the techniques used by different authors in order to describe the agrifood supply chain were analyzed, it was decided to carry out a field study by using semi-structured interviews with the actors involved in the vanilla supply chain. It should be noted that the semi-structured interview technique was chosen because it allows for flexibility while keeping with a basic interview structure. Questions were divided into two parts. The objective of the first part was to get to know the system of sowing, recollection, distribution, and customer service. The aim of the second part was to determine the implicated costs and income obtained. The members of the Santa Beatriz Ranch in Papantla, Veracruz, Mexico were interviewed.

After the interviews were carried out, the Value Stream Mapping (VSM) technique was used in order to graphically observe the specific actions that were required to cultivate vanilla and get it to the final client. Through the four stages of VSM (Figure 1), it was feasible to detail and to understand the flow of raw materials and of the information required in the process, as well as to map the activities which did or did not generate additional value, with the aim of finding areas which could be improved and reducing economic losses which could be generated in the process.

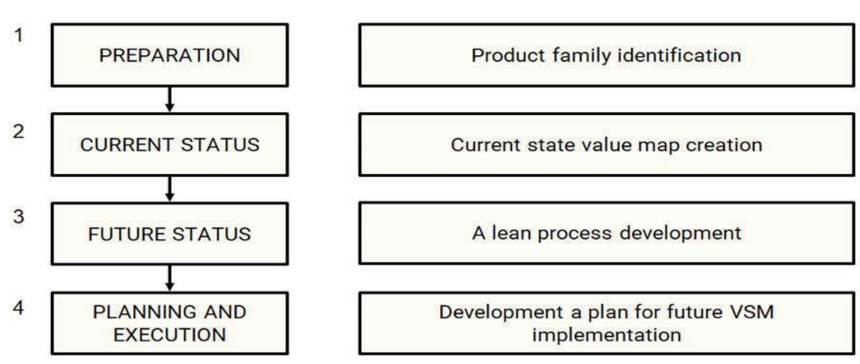

Figure 1. Stages of Value Stream Mapping (VSM). Prepared by authors based on Locher (2008).

By using sources such as SIAVI (from Spanish, *Sistemas de Información Arancelaria Vía Internet* or Internet Based Tariff Information Systems), UN COMTRADE Database, ITC (International Trade Center), SIAP (from Spanish, *Servicio de Información Agroalimentario y Pesquera*, or Agrifood and Fishing Industry Information Services), and FAO (Food and Agriculture Organization), information was gathered in order to better understand the status of vanilla production at a national and international level. In order to analyze the economic viability of vanilla production in the Santa Beatriz Ranch, the internal rate of return (IRR) was used, which represents the geometric mean of future income expected from an investment. The IRR is defined as the discount rate which makes the present net cash flow rate equal to zero. The equation for IRR is shown below. In this equation *VAN* is the current net value, *I* is the investment, and *Ft* is the cash flow of period *t*.

$$VAN = -I + \sum_{t=1}^{n} \frac{Ft}{(1+TIR)^t} = 0 \qquad (1)$$

RESULTS AND DISCUSSION

According to data from the Agrifood and Fishing Industry Information Services, around 58% of the surface of Papantla is dedicated to agriculture, although vanilla only occupies 0.41% of the available surface for farming, which is much lower than the surface devoted to sowing maize (31%), orange (18%), lime (2.2%) and banana (1.8%). The Santa Beatriz Ranch is an agrifood business dedicated to producing vanilla, pepper and citruses, as well as the production of natural vanilla extracts and other natural vanilla products. It should be mentioned that it is the only business in the region devoted to processing vanilla, with more than ten years of experience.

It should be highlighted that one of the most relevant problems brought forth during the interviews is the elevated sales price of sowing vanilla, which stimulates theft and generates insecurity for its sowers. Similarly, it became evident that in Papantla, vanilla is cultivated as a secondary product, since farmers plant it as a tradition, which became clear since from the 100 ha arable in the ranch, only 800 m^2 are used for vanilla.

The description of the supply chain of vanilla production in Santa Beatriz Ranch shows similar elements to other supply chains found when reviewing the literature presented in the second section; however, there are also some distinctive features (Figure 2).

The vanilla production supply chain consists of five links (suppliers, production, transportation, commercialization and the final client).

The link of suppliers includes both those that supply the raw materials —such as fertilizers, insecticides, farming material, cuttings, tutors, etc.— as well as the different sources of financing. It should be mentioned that the producer should have economic solvency since there are very few bank loans for agricultural producers, with high interest rates, although the federal government has implemented different programs such as: Production for Welfare, and the National Program for Fertilizers and Life Sowing, which are focused on the development of small-scale agricultural producers.

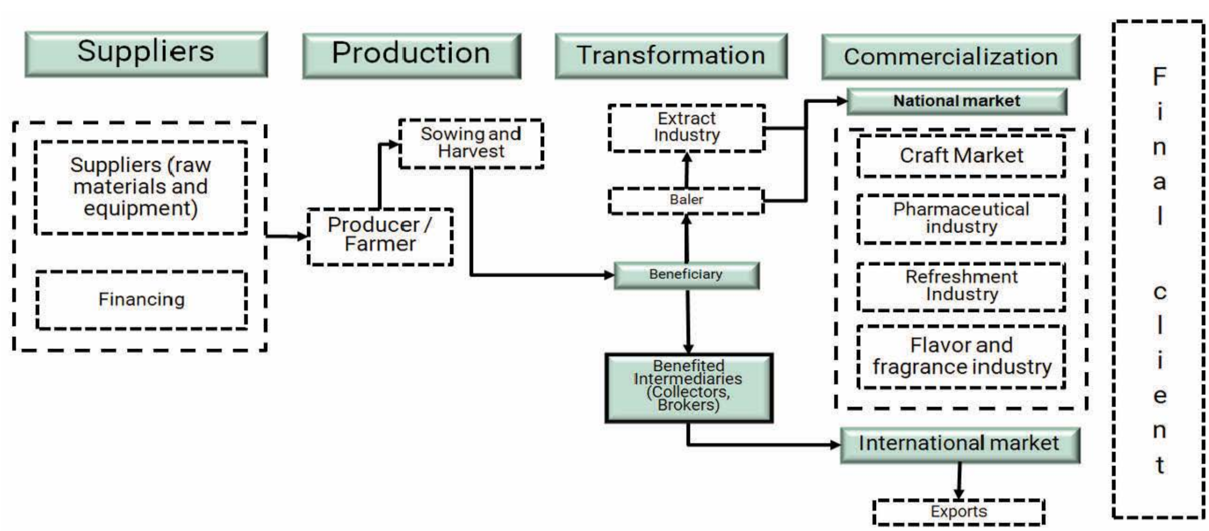

Figure 2. Description of the vanilla supply chain. Prepared by authors.

The link of production includes vanilla sowing and harvesting by the farmers. The starting point for production is the seedling, or cutting, from which the plant develops and afterwards, the fruit. Since vanilla is a climbing orchid, the use of trees or some substitute is necessary, which are called tutors. It is worth mentioning that there is a lack of integration of producers, since each one prompts the sale of cuttings, whose price varies depending on its quality. There are two systems for vanilla production: the traditional system or *acahual* system, which is the most widely used because of its low cost, and the technological system or with use of shade cloth.

In the transformation link there are different processes, the primary one being processing or curing, which lasts two to three months and consists of eliminating water by means of dehydration, oven-cooking and sun-drying. This process includes receiving, scuffing, classifying, placing in wooden crates for sweating, sun-drying, selecting, unloading and packaging. Once this process is finished, the product is sent for transformation where vanilla essence and other natural byproducts are obtained.

The commercialization link entails selling cured vanilla, vanilla extract and handcrafts by means of different local intermediaries, retail and wholesale, which make if possible for the product to reach its final consumer. Intermediaries carry out their activities in local, national and international markets. The national demand for vanilla is 100% covered by national production and its exportation is carried out by agents who service, generally, small and medium scale producers.

The final client link is made up of all the companies that use vanilla in its different presentations. This includes companies that produce different vanilla-based products, such as soft drinks, pharmaceuticals, ice-cream, liquors, wines, essences, lotions, etc.

The economic viability analysis of vanilla production using cash flows that was obtained during the interview process and calculated using the internal rate of return (IRR) of the two production systems (traditional or *acahual* and technological or shade cloth) showed that the time frame for economic viability analysis is ten years. Included in the production cost analysis are labor costs and those generated from farming vanilla for the first time; therefore, first harvest planting costs are taken into account without including funding costs, machinery, or area used for sowing vanilla. These are considered sunk costs, meaning expenditures which have already been incurred, and have already been devalued and used on a previous project and therefore are not relevant for decision making in vanilla farming, in either of the production systems which will be analyzed. However, it should be pointed out that there is an implicit opportunity cost by using those resources.

Table 1 shows the calculation of economic profitability of harvesting approximately 350 kg of vanilla using the tradition or acahual system during ten years. It is to be noted that in order to obtain 1.0 kg of cured vanilla, approximately 6 kg of green vanilla are necessary.

The direct cost of raw materials during the first year increases due to the cost of cuttings which must be used (Table 1). Either way, during the second year direct

Table 1. Return on investment of harvesting 350 kilograms of vanilla under the traditional or acahual production system (units in pesos).

Year	1	2	3	4	5	6	7	8	9	10
Orange	22230	22230	22,230	22,230	22,230	22,230	22,230	22,230	22,230	22,230
Cuttings	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000	90,000
Vanilla benefited	-	-	495,000	495,000	495,000	495,000	495,000	495,000	495,000	495,000
Total income	112,231	112,231	607,230	607,230	607,230	607,230	607,230	607,230	607,230	607,230
Direct Labor	144,000	276,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000
Direct Raw Material	36,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Direct expenses	19,075	18,045	18,045	18,045	18,045	18,045	18,045	18,045	18,045	18,045
Indirect expenses	15,000	15,0,231	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Total expenses	214,075	315,045	183,045	183,045	183,045	183,045	183,045	183,045	183,045	183,045
Net flow	-101,845	-202,815	424,185	424,185	424,185	424,185	424,185	424,185	424,185	424,185
IRR	103.17%									

Table 2. Return on investment of harvesting 500 kilograms of vanilla under the technical system or shade mesh (units in pesos).

Year	1	2	3	4	5	6	7	8	9	10
Cuttings	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000
Vanilla benefited	-	-	825,000	825,000	825,000	825,000	825,000	825,000	825,000	825,000
Total income	120,000	120,000	945,000	945,000	945,000	945,000	945,000	945,000	945,000	945,000
Direct Labor	144,000	276,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000	144,000
Direct Raw Material	36,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Direct expenses	272,105	18,025	18,025	18,025	18,025	18,025	18,025	18,025	18,025	18,025
Indirect expenses	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Total expenses	467,105	315,025	183,025	183,025	183,025	183,025	183,025	183,025	183,025	183,025
Net flow	-347,105	-195,025	761,975	761,975	761,975	761,975	761,975	761,975	761,975	761,975
IRR	88.99%									

labor costs increase because of pollination which has to be carried out on the crops. It should be mentioned that farmers in this type of system use orange trees as tutors.

During the first two years there is no income since vanilla production dues not start until the third year or depending on agro-climatic conditions until the fourth year; therefore, positive cash flow is not seen until the third year (Table 1). In the traditional or acahual production system there is the added benefit of orange production, which is used as a tutor; therefore, this income is included in the analysis. Likewise, the IRR is 103.17% which means that vanilla farming is profitable, and if sources of funding are available with lower costs than this percentage vanilla production would still be profitable.

Table 2 shows the calculation of the profit margin from harvesting approximately 500 kg of vanilla using the technological or shade cloth production system for ten years, and as shown, the production amount is not the same as that used in the profitability analysis of the traditional or acahual production system (350 kg). This is because the same number of hectares is used in both systems and, therefore, it is possible to compare profitability.

The price of direct raw material increases due to the cuttings used. Likewise, the direct labor costs increase during the second year because of crop pollination. As shown, the direct labor and raw material costs in both production systems are the same. However, the indirect costs are significantly increased during the first year due to the investment required to acquire shade cloth.

During the first two years there is no income from the sale of cured vanilla, since the use of shade cloth does not make the plant ready for production sooner. It is important to highlight that using the technological production system or shade cloth there are no benefits from orange production, since shade cloth is used as a tutor, and therefore this income is not included in cash flow. Still, the IRR is 88.99%, which implies that the technological production system is profitable, even taking into account the financial cost from different sources and it would still be profitable, as long as the cost of financing is less than 88.99%.

When comparing the IRR, both systems are profitable and since they have high sunk production costs they are a good alternative to utilize resources which otherwise could be idle. Nevertheless, if there are alternative projects whose IRR is higher than 88.99%, resources could be used in those projects and vanilla production could be abandoned. Even though cash flows for the technological system are higher by almost 80% when compared to the traditional system, the IRR of the former is lower due to the high cost of shade cloth which has to be acquired in the first year and is not compensated with the increased cash flow after the third year. And even though it is out of the reach of this analysis, the different volumes of production and its inherent complexity should be taken into account, something related to the activities associated with the production systems and additional activities.

CONCLUSIONS

Using the VSM technique, the vanilla supply chain showed that it is made up of five links and it was possible to describe the flow of raw materials and information required in its process, as well s to map out the activities which did or did not generate additional value. The economic profitability of cultivating vanilla using the traditional system reported an IRR of 103.17%, compared with 88.99% with the technological system. Both systems have negative cash flow during the first two years since vanilla cannot normally be harvested until the third or fourth year. The amount of vanilla produced in the technological system is higher (42.85%) than the traditional system, but the latter has the additional product of oranges.

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Characterization of Sheep Farming in Agroecosystems of Indigenous Communities in Campeche, Mexico

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RESUMEN

Objetivo: Caracterizar la ovinocultura en los agroecosistemas de productores indígenas que recibieron financiamiento por la Comisión Nacional para el Desarrollo de los Pueblos Indígenas (CDI), en Campeche, México.

Diseño/metodología/aproximación: Se diseñó un cuestionario con características socioeconómicas y técnicas y se aplicó a 199 productores agrupados en 27 unidades de producción ovina, distribuidos en siete municipios de Campeche.

Resultados: La ovinocultura de las comunidades evaluadas se caracteriza por el pastoreo extensivo, bajo nivel tecnológico, carencia de infraestructura, y alta participación de la mujer en edad productiva que tienen disponibilidad para aprender e implementar innovaciones y tecnologías. El sistema de producción es tradicional enfocado a repoblar los rebaños, son medio de ahorro, autoconsumo, sin registros productivos y reproductivos. Los productores están dispuestos a implementar estrategias que contribuyan a mejorar sus unidades productivas.

Limitaciones/implicaciones: Las políticas de apoyo, así como esquemas de capacitación deben ser diferenciadas entre la ovinocultura indígena y la tradicional.

Hallazgos/conclusiones: Las unidades de producción ovina tienen infraestructura inadecuada para el manejo del rebaño, existe conocimiento limitado para un manejo adecuado, no hay registros de control y se clasifican como sistema de producción tradicional.

Palabras clave: Ovinos, razas, unidades indígenas de producción

ABSTRACT

Objective: To characterize sheep farming in agroecosystems of indigenous producers who received financing from the National Commission for the Development of Indigenous Peoples (Comisión Nacional para el Desarrollo de los Pueblos Indígenas, CDI) in Campeche, Mexico.

Design/Methodology/Approach: A questionnaire was designed with socioeconomic and technical characteristics and was applied to 199 producers grouped into 27 sheep farming units, distributed among seven municipalities of Campeche.

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Results: Sheep farming in the evaluated communities is characterized by extensive grazing, a low technology level, lack of infrastructure, and high participation of women of productive age that are available to learn and implement innovations and technologies. The production system is traditional and focused on repopulating flocks, which are a means of savings and auto-consumption, without productive and reproductive records. Producers are willing to implement strategies that contribute to improving their farming units.

Study Limitations/Implications: Support policies, as well as capacity-building plans, should distinguish between indigenous and traditional sheep farming.

Findings/Conclusions: The sheep farming units have inadequate infrastructure for flock management, they demonstrate limited knowledge for their adequate management, there are no control records, and they are classified as a traditional farming system.

Key words: Sheep, breeds, indigenous production units.

INTRODUCTION

Sheep farming in the southeast of Mexico is a mostly mixed-system activity that combines agriculture with animal husbandry. The aim of these systems is to sell animals and artisanal craftwork, produce wool for elaborating indigenous garments, and recycle nutrients by using livestock manure to fertilize crops (Gómez-Castro *et al*., 2011). As such, sheep farming is important for the food security of isolated regions and marginalized populations (Pérezgrovas and Castro, 2000). In Mexico, 11.6% of indigenous women do not have economic income, 32% have income lower than the minimum wage, 28% earn from one to two minimum wages, and 16% earn more than two minimum wages (CONEVAL, 2011). These figures indicate that the indigenous population requires support and finance schemes that are easily accessible which would allow them to improve their productive processes in order to develop their economic activity. Starting in the 2014 fiscal year, the Program for Improving Indigenous Production and Productivity (*Mejoramiento de la Producción y Productividad Indígena*, PROIN) was created as a governmental strategy to increase income, training, and employment opportunities in indigenous communities, fostering the consolidation of productive and tourist projects as well as food security to benefit the indigenous population, organized in groups, societies or businesses, that resides in localities with 40% or more of indigenous population; and to improve their monetary and non-monetary incomes while creating conditions for equality between women and men (CDI, 2014).

In Campeche, Mexico, PROIN financed projects for sheep breeding among organized groups made up of 60% women and 40% men, with the objective to improve their economic income. Backing for sheep farming was given assuming that the agroecological conditions of the state are adequate for its production, and that there is presence of breeds like Pelibuey and Blackbelly. Because of their rusticity and prolificacy, resistance to internal and external parasites, and adaptation to environmental conditions in precipitation and high temperatures (Nuñez-Domínguez *et al*., 2016), they are an option for food production for auto-consumption and commercialization. Currently, there is a lack of information regarding the state of sheep farming systems in Campeche that were supported by the National Commission for the Development of Indigenous Peoples (*Comisión Nacional para el Desarrollo de los Pueblos Indígenas*, CDI). Based on this, this study characterized sheep farming in the agroecosystems of indigenous communities supported by the CDI-PROIN program.

MATERIALS AND METHODS

The study was conducted from October to December 2015 with the participation of 199 producers grouped into 27 sheep farming units (SFU) and distributed in seven municipalities of the state of Campeche (Table 1). The municipalities are located between parallels 19° 14′ and 20° 00′ N, and 89° 50′ and 90° 42′ W, at 260 m altitude. The climate is sub-humid warm with summer rains (García, 1988), with temperatures between 26° and 30 °C and annual precipitation between 1200 and 2000 mm.

To characterize sheep farming, a questionnaire was designed and applied with semi-structured questions considering socioeconomic and technical characteristics. The first questions asked age, education, years active, importance of sheep farming, land tenure, type of sheep commercialization, number of animals sold per year, annual income from sale of sheep, current size of flock, land surface designated for sheep, breeds used, productive purpose, type of labor

Table 1. Municipalities granted financial support to raise sheep by the CDI-PROIN 2014-2015 program, in Campeche, Mexico.

Municipality	Number of towns	Households/Town		Farmers	
		Number	Percentage	Number	Percentage
Campeche	7	10	37.0	68	34.2
Hopelchén	2	2	7.4	17	8.5
Calkiní	1	1	3.7	8	4.0
Calakmul	3	3	11.1	21	10.6
Carmen	3	5	18.5	40	20.1
Candelaria	4	4	14.9	28	14.1
Champotón	1	2	7.4	17	8.5
Total	21	27	100	199	100

Source: Comisión Nacional para el Desarrollo de los Pueblos Indígenas (CDI), Campeche, 2015.

employed, infrastructure, and equipment. For technical characteristics, the questionnaire inquired about reproductive management, feeding, sanitation, technical assistance received, and water management. The information was obtained directly from the members of each group, and direct observation was also made on the management and available infrastructure of the sheep farming units. The data were analyzed with the Statistica software, version 7.1 (StatSoft, 2005).

RESULTS AND DISCUSSION

General Characteristics of Farmers

In the state of Campeche, 80% of sheep farmers that were supported by the CDI-PROIN Program consider sheep farming to be a secondary economic activity and as a "savings account" (Table 2), which agrees with that indicated by Gaspar *et al*. (2016). The other activities carried out by the farmers are domestic (75%), agricultural (18%), commercial (6%), and academic (1%). This is a similar situation to that of the farmers given support to purchase sheep through investment subsidies from the Program for Promoting Family Sheep Farming in the Estado de México (Martínez-González *et al*., 2011). Despite this, these systems contribute more than 30% of total monetary income and auto-consumption among family sheep production units (Nahed-Toral, 2002), and the producers perform other activities to cover family expenses (Nuncio-Ochoa *et al*., 2001). The producers have little experience in sheep farming: on average, 1.5 years; this is due to them having started in this activity because of the CDI financial support to acquire sheep.

The participation of women represented 78.4% of members in the production unit, and is the result of the CDI program's gender focus. Women's observed participation is more than the 10-13% indicated by Vélez *et al*. (2016), and more than the 30% observed in Valle del Mezquital, Hidalgo (Vázquez-García, 2014). Because they are a small species, raising sheep requires less space compared to cattle, their management is easier, and the majority of small flocks are close to or on the backland of producers' houses. This favors greater participation of women in the care and management of the flock, as they divide their attention between livestock and domestic chores.

All farmers interviewed speak an original language, either Maya (67%), Chool (24%), Mam Ixil, Totonaca or Tzental (9%), which coincides with that reported by Perezgrovas and Castro (2000) among rural sheep farmers in the state of Chiapas; this confirms that the support provided by the CDI in Campeche has benefitted the target population, and that it is necessary to consider it in training activities and the design and implementation of new projects. In other words, this affirms that the backing has managed to reach the target groups; however, production and

Table 2. Socioeconomic characteristics of indigenous farmers granted financial support to raise sheep by the CDI-PROIN 2014-2015 program, in Campeche, Mexico.

Variable	Mean ± S. D.
Age (years)	38.7 ± 6.3
Education (years in school)	2.4 ± 0.5
Experience raising sheep (years)	1.4 ± 0.8
Total land owned (ha)	21.0 ± 10.6
Land used for raising sheep (ha)	5.9 ± 3.7
Heads owned (number)	92.8 ± 52.2
Heads sold per year (number)	15.3 ± 14.1
Net income from sheep sales ($)	18 305 ± 17 389

S.D.= Standard deviation.

capacity-building plans for indigenous farmers should be differentiated from conventional sheep farming because the socioeconomic, geographic, cultural, and technological conditions of these social groups are different. The importance of this study emerges from this, with the aim of contributing to this aim.

The average age of farmers was 38.7 years, and only 4% were older than 50, indicating a favorable age group for adopting technology and innovation (Borroto *et al*., 2011), which could be advantageous for authorities in charge of following up on the backing granted. In education, 63% have primary school studies, 29% have secondary school studies, 7% have upper school studies, and 1% college studies, similar to that reported by Vélez *et al*. (2016). Because of the educational level and considering that the majority do not speak Spanish, access to sources of information (electronically) is limited, and therefore it is necessary to implement innovative strategies in training and technology transfer; for example, the use of illustrations with images for better comprehension, as well as written text in the local language.

The average number of sheep per farmer group was 49.4 heads with a range of 15 to 105, of which 78.3% are Pelibuey × Blackbelly crosses, and 21.7% are Pelibuey × Kathadin crosses. Sixty-eight percent (68%) of studs used are Pelibuey, 17.9% Dorper, 7.1% Kathadin, and 7.0% Blackbelly, which indicates a preference for Pelibuey animals due mainly to their prolificacy and rusticity (Nuñez-Dominguez *et al*., 2016); 59.3% of the production units have the goal of producing females for breeding, due to the interest in increasing the size of flocks, while only 22.2% of the animals are occasionally traded, and 18.5% are used for auto-consumption. This is similar to that found by Vázquez-García (2014).

The total workforce used is family labor, with important participation from women in livestock activities, and caring for the animals is done by the majority of family members, similar to what sheep-raising families do in the states of Veracruz (Pérez-Hernández *et al*., 2011) and Hidalgo (Vázquez-García, 2014). The producers sell their live animals at low prices (US$1.6 to US$2.1 kg of live weight). They trade ewes with one to two births, and year-old lambs, weighing approximately 38 to 40 kg; sales are made within the same production unit.

At the time of the study, all production units had management pens and food and water troughs, built with local materials. They also had spaces to shelter the animals, although 90% of the production units did not have adequate pens for each productive stage of the flocks; they lacked equipment and only 30% possessed agricultural machinery and basic equipment.

This situation is similar to what predominates in farming systems in Tabasco (Nuncio-Ochoa *et al*., 2001) and Campeche (Dzib-Can *et al*., 2006), and in general, it is similar to all of south and southeastern Mexico, which departs notably from sheep farming on the high plateau and north of Mexico, characterized by technological components and adequate infrastructure that allows for maintaining a greater number of animals in less space.

Of the farmers, 74% have an extensive farming system and 70% feed their sheep with grass. Twenty-one percent (21%) provide crop residues as well, and just 9% use a commercial balanced feed (Galaviz-Rodríguez *et al*., 2011). All sheep production units employ continuous breeding, similar to that reported in the state of Campeche (Dzib-Can *et al*., 2006) and Veracruz (Pérez-Hernández *et al*., 2011). The rate between the number of males for every female was 1:4, a proportion higher than the 1:25 that farmers with high technology levels implement, but similar to that of farms with medium to low technology levels (Dzib-Can *et al*., 2006), and this indicates the possibility of improving their breeding management.

All of the farmers have trained in basic organization and administration by way of CDI community promoters, but only 22.2% have been instructed on sheep management, principally on feeding, breeding, and sanitation themes; and the same producers mention that they require technical assistance and specialized training in parasite control, prevention and treatment of disease, forage conservation, and the establishment of agrosilvopastoral systems using local resources. With respect to this, it is considered important to promote environmentally-friendly farming by establishing agrosilvopastoral systems based on local resources, and taking advantage of the empirical experience of producers and the knowledge they possess about plants and their fruits. This way, through participative research, the species with potential to be used can be identified, selected, and evaluated directly in the production units (Villa-Herrera *et al*., 2009). Some plants that are locally available, and which farmers consider to be important to promote in order to complement the sheep's diet are West Indian elm (guácimo or pixoy, *Guacima ulmifolia* Lam.), breadnut (ojite, *Brosimun alicastrum* Swartz.), and river tamarind (guaje, *Leucaena leucocephala* (Lam). de Wit).

Only 3% of the production units evaluated keep productive and reproductive records; the rest do not record information, but they are interested in learning its use in order to improve. This is similar to the situation in Yucatán (Góngora *et al*., 2010) and Veracruz (Pérez-Hernández *et al*., 2011). Seventy-five percent (75%) of water provided to the flocks arrives by haulage to the farming unit, 15% is obtained from a well, and only 10% from the local drinking water system, which is similar to that reported by Pérez-Hernández *et al*. (2011) for communities in Veracruz. The former suggests the need to plan infrastructure for rainwater capture in the production units.

CONCLUSIONS

The sheep production units characterized lack adequate infrastructure for flock management. The support policies, as well as training plans, should be differentiated between indigenous and traditional sheep farming. Women's participation in raising sheep is high, and they have great willingness to learn and implement innovations and technologies. They lack basic knowledge in managing flocks and as a consequence, the production system is traditional, without control records. The producers want to continue in the activity and are willing to implement strategies that contribute to improving the production units.

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Spatial variability of some chemical properties of a Cambisol soil with cocoa (*Theobroma cacao* L.) cultivation

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ABSTRACT

Objective: To evaluate the spatial variability of some chemical properties of a Cambisol soil, in order to establish specific agronomic management zones for cocoa cultivation.

Methodology: A sampling of 42 georeferenced points equidistant at 40 m was carried out. Geostatistical variability maps were made with the results of the chemical analysis of the soil properties, using the ordinary Kriging interpolation technique.

Results: It was found that the percentage of saturation of acidity (PSA), acidity and H+ showed high variability; P-Olsen and interchangeable K, Ca and Mg displayed medium variability, and pH, MO, CIC and Al presented low variability. Soil properties pH, PSA; Exchangeable P-Olsen, Ca and Mg showed high spatial dependence (<25%) and OM, exchangeable K and CIC moderate spatial dependence (25-75%).

Study limitations/Implications: The generated maps allowed the identification of partial areas with different variability, as well as the direction of greatest variability of the property as a function of distance.

Conclusions: With the maps, it was possible to make recommendations for agronomic management depending on each specific management area.

Keywords: Cambisol, variability, recommendations, site-specific, cocoa, Kriging.

INTRODUCTION

The variability of the chemical and physical properties of the soil is an inherent condition, due to the fact that several processes intervene in its formation that, in turn, are controlled by the formation factors (climate, parent material, organisms, topography and time) (Jaramillo, 2010; Ovalles, 1992). In the state of Tabasco, the area cultivated with high-density cocoa plantations is expanding, which will imply a greater consumption of nutrients in the future. As there are no studies on the management of the spatial variability of the chemical properties of soils, the objective of this study was set to determine the spatial variability of the chemical properties of a Cambisol soil cultivated with cocoa to establish specialized management zones, which will allow the proper use of fertilizers, contributing to improve or maintain soil fertility.

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Imagen de Daniel Dan outsideclick en Pixabay

MATERIALS AND METHODS

The study was carried out in a 7-ha area cultivated with cocoa (the INIFAP-8 clone) at a high (2700 plants ha^{-1}) plantation density; with drip irrigation, located in Ranchería Caobanal, 2nd section, in the municipality of Huimanguillo, Tabasco.

Sampling sites were established from of a grid of 42 equidistant nodes (set every 40m), which were plotted at the office and subsequently, reframed in a field by using a GPS +/− 1 m accuracy. Samples were collected from 0 to 30 cm soil depth with a stainless-steel auger (Dutch type). For each sample, two subsamples were taken to obtain a weight of 1.0 kg soil (Salgado *et al*., 2013). The samples were analyzed in the soil fertility laboratory of Colegio de Postgraduados, Campus Montecillo. Determinations of soil reaction (pH) in water 1: 2 relation, electrical conductivity (EC), organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and interchangeable Aluminum (Al) were carried out with the methods established in the NOM-021-RECNAT (2001). The percentage of acidity saturation (PSA) was calculated with equation 1:

$$PSA = \frac{Acidity\ meq/100g}{(Acidity + Ca + Mg + k)meq/100g} \times 100 \quad (1)$$

For the chemical properties, the variability analysis was performed according to descriptive statistics, and the measures of central tendency and dispersion were determined. With these, the number of samples that should be taken to obtain the value of each parameter was calculated (Acevedo *et al*., 2008). Shapiro-WilK and Kolmorov-Smirnov (Jaramillo, 2011) normality tests were performed while outliers were determined by the box-and-whisker plot, and these were replaced by the mean of the neighbors following Jolliffe (2002). The geostatistical analysis was performed, calculating the experimental semi-variance values with Equation 2:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(Xi) - Z(Xi + h)]^2 \qquad (2)$$

Then, the experimental semivariogram was fitted to the theoretical semivariogram using the graphical method (Gotway and Hartford, 1996). With the theoretical model and the value of the parameters of the experimental semivariogram, the Kriging interpolation method was applied to obtain the distribution maps of the values of the variables in the study area, using the Vesper geostatistical program as well as the geostatistical modules of R (R Team, 2015) and ArcGis v. 9.0. (ESRI, 2012).

RESULTS

Statistical analysis of the data

The values of central tendency and dispersion for each of the variables are presented in Table 1. The pH presented the lowest variability (3.5%), while the highest variability was presented by Acidity (92.9%), H+ (92.7%) and PSA (154.6%). The observed variability values are similar to those found by Acevedo *et al*. (2008) and Salgado-Velázquez *et al*. (2020), with less variability pH (3.7%) and OM (25.5%); and with the highest variability, P-Olsen (53.6%) and K (70%).

Most of the analyzed properties had a distribution where the means and medians were similar (slightly asymmetric) except pH, MO, P-Olsen and K.

In all the studied properties, the kurtosis was greater than two except Ca and Mg, that showed a bias towards the right. This asymmetry is greater for P-Olsen, K, Zn and Mg. Regarding the bias, only the pH, MO, P-Olsen, K, Ca and Mg, presented values very close to zero. This means a clear asymmetric behavior of the data distributions. To corroborate the above, the Shapiro-Wilk and Kolmogorov-Smirnov goodness-of-fit tests were performed (Acevedo *et al*., 2008). Of the two tests, it was only agreed that the P-Olsen, K and the CIC, were adjusted to a normal distribution. The box-and-whisker plot and the analysis of the spatial distribution showed that the detected outliers were the main cause of the high values of asymmetry, kurtosis and CV, as well as of the non-normality at these distributions (Rodrigues *et al*., 2013a). Outliers then were replaced by the mean of the neighbors following Jolliffe (2002).

The minimum number of samples (n) to obtain the average value of the variable with a 5% error rate, except for the pH, MO and CIC, proved excessive, expensive and impractical (Table 2), underestimating in this study, P-Olsen, K, Mg, PSA, Acidity, Ca, H and Al, while pH, OM, and CIC were overestimated.

Geostatistical analysis of soil chemical properties

For all properties, the variograms were adjusted considering the distribution as isotropic. The best fitted variograms were selected based on the mean

Table 1. Central tendency and dispersión values for the soil chemical and physical properties.

Soil property	Min. value.	Max. value.	Range	1st. Q	3rd. Q	M	Me	Variance	SD	CV(%)	S	K	SW	KS
pH	3.9	4.5	0.6	4.1	4.3	4.2	4.1	0.02	0.14	3.5	-0.04	2.5	0.061	0.0035
PAS (%)	0.0	35	35	1	6.5	6.2	2.0	91.3	9.5	154.6	1.8	4.9	<0.001	<0.001
SOM (%)	1.5	2.8	1.36	2.0	2.4	2.2	2.1	0.08	0.29	13.3	0.09	2.7	0.866	0.0432
P (ppm)	4	46	42	17	29	23	24	72.1	8.5	36.9	0.02	3.1	0.891	0.4484
K (meq/100 g)	0.28	0.99	0.70	0.43	0.68	0.56	0.53	0.03	0.18	33.1	0.47	2.2	0.080	0.2435
Ca (meq/100 g)	0.82	14.8	13.9	3.1	10.1	6.7	6.4	15.9	3.9	59.7	0.18	1.9	0.040	0.1339
Mg (meq/100 g)	0.37	5.1	4.7	1.4	3.7	2.5	2.6	1.7	1.3	52.2	-0.07	1.7	0.043	0.1209
CEC (meq/100 g)	13.5	24.0	10.5	17.3	19.9	18.6	18.5	5.6	2.4	12.8	-0.08	2.8	0.8375	0.4775
Acidity (meq/100 g)	0.0	1.2	1.2	0.13	0.50	0.35	0.25	0.10	0.32	92.9	1.07	3.1	<0.001	<0.001
H (meq/100 g)	0.0	0.5	0.5	0.013	0.19	0.12	0.10	0.01	0.11	92.7	1.1	4.4	<0.001	0.035
Al (meq/100 g)	0.0	0.7	0.7	0.07	0.36	0.22	0.15	0.21	0.05	20.9	0.98	2.7	<0.001	<0.001

M=Median, Me=Media, S=Skewness, K=Kurtosis, SD=Standar deviation, SW=Shapiro-WilK y KS=Kolmogorov-Smirnov.

square error (RMSE) and the Akaike criteria (AIC) using VESPER 1.6 (Minasny *et al*., 1999; Rodrígues *et al*., 2013a). In addition, the Spatial Dependency Index (SDI) was calculated, which is the relationship between the variance of the nugget effect and the sill (Cambardella *et al*., 1994) for each variogram, and expressed as a percentage (Table 3).

The semivariograms indicated that the semi-variance increases as distance increases (Figures not shown). These results agree with what was reported by Acevedo *et al*. (2008), who estimated the distribution of K, P, OM and pH, and found that the semivariograms presented spatial correlations; that is, the semi-variance increases as the distance increases. It is observed that the pH, PSA, P-Olsen, Ca and Mg presented an SDI that is considered high according to Cambardella *et al*. (1994), and moderate for the other soil properties. These results were similar to those reported by Arévalo-Hernández *et al*. (2019), in a cocoa plantation established as an agroforestry system.

Kriging

The distribution of the variability of the chemical and physical properties of the soil is depicted in Figure 1, and the cross-validation to all the adjusted semivariograms and the prediction errors are shown in Table 3, which are discussed below for each soil property.

Table 2. Calculation of the mínimum number of determinations to be made to obtain the averege value of the variables with certain presicion.

Soil property	t value 0.05/2	Error	Error (d^2)	NS
pH	2.0195	0.05	0.0441	1.0
PAS (%)	2.0195	0.05	0.0955	3901.0
SOM (%)	2.0195	0.05	0.0123	28.0
P (ppm)	2.0195	0.05	1.3225	222.0
K (meq/100 g)	2.0195	0.05	0.0007	203.0
Ca (meq/100 g)	2.0195	0.05	0.1102	591.0
Mg (meq/100 g)	2.0195	0.05	0.0163	443.0
CEC (meq/100 g)	2.0195	0.05	0.8714	27.0
Exchangeable acidity (meq/100 g)	2.0195	0.05	0.0003	1437.0
H (meq/100 g)	2.0195	0.05	0.00004	1346.0
Al (meq/100 g)	2.0195	0.05	0.0001	8715.0

d^2=mean value × 0.05,
NS=number of samples to collect to obtain the mean value ($P \leq 0.05$).

The Hydrogen potential (pH) is adjusted to an exponential spatial variability model (Table 3) and generates two management zones (Figure 1a). Both pH classes were classified as strongly acidic (<5.0), which restricts the availability of nutrients in the Cambisol soil (Letelier, 1967). The annual application of 1.0 t ha^{-1} of dolomitic lime is suggested to raise the average unit the pH of the Cambisol soil.

The percentage of acidity saturation (PSA), organic matter

(OM), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg) and cation exchange capacity (CEC) were adjusted to a Gaussian-type spatial variability model. On the contrary, phosphorus (P-Olsen) is adjusted to a spherical-type spatial variability model (Table 3) and, in general, they generated three agronomic management zones on the site (Figures 1b, 1c, 1d, 1e, 1f and 1g) except the CIC that generated two areas of agronomic management (Figure 1i). The PSA of 0-20 coincides with the highest class of soil pH which would reflect lower toxicity from IA to the crop. The latest PSAs also match the lowest pH. The foregoing reinforces the idea of improving the liming program, applying dolomitic lime 1.0 and 1.5 t ha^{-1} for the pH zones >4.8 and <4.3, respectively; supplemented with 0.5 t ha^{-1} of gypsum ($CaSO_4$), this salt is soluble and allows calcium to pass deeper into the soil (Kingston *et al*., 2007).

Table 3. Criteria for model selection, model characteristics and prediction errors of the selected semivariograms for the soil physical and chemical properties.

Variable	Criteria for model selection		Modelo	Nugget (Co)	Partial sill (C)	Sill (Co+C)	Range (Ao)	Model prediction errors				SDI (%)
	RMSE	AIC						1	2	3	4	
pH	0.001	-188.9	Exponential	0	0.021	0.021	106.85	0.125	-0.019	0.977	0.130	0
PAS (%)	2.34	133.4	Gaussia	0.280	1.463	1.744	286.41	0.696	-0.018	1.124	0.614	16
SOM (%)	0.006	-128.3	Gaussian	0.063	0.109	0.172	613.72	0.259	-0.009	0.987	0.264	37
P (ppm)	4.32	117.6	Spherical	0	75.938	75.938	78.46	6.475	0.006	0.896	7.489	0
K (meq/100 g)	0.004	-203.1	Gaussian	0.020	0.029	0.050	395.29	0.154	0.012	0.998	0.154	41
Ca (meq/100 g)	1.79	84.06	Gaussian	0.066	0.702	0.768	209.02	2.061	0.011	1.022	2.026	9
Mg (meq/100 g)	0.203	1.36	Gaussian	0.264	1.841	2.105	183.04	0.696	0.007	1.029	0.679	13
CEC (Cmol (+) kg-1)	0.870	56.68	Gaussian	0.009	0.008	0.018	113.65	2.040	-0.019	0.986	2.087	51

1. Standardized mean error; 2. Mean square error; 3. Averege standard error and 4. Standardized quadratic mean error.
SDI=[Co/(Co+C)]×100

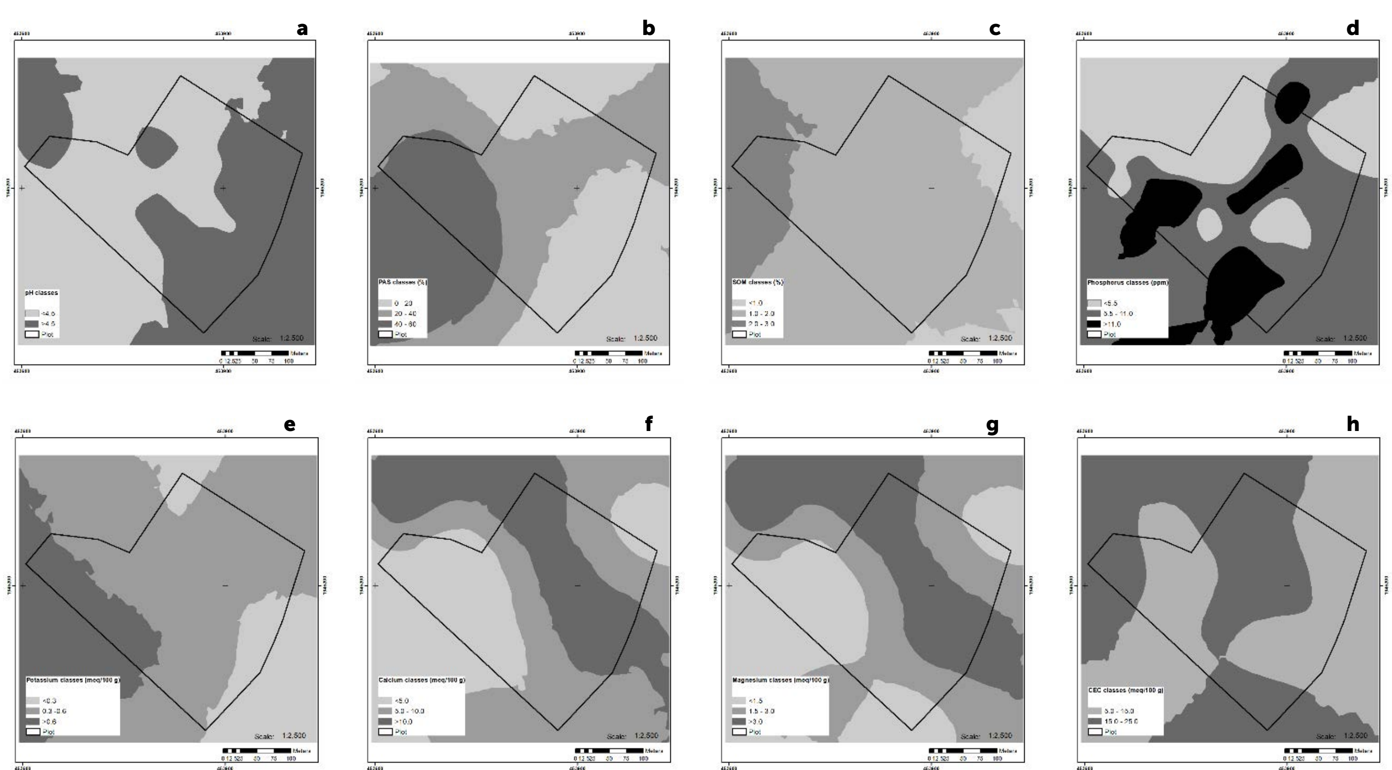

Figure 1. Maps generated by the kriging interpolation method: a) pH, b) PAS, c) SOM, d) Phosphorus, e) Potassium, f) Calcium, g) Magnesium y h) CEC.

The OM classes were classified as very poor (<1.0%), poor (1.0-2.0%) and medium (2.0-3.0%); for k it is considered low (<0.20 meq/100 g), medium (0.3-0.6 meq/100 g) and high (>0.6 meq/100 g); for Ca as low (<5.0 meq/100 g), medium (5.0-10.0 meq/100 g) and high (>10.0 meq/100 g); and for Mg, is classified as low (<1.5 meq/100 g), medium (1.5-3.0 meq/100 g) and high (>3.0 meq/100 g) in Cambisol soil, according to the classification of Tavera (1985). Conserving OM ensures the long-term supply of nutrients to the soil, which is why the application of compost is recommended. Since the plantation is at high density, it is recommended to apply 100 kg ha^{-1} of nitrogen per year. Silva *et al*. (2016) found that the apparent density of the soil, the total volume of pores and the geometric mean diameter depend on the total amount of organic carbon in the soil cultivated with cocoa.

The middle and upper class reflect the accumulation of phosphorus through chemical fertilization carried out on crops such as watermelon and habanero pepper, before establishing the cacao plantation. It is recommended to supply 100, 75 and 50 kg ha^{-1} of P_2O_5 per year for the low, medium and high class, respectively. And for K, it is recommended to apply 150, 100 and 50 kg ha^{-1} of K_2O per year. The low class of Ca is located from southeast to northeast, this coincides with the class with the lowest pH. As well as the low class of Mg coinciding with the low classes of Ca and pH; the middle class of Mg coincides with the highest classes of Ca and pH.

The low class of CIC (5.0 - 15.0 meq/100 g) is associated with the low classes of pH, PSA, Ca and Mg; in this case, it is necessary to apply compost or to leave pruning remains on the soil surface to increase the CEC in the long term. In this regard, Daymond *et al*. (2002) found that the pruning of shade trees resulted in an accumulation of plant debris in the cocoa crop. The middle class (15.0-25.0 meq/100 g) is recommended for cocoa cultivation.

CONCLUSIONS

The PSA, Acidity and interchangeable H+ presented high variability; P-Olsen, interchangeable K, Ca and Mg showed medium variability; and pH, OM, CEC, and IA, low variability.

The geostatistical analysis established specific agronomic management areas on the site. It was determined that the properties of the soil pH, PSA; P-Olsen, Ca and Mg showed high spatial dependence (<25%) and OM, K and CEC moderate spatial dependence (25-75%). With the maps generated by the ordinary Kriging method, partial areas with different variability were identified, as well as the direction of the greatest variability of the property as a function of distance. With these maps, it was possible to define agronomic management recommendations based on the needs of each specific management area.

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AGRO PRODUCTIVIDAD

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Physicochemical, microbiological and nutritional quality of a tomato industrial by-product and its valorization as a source of oil rich in carotenoids

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ABSTRACT

Objective: To valorize an industrial tomato byproduct from Northwest Mexico, based on the evaluation of its physicochemical, microbiological, and nutritional quality and it's potential as a functional ingredient to obtain a carotenoids rich oil.

Design/methodology/approach: Tomato by-product was collected from the food industry and oven-dried. The fresh and dry tomato by-product quality was evaluated through physicochemical, microbiological, proximal composition, dietary fiber, and minerals analysis. HPLC carotenoids analysis was performed from Soxhlet n-hexane extracted oil and dry-byproduct.

Results: The by-product showed 81 and 9.7% of humidity; 0.26 and 0.53% meq of citric acid for titratable acidity in fresh and dried, respectively, and 4.74 °Brix in fresh. Their color got paler due to the drying process, turning less red. The aerobic mesophylls, total coliforms, fungi and yeasts microbiological analysis in a fresh by-product (170, <10, <10 CFU g^{-1}, respectively) and dried (180, <10, ≤95 CFU g^{-1}, respectively), proved their acceptable microbiological safety. Their dietary insoluble (52%) and soluble (9%) fiber stands out, protein (14%), lipids (9.09%) content, as well as Mn> Zn> Fe> Cu, and K> P> Ca> Mg> Na. The carotenoids rich oil was 13 times more concentrated in lycopene (4.98 mg g^{-1}) and twice β-carotene (0.48 mg g^{-1}) content compared to the dry by-product from which it comes (0.38 mg g^{-1} and 0.22 mg g^{-1}, respectively).

Limitations on study/implications: Great efforts were required to dry high amounts of the tomato industrial by-product.

Findings/Conclusion: The tomato industrial by-product from Northwest Mexico possesses suitable physicochemical, microbiological, and nutritional quality to be used as a functional ingredient to generate new products, for example, a carotenoid-rich oil.

Keywords: carotenoids, industrial by-product, quality, tomato oil, valorization.

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INTRODUCCIÓN

Tomato (*Solanum lycopersicum*) is a world-wide vegetable production (182 million tons in 2017) (FAOSTAT, 2019). It is consumed fresh and processed. Annually, more than 40 million tons are destined to industry to produce juices, purees, ketchup, sauces and pasta; During its processing, by-products are generated, mainly consisting of skins and seeds, which constitute between 1.5 and 5% of the initial weight (FAO, 2016; Silva *et al*., 2019a). At a food processing industry in the northwestern region of Sinaloa, Mexico, which processes until thousand tons of tomatoes annually, up to 3,750 tons of by-product are generated, mainly used as livestock feed (La Costeña, personal communication).

The great antioxidant potential of industrial plant by-products has been described due to the quantity and quality of their bioactive compounds (Silva *et al*., 2019a; Urbonavičiené *et al*., 2018). The tomato by-product has important nutrition and health components, particularly carotenoids, fiber, vitamins, phenolic compounds and unsaturated fatty acids (Botinestean *et al*., 2014: Silva *et al*., 2019b). Also, plasma and liver cholesterol-lowering properties of tomato pomace and seed oil have been reported (Shao *et al*., 2013).

There are reports of the valorization of an industrial by-product of tomato using them to produce edible oil for salads, sauces and desserts; as an ingredient to improve the functional, sensorial quality and oxidative stability in bread, cookies and ice cream (Nour *et al*., 2015; Karthika Devi *et al*., 2016; Guerrero García Ortega, 2017; Mehta *et al*., 2018; Szabo *et al*., 2018; Matejová *et al*., 2019). However, in Mexico, there are no reports of the properties and quality of this by-product generated in the food industry, or of products made from it. The objective in this research was to value the tomato by-product of an industry in Northwest Mexico, from the evaluation of their physicochemical and microbiological quality as a by-product fresh and dried; in addition to its nutritional quality, dietary fiber and minerals, and its potential as a functional ingredient to obtain an oil rich in carotenoids. In such a way that this by-product can be used in the food, cosmetic or pharmaceutical industry.

MATERIALS AND METHODS

From January to March 2018, two 20 kg samples of industrial tomato by-products: skin and seeds from scalding and pulping in the production of tomato paste, were collected at La Costeña® Company at Guasave, Sinaloa. The physicochemical and microbiological evaluation of the fresh by-product was carried out, followed by drying in a forced convection oven (D-20 Food Dehydrator Stainless Steel Shelves, model # 32750) at 55 °C for 120 min, until reaching water activity values (aw) between 0.4 and 0.6 (Segoviano-León *et al*., 2020), then grounded for 1 min in a food mill (Mr. Coffee IDS-55). Flour of 1 mm particle size (18.47%), 0.707 mm (35.93%), 0.5 mm (28.93%), and 0.25 mm (16.67%) was evaluated in certified stainless steel sieves (TYLER); the flour was then stored in vacuum, in polyethylene bags at −20 °C and protected from light. The physicochemical, microbiological evaluation, proximal analysis and mineral content of the dry by-product were assessed. From the dry by-product, oil was extracted, which was then evaluated for its carotenoid content via HPLC, as well as the industrial dried tomato by-product.

Microbiological analysis of the industrial by-product of tomato

The total coliforms were counted on a 3M Petrifilm plate (6410/6416/6443), fungi and yeasts on a 3M Petrifilm plate (6407/6417/6445) and 3M Petrifilm aerobic mesophiles (6400/6406/6442), following the NOM-113-SSA1-1994, NOM-111-SSA1-1994 and NOM-092-SSA1-1994, respectively. The results are reported as colony-forming units (CFU) per g of sample.

Physicochemical evaluation of the industrial by-product of tomato

As a quality reference, the evaluation was done in the fresh samples, later dried to increase the shelf life and facilitate its handling. 1) Humidity, by the official method of the AOAC (1998) brought to constant weight at 105 °C, for 4 h in a forced convection oven (BINDER Thermo Fisher Scientific, Pittsburgh, PA, EU). 2) Total organic acids, NMX-F-102-S-1978 of titratable acidity for products made with fruits and vegetables, from 20 g of fresh and dry by-product grinding juice with 50 mL of distilled water titrated with NaOH 0.1 N. 3) Soluble solids, the °Brix of the juice obtained from the fresh by-product when pressed was assessed with a portable refractometer (Atago 3810 PAL-1). 4) CIELAB color (L *, a *, b *), 25 readings were taken from the fresh and dry samples without grinding, in Petri dishes with five reading points, using a Chroma meter CR-400 Konica Minolta colorimeter. 5) Proportion of skin and seeds, these were manually separated, and the weight of each portion was recorded from 100 g of dry by-product.

Nutritional composition of the industrial by-product of tomato

Proximal analysis. Performed at a certified laboratory EURONutec, Nutec Group (AOAC, 1998). Dietary fiber analysis was done with the Sigma-Aldrich kit (TDF 100A) following the AOAC method 960.52 (1997).

Minerals. These were analyzed by wet digestion (Na, Ca, Mg, Fe, Mn, Cu, Zn, Mn) (Johnson & Ulrich 1959) and subsequent analysis by atomic absorption spectrometry. For K, the flamometric flame emission method was used with a flamometer (Buck Scientific PFP-7). P was evaluated with the vanadate-yellow molybdate method by acid digestion with a UV / visible spectrophotometer (Genesys Varían) at 470 nm.

Oil extraction. This was obtained in a Soxhlet with 2 g of the dry industrial by-product and 80 mL of hexane at 80 °C for 5 h (NMX-F-089-S-1978). The solvent was removed by rotary evaporation (Yamato, RE300) and forced convection oven (BINDER) at 55 °C for 1 h, for the residual. Oil yield was calculated by weight difference and stored at −20 °C, under a nitrogen gas atmosphere protected from light.

Carotenoids from tomato industrial by-product and oil

These were extracted from the dried tomato by-products following the method by Silva *et al.* (2019b). 500 mg of by-product was mixed with 50 mL of food-grade ethyl acetate, homogenized and sonicated (Fisher Scientific FS20 Sonic Cleaner) for 20 min and stirring for 2 h at 200 rpm and 55 °C (protected from light). After centrifuging at 4000 g for 10 min at 20 °C (Sorvall ST16REI), the recovered supernatant was dried by rotary evaporation and stored at −20 °C. The carotenoids from the oil were extracted following the method by Gimeno *et al.* (2002), from 400 mg of oil mixed with 200 mg of ascorbic acid, 15 mL of absolute ethanol and 4 mL of KOH (76% m/v), then incubated by shaking for 30 min at 60 °C and 200 rpm. 5 mL of NaCl (2.5% m/v) and 7 mL of n-hexane: ethyl acetate solution (85:15 v/v) were added. The organic phase recovered was dried by rotary evaporation at 40 °C, and stored at −20 °C. For the determination of carotenoids by reverse phase HPLC, the extracts were resuspended in 1 mL of hexane and methanol, respectively. Carotenoids were identified based on reference standards: β-carotene and lycopene (Sigma Chemical Co., St. Louis, MO, USA), by DAD Dionex HPLC (DIONEX Ultimate 3000) with a diode array detector, Acclaim Polar column Advantage II (C18, 3 μm, 120 Å, 2.1 × 150 mm), at 452 and 471 nm; acetonitrile: methanol: methyl chloride (43:43:14 v/v/v; Sigma-Aldrich) as isocratic mobile phase and flow of 0.3 mL min^{-1}. The results were expressed in mg of lycopene and β-carotene g^{-1} of the dried tomato by-product and the oil. For comparative purposes, a commercial cosmetic-type tomato seed oil (BRAND Aceites Vegetales AV) was also analyzed.

Statistical analysis

The analyzes were performed by triplicate, expressing the mean of the replicates ± standard deviation. The proximal analysis was performed as an external service certified by Grupo Nutec.

RESULTS AND DISCUSSION

Physicochemical characterization

The physicochemical parameters of the fresh and dry by-products are shown in Table 1, they represent a reference of its initial quality and after being dried, the latter to increase its shelf life and facilitate its handling.

After drying, the final aw was 0.42, as reported by Segoviano-León *et al.* (2020) to preserve carotenoids. The soluble solids or °Brix determine the commercial quality of fresh tomato, due to their effect on sweetness, acidity and flavor intensity. The value obtained in the fresh by-product corresponds to the range established for different stages of tomato maturation (4.1 and 4.7 °Brix) (Hernández *et al.*, 2008) and the variety apple (4 °Brix) used for flour (Monsalve and Machado, 2007). The titratable acidity of the tomato by-product coincides with the early stages of maturation of fresh whole tomatoes and slightly lower than tomato variety apple (0.29 mg eq. Citric acid) at commercial maturity (Monsalve and Machado, 2007; Hernández *et al.*, 2008); and increases in

Table 1. Physicochemical parameters of industrial by-products of fresh and dried tomato.

Parameters	Fresh by-product	Dry by-product
Moisture (%)	81.3 ± 1.87	9.71
Soluble solids (°Brix)	4.74 ± 0.38	nd
Titratable acidity (citric acid %)	0.26 ± 0.03	0.53 ± 0.004
Color L*	41.18 ± 1.52	33.53 ± 3.25
a*	22.38 ± 1.01	16.1 ± 1.32
b*	27.75 ± 1.15	26.25 ± 3

nd: not determined.

the dry by-product because organic acids concentrate by water elimination. Color is another important quality aspect, it was affected by drying, reducing the intensity of the color red, becoming paler. Furthermore, the industrial by-product of dried tomatoes is made up of 40% seeds and 60% skin (epidermis), similar to other tomato by-products from Brazil (38.5 and 61.5%) and Tunisia (35% and 65%) (Silva *et al.*, 2019a; Kehili *et al.*, 2019).

Microbiological analysis

The microbial account in the fresh and dried tomato by-product is shown in Table 2. Since there are no specifications for this product, the hygiene and sanitation practices in the preparation of food in fixed establishments were taken as a reference (NOM-093-SSAI-1994).

The results indicated that the microbial count of the fresh and dry by-product is lower than that specified in the Mexican standard, and that reported in dehydrated commercial tomatoes <10 to 22×104 CFU g^{-1} of aerobic mesophiles and <10 to 18,000 CFU g^{-1} of fungi and yeasts (Moreno *et al*. 2014), which is similar to that reported by Monsalve and Machado (2007) for dehydrated commercial tomatoes, which suggests that there is no bacterial contamination when drying in the stove; demonstrating that the industrial process that originates the tomato by-product and all the handling until drying takes place in favorable food safety conditions for its use.

Nutritional quality of the industrial by-product of tomatoes

Proximal analysis. The tomato by-product (Table 3) presented reports similar content to that reported in Venezuela (Alvarado *et al.*, 2001) and was slightly lower than that in Brazil (50.74% fiber, 20.01% protein, 14.14% fat and 3.60% ash) (Silva *et al.*, 2019b).

Dietary fiber. Its high content of total dietary fiber of 67.32% (52.46% insoluble and 9.28% soluble) is outstanding, whose consumption has positive implications on health, and corresponds to the edible fraction resistant to digestion and absorption in the small intestine, this value represents 27 times more than of the contribution of fresh tomatoes (Abdullahi *et al.*, 2016). The recommendation for dietary fiber consumption is 19 to 38 g d^{-1} (USDA, 2015; Quagliani *et al.*, 2016); Considering the tomato by-product as an ingredient, the addition of 20% to a food formulation would cover 50% of the daily recommended requirement.

Minerals. Zn and Fe stand out for their biological importance related to malnutrition. The macro K> P> Ca> Mg> Na and micro minerals Mn> Zn> Fe> Cu of the industrial tomato by-product are presented in Table 3. Except for Ca, the tomato by-product of Caracal and Romania tomatoes has a high minerals content: K, Mg and Na (3.03, 0.21 and 0.067 g 100 g^{-1}, respectively), in addition to Zn, Fe, Mn and Cu (63.3, 56.3, 13.5 and 11.5 mg Kg^{-1}, respectively) (Nour *et al*. 2018). However, it is higher in P, K, Ca, Mg and Cu than the by-product of red tomato mixed with immature green tomato (King & Zeidler, 2004) and 10 times higher in P and Ca, and 28 times more in Na, in comparison fresh tomato of various varieties (Fragni *et al.*, 2018).

Extraction of oil and carotenoids from the by-product of dried tomato and oil

The yield of the oil extraction *via* the Soxhlet method with n-hexane was 8.23 g 100 g^{-1} of dry by-product, this value corresponds to the range (3 and 15 g 100 g^{-1}) reported by Vági *et al*. (2007) from an industrial tomato by-product.

Table 2. Microbiological quality of industrial by-product of fresh and dried tomato.

	Fresh by-product	Dry by-product	Reference NOM-093-SSAI-1994
Aerobic mesophiles (CFU/g)	170	180	150,000
Total coliforms (CFU/g)	<10	≤10	100
Yeast and mold (CFU/g)	<10	≤95	nr

nr: not referenced.

Table 3. Proximal analysis and mineral content of industrial tomato by-product*.

Composition	g 100 g^{-1}	Macronutrients g 100 g^{-1}		Micronutrients mg kg^{-1}	
Ash	3.82	P	0.27	Fe	3.41
Crude fibre	32.80	K	0.43	Cu	2.55
Lipids	9.09	Ca	0.12	Zn	5.71
Moisture	9.71	Mg	0.07	Mn	7.47
Crude protein	14.86	Na	0.04		
Carbohydrates/NFE	29.72				

*dry basis; NFE: nitrogen free extract.

The lycopene content (4.98 ± 0.09 mg g^{-1}) and β-carotene (0.48 ± 0.002 mg g^{-1}) of the oil was 13 and 2 times the content of dried tomato by-product (0.38 ± 0.15 and 0.22 ± 0.087 mg g^{-1}, respectively); as well as 3.8 and 2.8 times higher than lycopene (1.31 ± 0.04 mg g^{-1}) and β-carotene (0.17 ± 0.04 mg g^{-1}) of the cosmetic-type commercial tomato seeds oil. It was six times higher in lycopene and three times lower in β-carotene than the oil obtained from another industrial tomato by-product (Machmudah *et al*., 2012). When compared to palm oil, which is recognized to be carotenoids rich (1.385 mg β-carotene g^{-1} oil) but lack lycopene (Sampaio *et al*., 2013), it contains a third of β-carotene, but is a peculiarly lycopene-rich oil, although there are no values for its recommended daily intake (RDI), it has been suggested that the intake of 4 and 4.4 mg d^{-1} of β-carotene for men and women and lycopene >6.46 mg d^{-1}, reduces cancer risk (Institute of Medicine, 2000).

CONCLUSIONS

The industrial by-product of tomato from Northwest Mexico has an adequate physicochemical and microbial quality with high nutritional value based on its of dietary fiber content, protein and minerals, which can be used as a functional ingredient for the production of new products. It is a source for obtaining a unique oil rich in lycopene, in addition to β-carotene, which offers a potential use to generate gourmet oil or new products with important health benefit properties. This work contributes to the valorization of the industrial by-product of tomato from the northwest region of the country, considered the main production area of *Solanum lycopersicum* in Mexico.

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Characterization of the preferences towards jalapeño peppers from the perspective of the Sonoran consumers

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ABSTRACT

Objective: To assess the Sonoran (Mexico) consumer perspective regard their buying habits, consumption and the attitudes and attributes they most valued from jalapeño pepper.

Design/Methodology/Approach: The assessment took place in three phases. The first consisted of the design of a questionnaire, the second its application to a sample of n=200 consumers and finally univariate (means and modes) and bivariate (Chi-square) analyzes on the obtained data.

Results: The flavor is a key element in the consumption of jalapeño peppers. There is a tendency towards frequent consumption, although the portions are measured since they are usually less than 0.5 kg. It was identified that for the consumer it is important no damage or browning is visible on the external appearance of the peppers, and that they prefer peppers of a dark green color over another coloring. Specifically, there is a willingness to pay between $ 0.5 and $ 1.0 US per kilogram. The frequent consumers of jalapeño pepper are under 40 years old, accentuated in the 18 to 24 years old segment, with medium income level. In this segment, there is the preference for aroma and hotness (pungency) that the chili peppers have.

Study limitations/implications: This study is limited to consumers from the northwestern region of Mexico. The obtained information provides guidelines to deepen the knowledge of this product from their market perspective. The added- value strategies should be aimed to increase the external quality of the product.

Keywords: attributes of chili peppers, expressed preferences, consumer.

INTRODUCCIÓN

Mexico is one of the main producing countries of chili peppers (*Capsicum annuum* L.), with a production of just over three million tons, it occupies the second position in the world (FAOSTAT, 2020). In its national context, this crop has a planted area of 152 thousand hectares and a production value of 32 million pesos (SIAP, 2019). Even when the production data is positive, various problems inhibit its production in the country, highlighting the costs of its inputs, their poor marketing, poor production organization, insufficient credits, and the lack of added value, among others (Galindo, 2007).

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The diversity of peppers is wide, there are more than a hundred varieties nationwide, concentrated in 22 groups of green peppers and 12 for dried peppers. In the former, the jalapeño pepper (*Capsicum annuum* L.) stands out, it represents a third (31.0%) of the national production. Except for Aguascalientes, the jalapeño pepper is grown throughout the country. The main producers are the states of Chihuahua (32.3%), Sinaloa (17.5%), Zacatecas (13.5%) and San Luis Potosí (9.8%), which together produce 73.1% of the national harvest (SIAP, 2019). In the case of Sonora, the registered production volumes have positioned it among the top ten pepper producing states at the national level, and is third in importance in the northwest of the country. According to the national agricultural planning 2017-2030 (SAGARPA, 2017), the state of Sonora is located between the strategic and historical regions in the production of jalapeño pepper, having an annual production increase of 2.61% in the last three years. In such a way that it went from 187,470 t in 2017 to 192,365 t in 2019 (SIAP, 2020). The production of green peppers that takes place in the state is of five types: bellpepper of export, in a greenhouse for export, open field, greenhouse, shade mesh and shade mesh for export, with a production of 94,380 t, which represents 50.3% of the total of varieties; these are followed by jalapeño pepper sown in open field, for export and shade mesh with a production of 59,351 t (31.7%); Anaheim peppers in open field, export and shade mesh with 24,451 t (13.0%); serrano pepper for export and open field with a production of 9,008 t (4.8%) and open field poblano pepper with 280 t of production (0.1%) (SIAP, 2018). These figures suggest that there is significant potential for the positioning of jalapeño pepper, both in terms of its production and market. Despite these indicators, it must be considered that the market is highly competitive and the consumers can access a wide variety of green peppers. According to Pindyck and Rebinfield (2001), consumers allocate their income to the acquisition of different goods and services to maximize their well-being. In this process, some of the important variables are the price of goods and income. These variables limit the amount of purchase by the consumers; although other socioeconomic variables act as demand shifters that affect the number of purchased goods. Although several studies address the agronomic production process of jalapeño pepper (Pire and Pereira, 2018; Ramírez *et al*., 2017; Beltrán *et al*., 2016 *inter alia*), respect the demand and research on market behavior information is scarce, even more so when it comes to northwest Mexico (Pérez *et al*., 2017; Mejía *et al*., 2020). To learn about this market, different aspects must be considered, such as the customers' expectations (Lupín and Rodriguez 2009). At the same time, it should be considered that there is no uniform consumer, but due to the changes in social and personal values, consumer preferences are also permanently changing (Schreiner *et al*., 2013).

In this regard, consumer-oriented studies have found that for peppers, color was a relevant characteristic for their acquisition among consumers in the state of Alabama, United States (Frank *et al*., 2001). In addition, for certain types of chili peppers, such as the "piquin" pepper (*Capsicum annuum* L. var. Glabriusculum), their taste encourages consumers to pay a higher price compared to serrano or jalapeño peppers (Villalón-Mendoza *et al*., 2016). Meanwhile, in products such as tomatoes, it has been identified that the availability of product "fresh" affects its purchasing behavior; that is, they are acquired when available, even during periods of scarcity within a year (Adeoye *et al*., 2015). Therefore, and due to the importance of the consumption of jalapeño pepper in the population, it was considered necessary to carry out a study to characterize the consumers of this vegetable, in aspects such as the type of product they demand and the characteristics they prefer. The main objective of this research was to assess, from the perspective of the Sonoran consumer, their buying and consuming habits for jalapeño pepper, as well as the attitudes and attributes that they most value of this product to contribute to its state of knowledge from a market perspective.

MATERIALS AND METHODS

To achieve the main objective, an empirical investigation was carried out at the city of Hermosillo, Sonora, which has 884,273 inhabitants and is located in the northwest area of Mexico (INEGI, 2015). The study was carried out in three phases, the first one consisted of the design of a questionnaire aimed at consumers. The survey was pre-tested to reduce errors and provide an understanding of the variables. For the sample size, a probability sampling was applied, using the infinite population formula and a simple random sampling was calculated with a 7% error, obtaining a sample size of n=200 surveys. In the second phase, the fieldwork was carried out. The people who responded to the survey were 18 years of age or older and received no monetary compensation for their participation. The information was collected in January and February 2020. For the third phase of the research, a database was developed in the IBM SPSS 20 software. To perform the analysis of the information, we proceeded to identify the type of measurement scale used in each question. The methods used for the data analysis were two: univariate (means and modes) and bivariate (*Chi-square*).

RESULTS AND DISCUSSION

The obtained results show that most of the participants were women (52%), whose recurring occupations were as administrative staff (29.5%), followed by students and houseworkers, with 16.5 and 15% respectively. The largest proportion of those surveyed has university studies (59%) and high school (26%). The most represented age ranged from 18 to 34 years (52%), followed by those over 60 (10%). The most common incomes range from 5 to 10 thousand pesos per month (33%), as well as between 10 to 15 thousand pesos (28.5%), while the greater than 20 thousand pesos per month income range proportion was significantly lower (4%). An implicit condition for participating in the study is that the respondents were jalapeño pepper consumers.

According to the data, it was observed that out of the different ways in which they can be tasted, the processed peppers option stands out as the most common (59.5%), followed by fresh peppers (39%), then dry or smoked (1.5%). Among the reasons for consumption, the flavor is the most prominent (44.8%), as well as their multifunctionality in its uses (18.5%) or the amount of hotness (pungency) they have (14.2%). Other related aspects such as aroma, color, nutritional value, among others, presented less incidence in the causes for choice among consumers (Table 1).

Regard the consumption frequency, those that consume "some days" during the week prevailed with 51.5% of the total, followed by those that consume it daily, from Monday to Friday (20%). Also, weekend consumers were recorded (15%) and less than once a month consumer (13.5%). The most frequent consumption, 78.5% of the cases, were of less than 0.5 kg, and 19.0% consumed between 0.5 kg and 1.0 kg, while higher consumption was registered to a lesser extent (2.5%). These results indicated that there is a tendency towards frequent consumption over occasional consumption and that the portions consumed are less than half a kilo (Table 2).

Regard the attributes of the jalapeño pepper that are most important to consumers, it is to be noted that according to the mean scores, considering a five-point Likert scale where 5 is in total agreement, the absence of physiological damage is the most important attribute for consumers, with an average value of 4.44 (Table 4). Another was the absence of injuries or damage on the product (4.35), while the external color, the degree of hotness and consistency were also revealed as highly valued attributes by consumers with mean scores of 4.03 in the first two and of 4.01 at last. With values above the average but lower than the main attributes, the size (3.87), the shape of the pepper (3.65), aroma (3.57) and width (3.47 and 3.04, respectively) (Table 3).

From the different characteristics that jalapeño peppers can have, the preferred color for 90% of consumers was a bright dark emerald green, other options such as medium yellow and orange-red were significantly less chosen, with 5.5 and 4.5% respectively. Regarding size, the preference for medium-size jalapeño peppers (64.5%) prevailed, which ranged from 5 to 7.5 cm. The most recurrent desired consistency was of high to the touch (53%), while the preferred width of the fruit was medium (66%), with a weight of 25 to 30 g (70%), while the most sought-after "striped" (physiologically mature) registered 69.5% of consumers (Table 4).

Table 2. Consumption frequency of jalapeño pepper.

Consumption	Sample (%)	Consumption amount	Sample (%)
Dailye (Monday – Friday)	20.0	Less than 0.5 kg	78.5
Some days during the week	51.5	From 0.5 kg to 1 kg	19.0
Weekends	15.0	From 1 kg to 2 kg	2.5
Less than once a month	13.5		

Table 1. Main reasons for jalapeño pepper consumption.

Characteristics	Sample (%)	Characteristics	Sample (%)	Characteristics	Sample (%)
Flavor	44.8	Spicy	14.2	Other (nutritional, easy to get, is what is given)	7.6
Multifunctionality in its uses	18.5	Aroma	7.9	Mildly spicy	7.0

Table 3. Average scores regard jalapeño pepper attributes.

Attributes	Average values	Attributes	Average values	Attributes	Average values
The absence of physiological damage	4.44	Product consistency	4.01	Odor	3.57
The absence of injuries or blows	4.35	Size	3.87	Widht	3.47
External color	4.03	Jalapeño peppershape	3.65	Weight	3.04
The degree of pungency of the jalapeño pepper	4.03			Jalapeño pepper lines	2.92

Table 4. Characteristics of the jalapeño pepper most valued by consumers.

Color	Sample (%)	Width	Sample (%)
Brilliant dark emerald green	90.0	Medium (3.0 a 3.5 cm)	66.0
Middle yellow	5.5	Big (3.5 a 4.0 cm)	31.5
Orange red	4.5	Jumbo (3.7 a 4.5 cm)	2.0
Size		**Line**	
Medium (5 a 7.5 cm)	64.5	0 al 10%	69.5
Big (8 a 10 cm)	33.5	De 10 a 15%	27.0
Jumbo (≥10 cm)	2.0	Más de 20%	3.5
Consistence		**Weight**	
Medium consistency and to a lesser degree to the touch	38.5	25 a 30 gr	70.0
High consistency to the touch	53.0	30 a 45 gr	26.5
Consistency extremely high to the touch	8.0	45 a 60 gr	0.5

Regard the willingness to pay for jalapeño peppers, 42% of consumers consider that a value between $0.5 to $0.75 US per kg was adequate to promote their consumption, followed by $0.75 to $1.25 US per kg (34.5%). Other values at the lower and upper end of the price were less viable options according to the consumers.

The results obtained with the Chi-square test (Table 5) showed that there is a positive association between the frequency of consumption and the sociodemographic and economic characters so that in the daily consumption the proportion of consumers is higher (2%) compared to other options. When consumption is carried out on some days during the week, the trend is focused on young people age 18 to 24 (11%), while consumption on weekends and sporadic consumption takes place less than once a month, it has a higher in the 25 to 29 years segment, in the first case (5%) and 30 to 34 years in the second (4.5%). It is also noted that the college degree is more frequent in any of the consumption frequencies and that the proportion of people who consume several times a week have a higher income than $1,500 USD per month, accentuating in the range between $250 and $500 US, while occasional jalapeño pepper consumers represent a slight trend towards higher income.

In the correlation analyses, it was observed that there is a positive association between the type of consumption of pepper to the frequency of consumption (Table 6), in such a way that processed and fresh peppers are more commonly consumed among the people who taste it in the range of some days per week (29 and 21% in each case). Likewise, the aroma and strong hotness are reasons for its consumption, especially among those who eat it often, either daily (75.5 and 7.5%) or some days during the week (6.5 and 13%). It was also observed that consumption quantities of less than half a kilogram are more accentuated in those who consume it some days per week (44%), followed to a lesser extent by sporadic consumers (13.5%). Consumption in portions greater than half a kilogram is more prevalent among those who consume jalapeño peppers daily. At the same time, it is noted that in 37% of the cases, those who consume jalapeño peppers several times during the week have up to three members in their family who also consume the product. This trend decreases to 14% when four to six members consume jalapeño peppers in a homestead.

Regard their attributes, it was observed that it is appreciated by 23 and 10.5% of consumers for being moderately spicy, particularly for those who consume it several days

Table 5. Description of the obtained segments based on the consumption frequencies of jalapeño pepper and their socio-demographic and economic characteristics.

Segmentation/ variables	Chi-square Test X2 (Probability value)	Frequency of consumption (%)			
		Daily L-V (N=40)	Some days of the week (N=103)	Weekends (N=30)	At least once a month (N=27)
Age					
18-24	0.059*	4.5	11.0	1.5	2.5
25-29		2.5	8.5	5.0	2.0
30-34		3.0	4.5	2.5	4.5
35-39		1.5	6.0	0.0	0.5
40-44		1.0	5.5	2.0	0.5
45-49		0.5	6.0	0.5	0.5
50-54		2.5	3.0	1.5	0.5
55-59		2.5	1.0	0.5	1.5
≥60		2.0	6.0	1.5	1.0
Study level					
Up to primary	0.82**	0.5	0.5	0.5	0.0
Secondary		1.5	3.0	0.0	0.5
High school		7.5	15.5	2.0	1.0
Bachelor degree		9.5	29.5	10.0	10.0
Higher (Master degree and PhD)		1.0	3.0	2.5	2.0
Monthly income level					
≤5 thousand mexican pesos	0.058*	4.0	12.0	1.0	2.0
5-10 thousand mexican pesos		4.0	19.5	6.5	3.0
10001-15 thousand mexican pesos		7.0	13.0	3.0	5.5
15001-20 thousand mexican pesos		4.0	5.0	4.0	2.5
20001-30 thousand mexican pesos		1.0	2.0	0.0	0.0
≥30 thousand mexican pesos		0.0	0.0	0.5	0.5

a week and sporadic ones who do so once a month. "striped" peppers are more accepted in the lower limits of 0 to 10% in 41% of frequent consumers, compared to 10.5% of weekend consumers. For their part, 3% of those who consume jalapeño peppers daily consider that there are problems with their packaging. When considering other alternatives to consume jalapeño peppers, 17.5% of the regular consumers consider that incorporated in cheeses is another product where they like to consume it. Finally, it is noted that the bell or brown chili is a viable substitute for all consumers, but more so for those who consume several times a week (11.5%), on weekends (5%) and at least once a month (4%).

CONCLUSIONS

These findings show that for the Sonoran consumers, the taste is a key element for the consumption of jalapeño peppers, there is a trend towards frequent consumption, although measured portions since they are usually less than half a kilogram. For the consumers, it is important that the external appearance of the peppers does not show damage and that they prefer the chili in a dark green color over other presentations. There is a marked trend towards medium size, weight and width, with slight "stripes" less than 10%. Likewise, it is noted that there is an intermediate willingness to pay in ranges between $0.5 and $1.0 US per kilogram. On other hand, frequent consumers of jalapeño peppers are under 40 years of age, accentuated in segments from 18 to 24 years of age, with a medium-income level. In this segment, there is a preference for the aroma and hotness of the pepper. The jalapeño pepper consumer preferences show some guidelines that can be useful when establishing production and commercial guidelines. Added-value strategies can be aimed at increasing the external quality of the product.

Table 6. Description of the segments obtained based on the motivations and preferences of consumption towards jalapeño peppers.

Segmentation/ variables	Chi-square Test X2 (Probability value)	Frequency of consumption (%)			
		Daily L-V (N=40)	Some days of the week (N=103)	Weekends (N=30)	At least once a month (N=27)
Mode of consumption					
Consume the jalapeño pepper dried or smoked	0.011*	0.0	1.5	0.0	0.0
Consume the processed jalapeño pepper		9.0	29.0	9.5	12.0
Consume fresh jalapeño pepper		11.0	21.0	5.5	1.5
Consumption reasons					
Consume because of the fragance	0.006*	5.5	6.5	1.0	0.0
Consume for the spicy	0.017*	7.5	13.0	2.0	1.0
Consumption per week					
From 1 to 2 kilogram	0.000*	1.5	0.5	0.5	0.0
From half to 1 kilogram		9.5	7.0	2.5	0.0
Less of half kilogram		9.0	44.0	12.0	13.5
Family that consume it					
More than 9 members	0.002*	0.0	0.0	0.5	0.0
7 to 9 members		1.5	0.5	0.0	0.0
4 to 6 members		6.5	14.0	1.0	1.0
1 to 3 members		12.0	37.0	13.5	12.5
Attributes that are valued					
Very spicy	0.017*	5.5	8.5	0.5	1.0
Spicy		8.0	19.5	6.5	2.0
Moderately spicy		6.5	23.0	8.0	10.5
Striped at more than 20%	0.000*	2.0	0.	0.0	1.0
Striped from 10 to 15%		9.5	9.5	4.5	3.5
Striped from 0 to 10%		8.5	41.5	10.5	9.0
Problems and sustitutes					
Packaging problem	0.069**	3.0	2.5	1.0	2.5
Consume in cheeses	0.010*	1.5	17.5	5.5	4.5
Bell or brown sustitutes	0.094**	2.0	11.5	5.0	4.0

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AGRO PRODUCTIVIDAD

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Production and quality of habanero pepper (*Capsicum chinense* Jacq.) with chemical and organic fertilization

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ABSTRACT

Objective: To compare the effect of earthworm humus (vermicompost) with respect to that of a standard fertilization treatment with conventional chemicals on the yield and fruit quality in the cultivation of habanero pepper (*Capsicum chinense*).

Design/methodology/approach: The experimental design was of randomized blocks with seven replicates. The treatments consisted of 100% worm humus, 50% worm humus + 50% soil combination, as well as soil with chemical fertilizers as a control. The number of fruits, the quality of the fruits (length, diameter, and weight) of three cuts (harvests), in addition to the yield per plant, were evaluated. The data were analyzed with an analysis of variance and when statistical differences were detected, a means comparison was performed with the Tukey test ($P>0.05$).

Results: The 100% vermicompost treatment did not significantly reduce the height and diameter of the plant stem. Regard yield, a 15% increase was observed, although it was not significant compared to the control. Likewise, the quality of the fruits did not decrease.

Study limitations/implications: The combination of 50% vermicompost and soil or less could affect the development and yield of habanero pepper crops.

Findings/conclusions: Supplying earthworm humus does not affect the yield or quality of habanero pepper fruits, which is an alternative for nutrients supply at low cost which is also an environmentally friendly practice.

Keywords: humus, vermicompost, compost, nutrients.

INTRODUCCIÓN

The habanero pepper (*Capsicum chinense* Jacq.) is a vegetable high production at the state of Yucatán, Mexico, which in recent years has taken great economic importance (SIDETEY, 2014). At the national level, Yucatán contributes

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41% of the total production (SIAP, 2015), with a cultivated area of around 243 ha and an average yield of 13.69 t ha^{-1} (SIACON, 2018). Like all horticultural species, the yield and fruit quality depend on the nutrient availability and content in the soil (Borges-Gómez, 2010), which are often lower than their demand. This makes it necessary to use agricultural amendments, mainly synthetic (Noh-Medina *et al.*, 2010), that raise production costs and generate environmental damage. This has motivated the search for low-cost and sustainable production alternatives (Nieves-González *et al.*, 2013). Currently, 40% of the increase in agricultural production is attributed to synthetic fertilizers; However, their economic benefits are diminished due to fertilizer's high cost, in such a way that it is estimated that they increase the cost of production between 10 and 25% (Salgado and Núñez, 2012). A low-cost alternative that can potentially correct the nutrients deficiency in the soil is supplying organic amendments, which, in addition to providing nutrients, improves some physical properties; while, in the plant, humic acids stimulate the development of roots and stems, improve nutrients absorption, and control some soil pathogens (Felix-Herrán *et al.*, 2008). Furthermore, given the goals set by FAO to ensure food for the world population, without affecting the environment and soil resources, through a more productive and resilient agriculture (FAO, 2018), alternatives have been proposed, such as the usage of low-cost available organic waste, like manure and composted plant waste (López *et al.*, 2012; Nieves-González *et al.*, 2013). In this regard, vermiculture, in which the Californian red worm (*Eisenia foetida*) is used to solubilize insoluble minerals, has become increasingly important (Román *et al.*, 2013), because it improves the microbiological characteristics of the organic waste, due to the presence of *Bacillus* sp. responsible for macronutrients releases, such as N (nitrogen), P (phosphorus) and K (potassium) (Torres-González *et al.*, 2017).

The application of vermicompost in agricultural production has shown the capability to reduce the use of chemical fertilizers without affecting yields. In this regard, Olivares-Campos *et al.* (2012) report that when applying vermicompost in a lettuce crop, the nutritional foliar N content was similar to the equivalent contribution of inorganic nitrogen fertilizer, which produced a similar behaviour in their production.

Particularly, for habanero pepper cultivation, there is little evidence that shows the impact of this kind of organic amendments on the production and quality of the fruit, which is why the present work aimed to compare the usage of earthworm humus or vermicompost compared to a standard treatment with conventional chemical fertilization, on the yield and quality of habanero pepper fruit (*Capsicum chinense*).

MATERIALS AND METHODS

The experiment took place in a 30 m^2 tunnel-type greenhouse at Oxkutzcab municipality, Yucatán, Mexico, during the autumn - winter 2019 cycle. The plant material developed from habanero pepper var. Mayapan seeds, these germinated in 200-cavity polystyrene containers in Canadian peat (Peat moss®). During the seedling stage, irrigations (with well water) were applied every second day, in 1 L per tray doses during the first two weeks after seedling emergence, followed by daily applications, in the same dosage, until transplant. Regard the fertilization in the seedbeds, it began nine days after seedling emergence, and when the seedlings exhibited the first pair of well-defined true leaves. After that, every third day. During the first and up to the second week after fertilization began, nutrients were applied as follows: 0.15 g L^{-1} of urea, 0.25 g L^{-1} of MAP and 0.1 g L^{-1} of NKS; from the third week onwards: 0.3 g L^{-1} of urea, 0.5 g L^{-1} of MAP and 0.2 g L^{-1} of NKS.

The soil used for the experiment was Luvisol type, locally known as K'ancab, with a loamy texture (40% sand, 44% silt and 16% clay) (Borges-Gómez *et al.*, 2014). The vermicompost was produced by decomposing a mixture of organic materials (green and dry leaves, horse manure and discards of regional fruits, chopped as finely as possible, in addition to a portion of soil) made by the Californian red worms (*Eisenia foetida*). The mixture was supplied as worm food every third day along with water to maintain a constant humidity of 80%. After three months, when it had a brown appearance, the humus was collected, sieved with a 2 mm sieve, which broke existing lumps.

The pant transplantation occurred 40 days after sowing (das), when the seedlings reached 15 to 20 cm height, to 5 L volume black plastic bags containers. The distance used between the rows of bags was 80 cm and 30 cm between bags. The treatments consisted of 100% humus (H) and a mixture (1: 1 V/V) of humus+soil (H+S), supplied as a substrate, both without chemical fertilizer addition, plus a control which consisted of 100% soil with synthetic fertilizer supplied through irrigation every third day, at doses of 0.38 g of urea, 0.17 g of MAP and 0.20 g of NKS, per plant. The experimental design was of randomized blocks with seven replications and three plants as an experimental unit.

At 120 days after transplantation, data on the plants' height and stem diameter were recorded; the first with a tape measure, from the base of the stems to the apical meristems; the second with a digital vernier at a 5 cm height from the base of the stem. For the yield assessment, the total number of fruits per treatment in each cut was weighed, the three cuts were later added. In each harvest, the number of fruits produced by each plant was counted and at the end of the experiment, their average was calculated. For each treatment repetition, fruits were selected, their length measured with a millimeter ruler from the peduncle to the tip of the fruit; with a digital vernier, the diameter measured in the middle part of the fruits. Finally, to obtain the individual weight per fruit, fruits were weighed in a compact PCE-BSH 1000 scale with a 0.2 g precision.

The irrigations during crop development were manually carried out, applying 0.5 L per plant day^{-1} from the transplant until 20 days after (dat) with 1 L per plant day^{-1} of the 20 until 50 dat. From day 50 to 90 dat 1.5 L per plant day^{-1} and 2 L per plant day^{-1} from day 90 until harvest (Tucuch-Haas *et al*., 2012). Among other agronomic tasks, pruning took place to leave three branches per plant and tutored with thread. The data were analyzed with an analysis of variance, when statistical differences were detected, a comparison of means was carried out with the Tukey test (P≤0.05) in the SAS version 8.1 (SAS, 2004) statistical package.

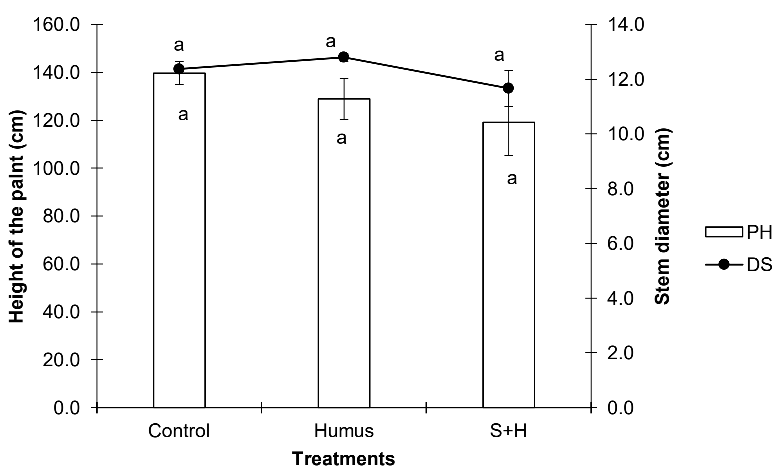

Figure 1. Effect on the height and diameter of the stem of habanero pepper plants (*Capsicum chinense* var. Mayapan) supplied with organic and inorganic sources, evaluated at 120 ddt. S + H = Soil-Humus combination; PH = height of the plant; DS = stem diameter. Treatments with the same letter are statistically equal (Tukey, P≤0.05).

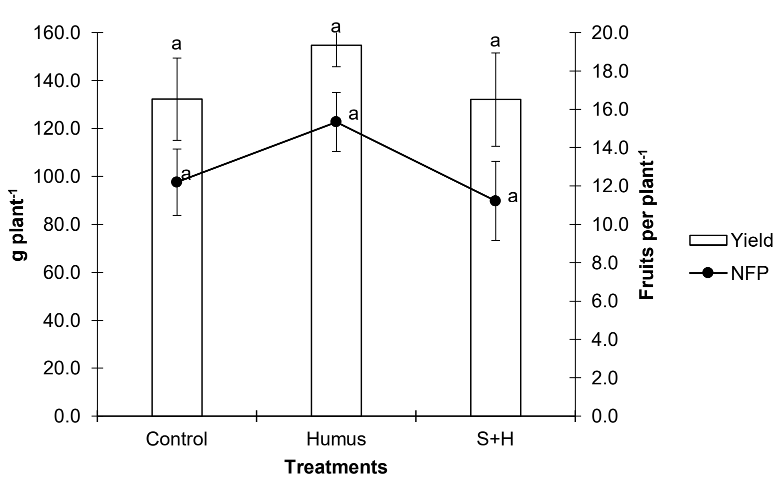

Figure 2. Effect of worm humus and chemical fertilizers on the yield and number of fruits per plant, accumulated from three harvests, on a habanero pepper crop (*Capsicum chinense*). S + H: Substrate-Humus combination; NFP: number of fruit per plant. Treatments with the same letter are statistically equal (Tukey, P≤0.05).

RESULTS AND DISCUSSION

The height variable reports no differences (P≤0.05) between the control and the treatments (Figure 1). This response is similar to that by Abreu *et al*. (2018) in plants from the same genus, and by Díaz *et al*. (2016) in squash cultivation (*Cucurbita* sp.). This behaviour demonstrates the earthworm humus ability in combination with the soil to supply the nutrients required during the vegetative development of crops.

The statistical analysis for the yield and total fruits number variables (sum of three cuts) had no significant differences (P≤0.05) between the control and treatments (Figure 2); However, the highest yield occurred in plants grown in 100% humus, with a value of 154.8 g per plant (15% higher than the control), followed by the control with 132.2 g and the humus-soil combination with similar values of 132.2 g per plant.

The number of fruits per plant followed the same trend behavior performance, registering 15.3 fruits per plant for the 100% humus treatment; 12.2 fruits per plant for the control; and 11.9 fruits per plant for the soil-humus combination. These trends are consistent with that reported by Reyes *et al*. (2017), who found that supplying 100% worm humus does not reduce the yield in *Capsicum annuum* and supports the idea of Abreu *et al*. (2018), where they propose that worm humus can be an effective alternative to reduce the use of chemical fertilizer without affecting productivity.

The similarity between the control and 100% humus, was perhaps due to the physical and biological attributes, which have been suggested, are improved with humus (Pérez *et al*., 2008), along with the high bacterial fauna content and high content of assimilable nutrients for the plants (Manaf *et al*., 2019). In this regard, Torres-González *et al*. (2017) characterized and identified the microorganisms present in vermicompost, identifying bacteria from the genus *Bacillus* sp. and concluded that these make a more efficient generation of macronutrients such as nitrogen (N), phosphorus (P) and potassium (K), essential elements for plant nutrition.

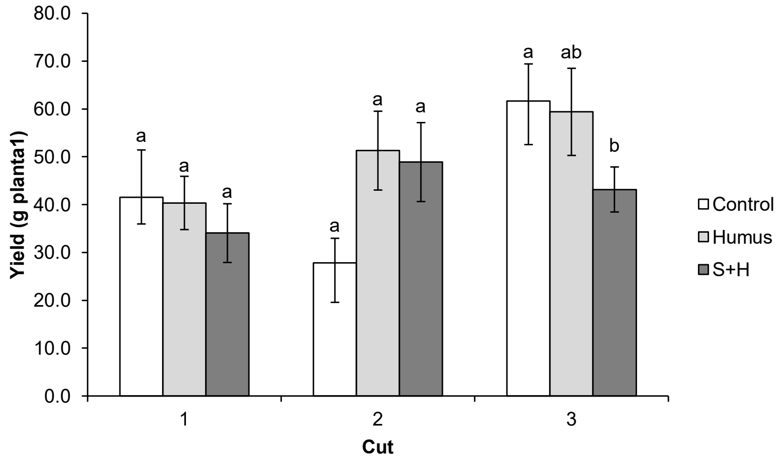

Figure 3. Fruit yield response of a Habanero pepper crop (*Capsicum chinense*) regard the effect of the substrate used as a nutrient source, from three cuts. S + H: Substrate-Humus combination. Treatments with the same letter are statistically equal (Tukey, P≤0.05).

Figure 3 shows the yield dynamics of the habanero pepper crop, from the three evaluated cuts, by treatments effect, where it can be seen that, particularly for the 100% vermicompost treatment compared to the control, in harvest one and three there were no significant differences (P≤0.05); not so for the second harvest, which was up to 80% higher than the control and favored the total yield (sum of three cuts), representing a slight increase respect to the control. For the humus + soil combination and the control, the first harvest showed no significant differences; but did at harvest two and three; in the latter the difference was negative. The above differs from that reported by Reyes *et al*. (2017), where the worm humus treatment exceeded the control in the first and second harvests and similar in the third.

The fruit quality, determined by the length, diameter and weight showed no differences (P≤0.05) with respect to the control in any of the parameters, which suggests that the fruit quality is not affected when using fertilizers from organic sources (Figure 4). Similar research, such as that of Reyes *et al*. (2017), supports these results by finding that worm humus favored the length, diameter and weight of the fruits. Authors such as Macías *et al*. (2012), when using manure as a source of nutrients in the production of jalapeño pepper (*C. annuum*), recorded that this organic amendment does not negatively affect the fruit quality. The obtained responses in all the evaluated variables showed that worm humus can supply the nutritional demand of habanero pepper crops, reflected with a similar response to chemical fertilization.

Various works developed with earthworm humus suggest this organic source as an important

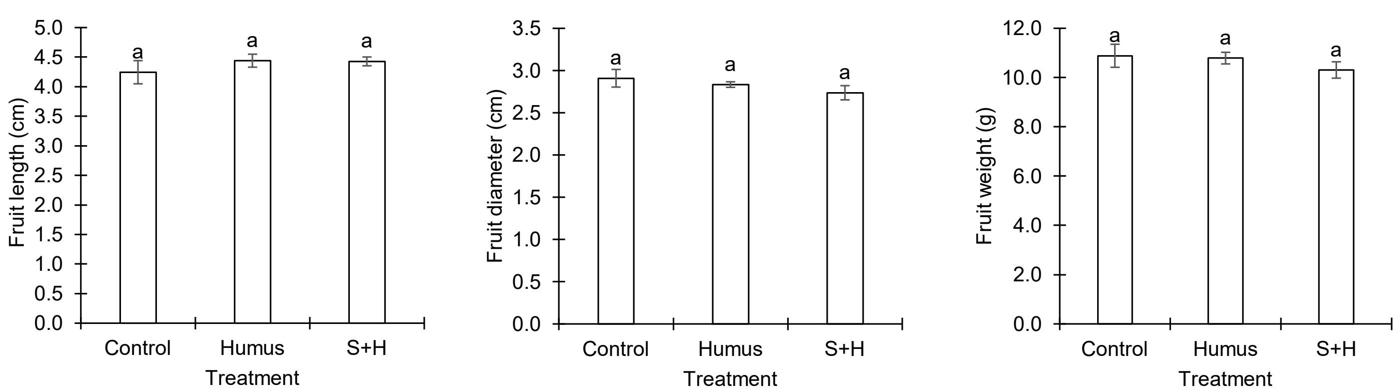

Figure 4. Response of a habanero pepper crop (*Capsicum chinense*) in the length, diameter, and weight of the fruit due to the effect of the substrate used as a nutritional source. S + H: Substrate-Humus combination. Treatments with the same letter are statistically equal (Tukey, P≤0.05).

means of supplying nutrients for agricultural production without affecting the quality of the fruit and yield, in terms of costs it could be a good alternative (Cantero *et al*., 2015; Abreu *et al*., 2018). These results, together with those reported for other organic sources such as compost (Vega *et al*., 2009) and manure (Vázquez-Vázquez *et al*., 2011), show the importance of organic amendments in agriculture to reduce the usage of inorganic fertilizers. In this regard, Vega *et al*. (2009) reported a significant economic effect with the use of vermicompost in the production of chili peppers (*C. annuum*), and Abreu *et al*. (2018) demonstrated that the potential of earthworm humus to reduce the application of chemical fertilizer without affecting the yield in *Capsicum* sp. Cantero *et al*. (2015) concluded that compost has a higher minimum marginal rate of return, and therefore, is a good alternative for sustainable fertilization.

CONCLUSIONS

The usage of earthworm humus as a substrate and source of nutrients in the production of habanero pepper does not affect the yield and quality of the fruits; which suggests it is an alternative to mitigate pollution due to excessive use of inorganic sources of fertilization and the reduction of the costs of production of this vegetable.

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Isolation and selection of rhizospheric bacteria with biofertilizing potential for corn cultivation

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ABSTRACT

Objective: To isolate and determine in a greenhouse environment the biofertilizing potential of rhizospheric bacteria associated to corn (*Zea mays* L.) at Campeche, Mexico.

Design/methodology/approach: Rhizospheric soils were collected from two corn production zones with different management conditions. Bacterial strains were isolated from these samples and their biofertilizing potential determined by *in vitro* and *in vivo* tests. The obtained data from both tests were assessed using an analysis of variance (ANOVA) and a means comparison test (LSD, $p \leq 0.01$).

Results: In total, 16 rhizospheric bacteria were isolated, a higher number in non-mechanized soils (n=10) compared to mechanized ones (n=6). In the *in vitro* tests, the most representative activity corresponds to nitrogen fixation (81%) attributed to a higher bacteria percentage, while the activity with lower bacteria numbers corresponds to IAA production (25%). At the *in vivo* tests in corn plants, the YM1 strain presented the highest fresh and dry root biomass (20 and 2 g plant^{-1}, respectively). The YM4 strain promoted greater plant height (63.33 cm), and YM5 registered the highest values in stem diameter (7.13 mm), root length (36.78 cm) and fresh shoot weight (12.03 g plant^{-1}).

Limitations/Implications: Strain evaluations were limited to controlled greenhouse conditions.

Conclusion: The YM1, YM4 and YM5 strains show potential for further evaluation as biofertilizers for corn cultivation under field conditions.

Keywords: sustainable strategies, plant growth, biofertilization.

INTRODUCTION

Corn (*Zea mays* L.) is considered the most important cereal in the world (Kurtz *et al*., 2016). In Mexico it is a basic crop for human and animal nutrition; it ranks first regard its acreage with approximately seven million hectares and a production volume of 23 million tons. Despite this, its national demand is around 39 million tons, so there is a production deficit (FAOSTAT, 2020; Reyes *et al*., 2018). Given this situation, it is important to increase corn's

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national production. However, this crop is highly extractive of the soil and therefore usually receives chemical fertilization, which represents 40-50% of their production cost and results in a lower profit margin for their producers (Reyes *et al*., 2018). The periodic use of fertilizers affects the environment and human wellbeing (Olanrewaju and Babalola, 2019). For this reason, it is important to investigate environmentally friendly production alternatives. In this sense, the bacteria found in the region around the plant's root systems are also known as plant growth-promoting rhizobacteria (PGPR) can be a strategy (Olanrewaju and Babalola, 2019). These bacteria can promote plant growth through various mechanisms, such as biological nitrogen fixation, and phosphorus, potassium, and some micronutrients solubilization, as well as promoting phytohormones synthesis and other metabolites associated with pathogens biocontrol such as antibiotics and siderophores. (Olanrewaju *et al*., 2017). There are several reports of groups of rhizobacteria associated with corn that promote its growth (Abedinzadeh *et al*., 2019; Bjelić *et al*., 2018; Karnwal, 2017; Richard *et al*., 2018; Toribio-Jiménez *et al*., 2017); however, native microorganisms may be better adapted to a specific region, making them ideal in strain selection processes, given that they could be more competitive than introduced bacteria (Karagöz, 2012). In this regard, even though in the state of Campeche, Mexico, corn is the main cultivated grain, with an area of approximately 150 thousand hectares (SAGARPA, 2019), there are no reports of native rhizobacteria used in its cultivation. Based on the above, the present work aims to isolate and determine in a greenhouse environment the biofertilizing potential of rhizospheric bacteria associated to corn (*Zea mays* L.) at Campeche, Mexico.

MATERIALS AND METHODS

The samples were collected from corn rhizospheric soil with different management conditions. At the ejido El Poste, Hopelchén, Campeche (19° 52' 12'' N and 89° 52' 16'' W) the samples considered as mechanized soil were taken, while at ejido Hool, Champotón, Campeche (19° 29' 84'' N and 90° 26' 03'' W) the non-mechanized soil samples. The rhizospheric soils were collected at a 0-20 cm depth, sampling five subsamples (golden five) that formed a composite sample. The soil was dried at room temperature for two days, sieved and stored in refrigeration until its microbiological analysis. The bacteria isolation was carried out via serial dilutions on base 10 following the methods by Velázquez-Gurrola *et al*. (2015). For this, 10 g of rhizospheric soil were diluted in 90 mL sterile water, up to 1/107. The specific solid media used were Pikovskaya and Rennie at 28 °C incubation. The different colonies were isolated and purified by exhaustion streak. The isolated strains were macroscopically characterized by polyphasic taxonomy and microscopically by Gram stain (Vincent and Humphrey, 1970). Likewise, the catalase test was performed (Hayward, 1960).

In vitro plant growth promotion was determined by inoculating 20 μL of each isolated strain in different specific media. The growth of the strain in Rennie medium indicates its nitrogen-fixing ability (Rennie, 1981). The phosphorus solubilization was determined in Pikoskaya agar medium as described by Ramírez *et al*. (2014). Potassium solubilization was determined with a modified Pikoskaya medium following Velázquez-Gurrola *et al*. (2015). Organic acid production was determined as described by Ogale *et al*. (2018). The phosphorus or potassium solubilization index (PSI or KSI) was calculated as the PSI or KSI ratio=(zone of halo+colony diameter)/colony diameter (Ramírez *et al*., 2014.). The production of indole-3-acetic acid (IAA) was determined as described by Sarker and Al-Rashid (2013) using Salkowaski reagent. The strains were grown in liquid Luria Bertani (LB) media and Nutritive Broth (NB) (given the bacteria requirement) with tryptophan (0.1%). The supernatant was used for AIA quantification with the aid of a Spectroquant NOVA60 spectrophotometer at a 540 nm length. The indole compound concentration was calculated with a linear regression equation of the calibration curve constructed with known IAA concentrations.

The *in vivo* growth promotion determination in corn plants was carried out in a greenhouse at the Campus Campeche of the Colegio de Postgraduados (19° 49' 79'' N; 90° 54' 76'' W). For it, the strains were selected and named as YM1, YM3, YM4, YM5 and for their effect in the in vitro tests. Bacteria were grown for five days in LB or CN media in an incubator (Thermo scientific MAXQ 4450) with shaking at 150 rpm at 28 °C. The cultures were centrifuged at 4000 rpm and the inoculants were prepared at a 10^8 CFU mL^{-1} concentration from the bacterial cell pellet. Corn seeds of the Dekalb 410 variety were disinfected with sodium hypochlorite (2%) and ethanol (96%) and placed in Petri dishes with sterile filter paper for 7 days until germination. Later, the plants were transplanted placing one plant per pot with a sterile substrate (earth, perlite and Peat moss). After 3 d, the plants were inoculated with 1 mL of the bacteria. In total, six treatments were evaluated in a completely randomized experimental design with five repetitions, these corresponded to: T1) control (with no inoculation), T2) inoculation with the YM1 strain, T3) inoculation with the YM3 strain, T4) inoculation with the YM4 strain, 5) inoculation with strain YM5 and T6) inoculation with strain YM6. Thirty days after inoculation, the following variables were assessed: Plant height (PH), stem diameter (SD), root length (RL), stem fresh weight (SFW), stem dry weight (SDW), fresh root weight (FRW) and root dry weight (RDW). The data obtained in the *in vitro* and *in vivo* tests were analyzed in the SAS statistical software for Windows version 9, through an analysis of variance (ANOVA) and comparison test of means (LSD, $p \leq 0.01$) (Steel and Torrie, 1986).

RESULTS AND DISCUSSION

In total 16 rhizospheric bacteria were isolated from corn soil subjected to different management conditions. A higher number of bacteria was isolated from non-mechanized soil from the ejido of Hool, Champotón, Campeche (n=10). A lower number, from mechanized soil from the ejido Poste, Hopelchén, Campeche (n=6) (Table 1). This can be explained, excessive mechanization has been documented to affect soil quality and the development of beneficial microorganisms (Padron *et al*., 2012).

From the total isolates, 62.5% (10 strains) were Gram-positive, the remaining Gram-negative (Table 1). Similarly, Toribio-Jiménez *et al*. (2017) and Abedinzadeh *et al*. (2019) reported a higher number of Gram-positive in corn. The 56% of the isolated strains were aerobic or catalase-positive, similar to those reported by Karnwal (2017).

Regard the *in vitro* plant growth promoter potential of the isolated strains, a nitrogen-fixing bacteria predominance (81%) was observed (Table 1). These results concur with reports of rhizospheric soils from corn (Toribio-Jiménez *et al*., 2017; Karnwal, 2017, Richard *et al*., 2018). In the production of indoloacteic acid (IAA), only 25% of the strains had this activity, the statistical analysis determined significant differences between them. The YRC2 strain reported the highest IAA production (4.264 μg mL^{-1}) registering statistical differences regard to the GRC4 (1.739 μg mL^{-1}), YM6 (0.526 μg mL^{-1}) and YM4 (0.736 μg mL^{-1}) strains. Olanrewaju and Babalola (2019) reported similar percentages in the number of bacteria capable of producing IAA in corn (20%). Similarly, the IAA production values found in the bacteria in this study were similar to those previously reported in bacteria obtained from rhizospheric soil of corn (0.10 to 3.6 μg mL^{-1}) (Mehnaz *et al*., 2010).

Respect phosphorus solubilization, 56% of the strains reported this activity. The statistical analysis of the phosphorus solubilization index (PSI) showed statistically significant differences between the strains. The GPA2 (0.453 mm) and YM1 (0.426 mm) strains had the highest ISP with no statistical difference between both. The YM6 (0.386 mm), YPB2 (0.363 mm) and YM3 (0.346 mm) strains had a medium activity PSI (Table 1). Olanrewaju and Babalola, (2019) reported a lower phosphorus solubilizing bacteria percentage in corn rhizospheric soil (29%), of which three reported medium and seven had slight activity.

Regard the potassium solubilization, 31% of the strains reported this capacity; however, no statistical significance was observed (Table 1). The main mechanism of potassium and phosphorus solubilization in bacteria is by organic and inorganic acids production (acidolysis) (Meena *et al*., 2014; Paredes-Mendoza and Espinosa-Victoria, 2010), in this study the high number of bacteria capable of producing organic acids (50%) suggests this is an important mechanism used by bacteria isolated from corn.

In the *in vivo* greenhouse plant growth promotion tests, statistical differences were observed in the assessed variables between the evaluated treatments. Plants treated with T4 (YM4) (63.33 cm) showed a higher PH (Table 2). This strain can produce IAA *in vitro*, as this auxin has regulatory effects on the growth and development of plants (Vessey, 2003), it could explain its effect on the PH variable. In turn, T5 treatment (YM5) reports the highest SD (7.13 mm), RL (36.78 cm) and SFW (12.03 g per plant). Also, the T2 (YM1) treatment showed the highest RDW (20.00 g per plant) and RDW (2.01 g per plant) (Table 2).

The data obtained on the root and shoot dry weight were higher than those previously reported from two corn varieties due to the application of *Pseudomonas putida* (CR7) and *Sphingobacterium canadense* CR11 bacteria (Mehnaz *et al*., 2010). The YM1 and YM5 strains *in vitro* showed nitrogen fixation ability, organic acids production, and phosphorus and potassium solubilization. In this regard, it has been reported that nitrogen promotes rapid

Table 1. Biochemical and physiological properties involved in plant growth-promoting of bacterial strains isolated from two sites at the state of Campeche, Mexico.

Site	strain	Gram reaction	Catalase test	Solubilization				Fixation of N	HCL	IAA(μg mL^{-1})
				P	PSI (mm)	K	KSI (mm)			
The ejido El Poste, Hopelchén	YM1	+	−	+++	0.426±0.02ab	++	0.475±0.14a	+	+	−
	YM2	−	−	−	−	−	−	+	+	−
	YM6	−	+	++	0.386±0.02 bc	++	0.566±0.09a	−	−	0.526±0.07c
	GRC4	−	−	−	−	−	−	+	−	1.739±0.10b
	GRB4	+	+	−	−	−	−	+	+	ND
	GPA2	+	−	+++	0.453±0.004 a	++	0.544±0.05a	−	−	−
The ejido Hool, Champotón	YRB6	+	+	−	−	−	−	+	+	−
	YPB2	+	+	++	0.363±0.00cd	++	0.483±0.04a	−	−	−
	YRA5	−	+	++	0.336±0.01de	−	−	+	+	−
	YRC4	+	−	+	0.166±0.08f	−	−	+	+	−
	YRB2	−	+	−	−	−	−	+	−	ND
	YRC2	+	+	−	−	−	−	+	−	4.264±0.24a
	YM3	+	−	++	0.346±0.0 cde	++	0.530±0.06a	+	−	−
	YM4	−	+	−	−	−	−	+	−	0.736±0.10c
	YM5	+	−	++	0.313±0.05 e	−	−	+	+	−
	YRB7	+	+	+	0.140±0.01 f	−	−	+	+	−

+: positive activity, −: negative activity, +++: high production, ++: medium production, +: low production; PSI = phosphorus solubilization index, KSI = potassium solubilization index. HCL: production of organic acids, ND: not determined. IAA: production of indoleacetic acid. Means with same letters within each column are not statistically different (LDS, 0.05).

Table 2. Effect of the inoculation of the selected strains on the growth in corn plants after 30 days of the inoculation.

Treatments	PH (cm)	SD (mm)	RL (cm)	SFW (g plant$^{-1)}$	SDW (g plant$^{-1)}$	RFW (g plant$^{-1)}$	RDW (g plant$^{-1)}$
T1: with no inoculation	59.57±2.3b	6.57±0.2ab	27.17±1.4d	8.37±0.1 b	1.97±0.2 a	13.14±2.1c	1.61±0.1c
T2:YM1	61.15±0.8 ab	6.63±1.1ab	33.40±1.2ab	11.12±2.3ab	1.63±0.3ab	20.00±0.0 a	2.01±0.1a
T3: YM3	62.47±2.1 ab	6.70±0.5ab	31.57±0.9bc	12.00±0.9a	1.84±0.1ab	17.15±0.6b	1.87±0.1ab
T4: YM4	63.33±4.1a	6.70±0.3ab	30.50±1.0bcd	10.92±2.4ab	1.68±0.4ab	17.57±2.8ab	1.71±0.2bc
T5: YM5	60.90±1.0ab	7.13±1.0 a	36.78±4.3a	12.03±3.8a	1.90±0.6ab	17.12±1.3 b	1.81±0.2ab
T6: YM6	59.37±0.3b	5.80±0.9b	28.67±2.0cd	11.60±0.7ab	1.30±0.1b	10.98±0.8 c	1.27±0.1d

PH: Plant height, SD = stem diameter; RL = root length; SFW = stem fresh weight; SDW: stem dry weight, RFW: root fresh weight, RDW = root dry weight. Means (n = 10) with the same letters in each column are not statistically different (LSD, 0.05). ±= standard deviation.

cell division and elongation (Peña and Reyez, 2007), coupled with the fact that phosphorus is an important micronutrient for plant growth since it participates in multiple metabolic processes (Karnwal, 2017). Viruel *et al*. (2014) demonstrated that phosphorus solubilizing bacteria can stimulate stem growth and higher biomass production.

The results indicate that the YM1, YM4 and YM5 rhizobacteria have positive effects on growth promotion of corn plants and therefore have great potential to be used in the field as biofertilizers in this study region.

CONCLUSION

Sixteen bacteria strains were isolated and a greater number of strains from non-mechanized soils. The plant growth promoter activity with the highest percentage of bacteria corresponded to nitrogen fixation. The lowest activity corresponded to IAA production. YM1, YM4 and YM5 strains showed a positive effect in promoting plant growth of corn plants in *in vivo* tests. Therefore, they show the potential to be evaluated as biofertilizers for corn cultivation under field conditions.

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Yield estimation of forage oat (*Avena sativa* L.) Chihuahua variety: ruler and plate methods

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ABSTRACT

Objetive: To analyze forage estimations with the direct method and the plant height.

Design/methodology/approach: The treatments were the plants age, assessed in a random block design. Simple linear regressions were carried out and adjusted using the SPSS statistical software.

Results: The highest and lowest yields occurred at 105 and 30 days after sowing (DAS), with 5,412 and 783 kg DM ha^{-1}, respectively. Height with the rule had a significant effect on forage production, with an R^2 of 0.83. For each increase per cm the plants increased 56,134 kg DM ha^{-1} within the studied range. The height with the plate had an R^2 of 0.97, so that 65.032 kg DM ha^{-1} are produced for each cm in height.

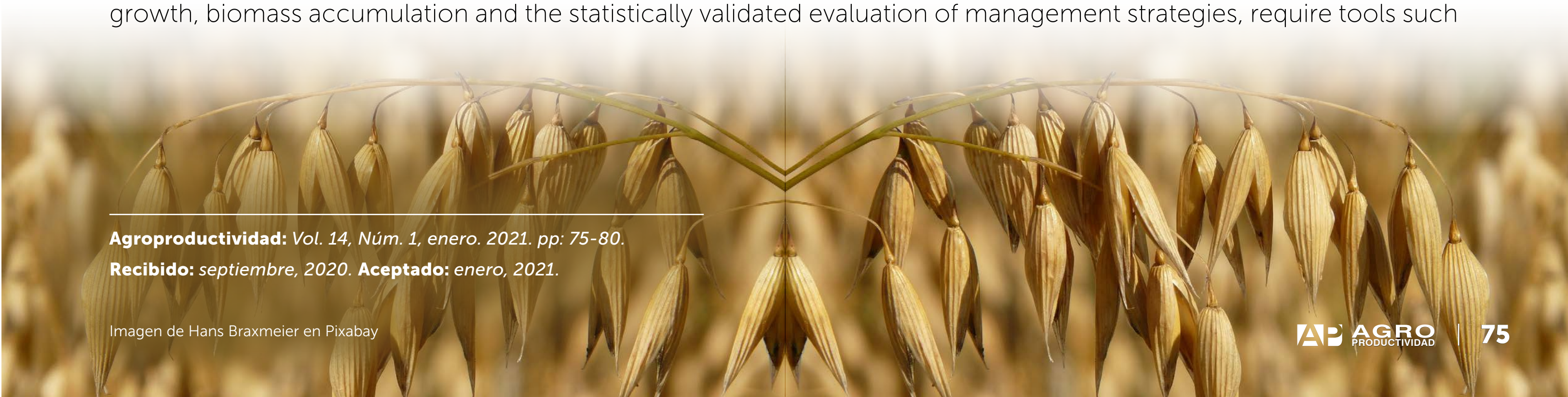
Study limitations/Implications: None

Findings/conclusions: The forage accumulation in *Avena sativa* L., var. Chihuahua varied depending on the age of the plant. The heights calculated with the plate method, had greater reliability for the forage yield estimate, compared to the graduated rule method.

Keywords: Estimation methods, plant height, forage yield.

INTRODUCTION

Avena sativa L. is a cereal adapted to different climatic conditions (Sosa *et al*., 2020), which makes it an available forage source during the dry seasons (Ávila *et al*., 2006). Recently, its sown area has increased, so that the agricultural land usage has changed (Zartash *et al*., 2018). However, forage species such as alfalfa (*Medicago sativa* L.) are widely used in agricultural production systems; never the less, they decrease their dry matter production during winter (Moreno *et al*., 2002). For this reason cereals such as oats, barley and triticale are viable alternatives (Feyissa *et al*., 2007). Therefore, the description of its growth, biomass accumulation and the statistically validated evaluation of management strategies, require tools such



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as growth analysis models (Di Benedetto and Tognetti, 2016), to also determine their animal load, these requires frequent plant growth and forage production measurements (Castro *et al*., 2011). Forage availability can be directly or indirectly estimated, the most accurate way, by the direct cut method, since it provides an objective indicator of the forage yield, as long as the number of samples is adequate (López *et al*. , 2011). This method is destructive and involves time investment, work and equipment (Mannetje, 2000). Therefore, fast, accurate and unbiased measurement variables are required, which correlate with forage availability (Castilo *et al*., 2009). Some of the recently developed involve the forage availability, pasture height and density (Hepp *et al*., 2017a), given that they are associated with growth and productivity (Hakl *et al*., 2012). For this, different instruments are used, among which: the compressed height meter or measuring plate, graduated ruler, capacitance rod, stand out. These require corroboration through calibration equations and prediction models (Hepp *et al*., 2017b). Therefore, the objective of this study was to analyze the estimate of available forage, of oats (*Avena sativa* L.), var. Chihuahua, through the direct and plant height methods, determined via the graduated ruler and measuring plate methods.

MATERIALS AND METHODS

Experimental site

The study was conducted from august, 2018 to january, 2019, at the Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México (19° 29' N, 98° 53' W and 2240 m). The climate is temperate subhumid, the driest of this group, with an accumulated annual rainfall of 636.5 mm, with rains in summer (June to October) and an average annual temperature of 15.2 °C (García, 2004). The soil is sandy loam, slightly alkaline, with a pH of 7.8 and 2.4 g (100 g)$^{-1}$ of organic matter (Wilson *et al*., 2018). The weather data was obtained from an agrometeorological station located 1 km from the experimental area (Figure 1).

Pasture management

An oat meadow (*Avena sativa* L.), var. Chihuahua. Fifteen 64 m^2 (8×8 m) plots were delimited on August 24, 2018. Seeds were broadcast sowed, at a sowing density of 115 kg SPV ha^{-1}, with 95% purity and 94% germination. No fertilization was applied, but gravity irrigation was provided every 15 days at field capacity, during dry season. Evaluations took place every 15 days, 30 to 135 days after sowing (DAS).

Experimental design and treatments

The treatments were the plants age and were distributed in a random block design. The experimental units were 64 m^2 plots, which represented the plant age (DAS).

Experimental evaluations

The average height of each experimental plot was determined by two estimation methods: 1) Graduated ruler method: a one-meter length graduated wooden ruler, a 1 cm precision was used, placed vertically from the base of the plant up to the last upper component,

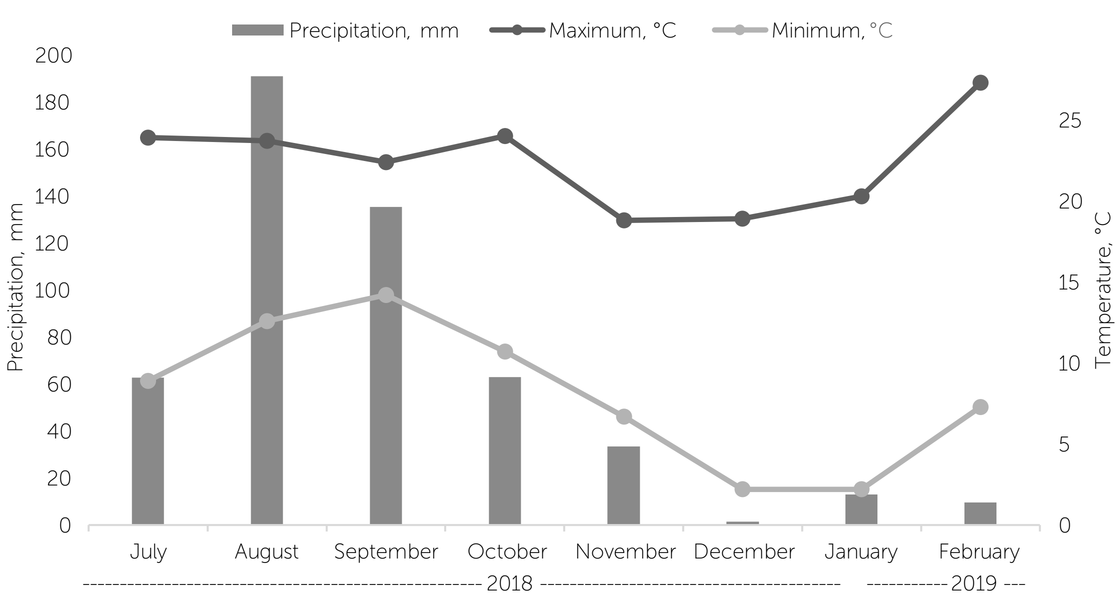

Figure 1. Maximum and minimum average temperatures (lines, vertical secondary axis) and accumulated precipitation (bars, vertical primary axis) from July 2018 to February 2019.

without disturbing the plant (Hodgson *et al.*, 1999). 2) Plate method (Jenquip®): a 50×50 cm aluminum plate was used, slide on its axis, compressing the mass of forage with the plate's weight (Hepp *et al.*, 2017a). Ten random readings (30 readings per plant age) were taken for each method. With the direct method, the forage weight (kg DM ha^{-1}) was determined, using two quadrants of 0.25 m^2 (50×50 cm), in which the forage was harvested from ground level and dried for 72 ha 55 °C in a forced air stove (Mod. Felisa FE-243A) until constant weight (López *et al.*, 2011).

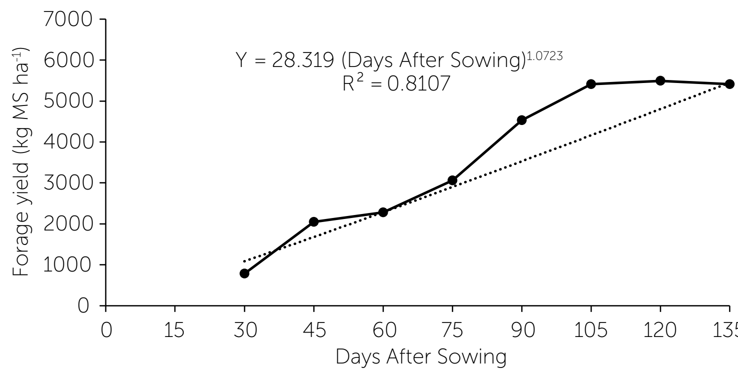

Figure 2. Forage yield curve (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages.

Statistical analysis

Simple linear regressions were performed; DMY=ALT (b); where DMY=Dry Matter Yield, ALT=Plant height, and b=is the regression coefficient in kg DM ha^{-1} per cm of plant height, with DMY and ALT already defined (Santillan *et al.*, 1979). The regressions were adjusted with the Statistical Package for Social Sciences software (SPSS, 2011), the significance of the correlation coefficients was calculated ($p<0.05$) and an analysis of variance and a means comparison (Tukey; $p<0.05$) were assessed.

RESULTS AND DISCUSSION

Relationship between yield and plant age

The forage yield of *Avena sativa* L., var. Chihuahua, was significantly different ($p<0.05$) at different ages of the plants (Figure 2). The best fit regression model was that of the potential, with $R^2=0.81$; therefore, the DMY was positively correlated with the age of the plant, given that 81% of the total variability of the DM yield data was explained in by the plants age. The differences ($p<0.05$) were observed at 105 DAS with 5412 kg DM ha^{-1}, respect to the first age (30 DAS, with 783 kg DM ha^{-1}), later the curve became asymptotic. This trend is observed when the rate of senescence and decomposition exceeds the rate of leaf and stem production (Hernández *et al.*, 1999). In temperate grasses, DM accumulation is maintained until week seven or eight of regrowth and decreases once the meadow reaches an optimal leaf area index, due to self-shading at the base of the plants (Chapman and Lemaire, 1993). Wilson *et al.* (2018), in var. Turqueza reported at 112 DDS 6.702 kg DM ha^{-1}, and in var. Saia, at 141 DAS 12,188 kg DM ha^{-1}, in a milky-mass state. For their part, Zartash *et al.* (2018) report 5,000 kg DM ha^{-1}, at 160 DAS and Hernández *et al.* (2018) in var. Chihuahua, 6,074 kg DM ha^{-1}, at 164 DAS. Therefore, the results of this study have no high differences with that reported in previous research, although these developed in different climate and soil conditions (Wilson *et al.*, 2017).

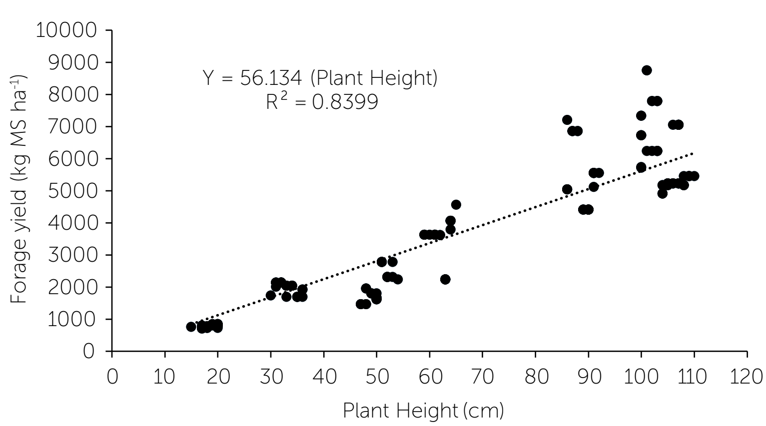

Figure 3. Linear regression between the non-compressed heights (X) obtained with the ruler method and yield (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slope of the line was statistically different from zero ($P<0.05$) but not the intercept ($P>0.05$).

Linear equations between yield and ruler height

The height with the graduated rule had a significant effect ($p<0.05$) on the DM production of oats (*Avena sativa* L.), var. Chihuahua. The regression equation showed an acceptable fit range (Figure 3), since the variation in DM performance was determined by at least 83% by the variation of the height measured with rule ($R^2=0.83$), that is, for each cm of increase in height, the forage yield increased 56,134 kg DM ha^{-1}. The above suggests that the estimated height with a ruler is a useful and practical tool to estimate DM yield in *Avena sativa*, var. Chihuahua. However, in cutting herbaceous plants in the United States, the rule method was reported as the least reliable, given its low coefficient of determination ($R^2=0.37$) and respect to the plate ($R^2=0.59$) (Ganguli *et al.*, 2000). Likewise, in Gramineae -

fabaceae meadows in Pennsylvania, West Virginia and Maryland, USA, correlation coefficients of R^2=0.16 were reported, respect to a capacitance meter (R^2=0.31), reporting error rates of 26 and 33 % (Sanderson *et al*., 2001). Therefore, to obtain reliable yield estimates from the height of the plants with a graduated rule, regression equations must be generated for each management condition and forage species (Castillo *et al*., 2009).

Linear equation between yield and height with plate

The relationship between the height with the plate and the forage yield, of oats (*Avena sativa* L.) had a significant effect ($p<0.05$). The equation showed an adjustment to a simple linear model (Figure 4) with an R^2 value of 0.97, which indicates that 97% of the variation in the DM yield is explained by the height via the plate, obtaining 65,032 kg DM ha^{-1} for each cm of plant height. This technique exceeds the reliability of the rule method, since its correlation coefficient is higher (0.97 *vs* 0.83; Figure 3 and 4). In prairies and pastures in the United States, where the R^2 values for the plate method range between 0.70 and 0.83, which exceeds the rule method, it registers values of 0.37 for prairies and 0.59 for natural grasslands (Gangulli *et al*., 2000). Even with low values (0.31) with the plate, in prairies in association of Gramineae - fabaceae, they exceed the capacitance meter and the graduated rule (0.31, 0.19 and 0.16, respectively) (Sanderson *et al*., 2001). In bermuda grass var. Brazos, values of R^2=0.90 were reported for the plate, surpassing the capacitance meter (0.89) and the rule (0.86) (Gonzales *et al*., 1990). For this study, the oat yield, var. Chihuahua, can be projected with greater reliability, by estimating the height with the plate rather than with the graduated rule (R^2=0.97 *vs* 0.83, Figures 3 and 4), since the plate combines height and density, and therefore, denser meadows present more resistance to measuring their height with the plate (Hepp *et al*., 2017). According to Griggs and Stringer (1988) the forage yield has more correlation with the estimated height with the plate respect to that of the rule. Likewise, Hakl *et al*. (2012) indicate that alfalfa (*Medicago sativa*) has a better coefficient of determination of height with a plate (R^2=0.72), than with the rule (R^2=0.53).

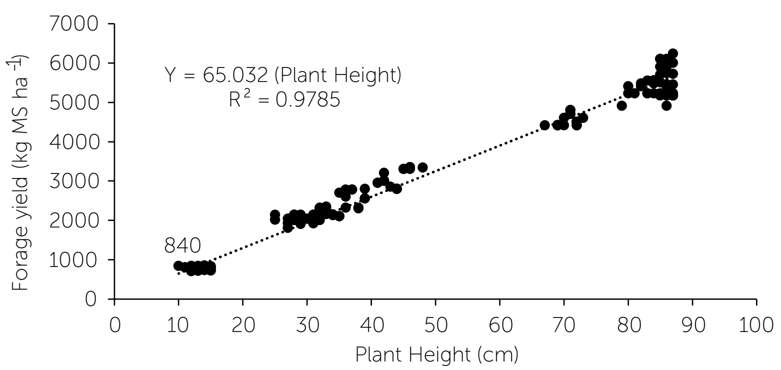

Figure 4. Linear regression between compressed heights (X) obtained with the plate method and yield (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slope of the line was statistically different from zero ($P<0.05$) but not the intercept ($P>0.05$).

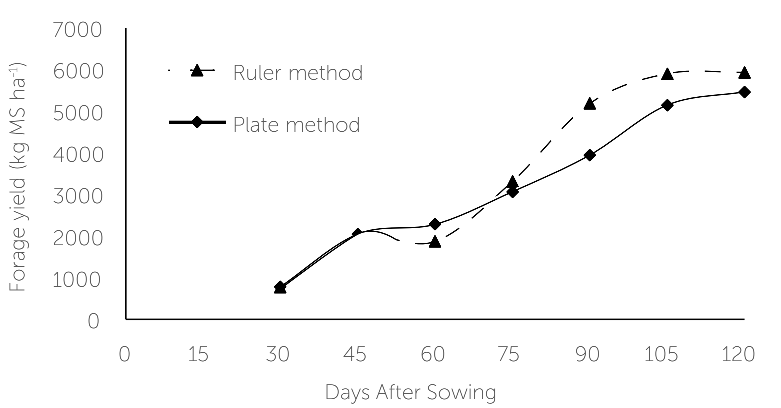

Figure 5. Average dry matter yields (Y) predicted with the ruler and plate methods, in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slopes of the lines were statistically different from zero ($P<0.05$) but not the intercepts ($P>0.05$).

Predicted yields of heights with the ruler and plate methods

Figure 5 shows the predicted values of the dry matter yield in out (*Avena sativa* L.), var. Chihuahua, harvested at different plant ages. From 30 to 45 DAS, the results from both methods were statistically similar ($p>0.05$). Subsequently, the equation obtained with the plate height was closer to the yield with the direct method, explained by the higher positive correlation between these two variables due to the higher coefficient of determination (R^2=0.97) (Figure 4). The highest predicted yields were recorded in both methods at 120 DAS, with 5,922 and 5,595 kg DM ha^{-1} respectively. These were significantly different ($p<0.05$)

from those recorded at the beginning of the study (1,035 and 806 kg DM ha^{-1}, at 30 DAS). Castillo *et al.* (2009) indicate that the higher the plant, the higher the obtained forage production is. In this study, due to the age of the plants, its height and the RMS increased in each method; however, with the rule there were higher heights, but the correlation coefficient was lower (R^2=0.83; Figure 3), which reflects a less reliable method respect to the plate. Hodgson (1999) mentions that when the height of the pasture and the density of forage are considered, by an estimation method, forage production is evaluated in a more reliable way. This is why Ganguli *et al*. (2000) report better results with the plate than with the rule, based on a higher correlation coefficient (R^2=0.83 *vs* 0.60, respectively).

CONCLUSIONS

The behavior of the accumulation curve of oats (*Avena sativa* L.) var. Chihuahua, varied as a function of the plants age. As the age of the plants increased, the forage yield increased up to 105 days after sowing. It is stated that the yield of the evaluated variety can be reliably estimated from the height with the plate method; however, further evaluation is required to better train the models. However, the height kept a high correlation with the forage yield, so it can be used as a practical criterion to determine the optimum harvest point of *Avena sativa* L. var. Chihuahua

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Analysis of the industrial quality of three sugarcane cultivars at "Santa Rosalía de la Chontalpa" sugarcane mill

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ABSTRACT

Objective: To evaluate the industrial quality of three sugarcane cultivars during the plant cycle at the supply area of "Santa Rosalía de la Chontalpa" sugarcane mill.

Design/Methodology/Approach: An experiment was established under a factorial design 3×3 (3 cultivars: CP 72-2086, MEX 79-431 and MEX 69-290; × 3 sampling dates: 330, 390 and 450 days after sowing (DAS)) on an Eutric Fluvisol soil. In each plantation, a sample of 10 stems with three replications was collected to determine the industrial quality by polarimetry.

Results: The industrial quality of the evaluated cultivars only differed statistically in terms of the percentage of purity, MEX 79-431 was the one that presented the lowest value for this variable. At 450 DAS, the highest value was observed for °Brix (17.28), POL percentage (14.92), purity (86.44%). The values obtained in the present study for the quality of juice in the evaluated cultivars are within the range of the standard values established for Mexico.

Limitations/Implications: Polarimetry is still the method used by most of the sugar mills in Mexico, even if other more environmental-friendly methodologies exist.

Findings/Conclusions: The trend line that best fit to MEX 69-290 and MEX 79-431, for °Brix, POL and purity, was a linear polynomial and to CP 72-2086, a polynomial quadratic. Fresh stems humidity and reducing sugars showed best fit with an inverse polynomial. °Brix presented strong and positive correlation with POL (R=0.99**); and strong and negative with reducer sugars (R=−0.95**) and fresh stem humidity (R=−0.91**).

Keywords: industrial quality, sugar cane, cultivars.

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INTRODUCCIÓN

The economic success of sugarcane cultivation is determined by the accumulation of sucrose in the internodes of their milling stems (Batta *et al*., 2002), the maturation process being fundamental for the industry, since it needs to alternate the farms and harvest periods to have a control that guarantees the supply of good quality raw material throughout the harvest (Moura *et al*., 2014). For this, it is necessary to have cultivars of early, medium and late maturing.

The sugarcane payment system currently adopted by the vast majority of sugar and alcohol industries is that of total recoverable sugars, called TRS. In this system, the quality of the sugarcane juice delivered to the mills and distilleries is evaluated by the content of soluble solids, apparent sucrose, reducing sugars and fibers. Therefore, cultivars that have a better quality of raw material and allow a higher industrial yield for the production of sugar and alcohol are of great importance for a rational exploitation of sugarcane (Da Silva *et al*., 2013). The ripening process of sugarcane is closely related to the age and cycle of the crop, and to the climatic conditions, but the genetic character is decisive. In terms of genetic materials, in Mexico, sugarcane production is mainly based on three genotypes: CP 72-2086, MEX 79-431 and MEX 69-290, which together occupy 74% of the designated area. to this crop in the country (Sentíes-Herrera and Gómez-Merino, 2014).

The reference values of the quality parameters of sugarcane juice in Mexico are: sucrose and POL of 12.5%, Brix degrees (°Brix) of 18 - 22, purity of 79 to 89%, fiber of 11 to 15%, humidity of 73 - 75% and reducing sugars close to zero (Salgado *et al*., 2003). For all the above, the objective of this work was to evaluate the industrial quality of three sugarcane cultivars during the plant cycle, in the supply area of Santa Rosalía de la Chontalpa sugar mill.

MATERIALS AND METHODS

The experiment was carried out under rainfed conditions, during the plant cycle in the supply area of "Santa Rosalía de la Chontalpa" sugar mill (ISRCH, in Spanish). Three sugarcane cultivars were used (CP 72-2086, MEX 79-431 and MEX 69-290). For this purpose, nine commercial plots (three for each cultivar) were located and georeferenced on a Eutric Fluvisol soil, with similar sowing dates. The local cooperating producers were responsible of the agronomic management of the crop. In each plantation, a sample with three replications (10 stems per replication) was collected, which were separated from sections 8-10. Stem samples and sections 8-10 were transported to the field laboratory of the ISRCH, where determination of the industrial quality of the samples was performed by polarimetry. Samplings were collected at 330, 390 days after sowing (DAS), and at harvest (450 DAS).

Experimental design and statistical analysis

The experiment had a 3 × 3 factorial design (3 Cultivars × 3 DDS). The statistical analysis consisted of the analysis of variance (ANOVA) for the effect of Cultivar (Cv), DAS and the Cv × DAS interaction with a significance level of $P \leq 0.05$ and the Tukey multiple means comparison, using INFOSTAT version 2018. A non-linear regression analysis was run with the juice quality data, determining the curve that best adjusted to each situation.

RESULTS AND DISCUSSION

Brix degrees

No statistically significant differences were found among cultivars (Table 1), recorded mean values were between 15.23 and 15.85 °Brix, lower than the mean values of 20.4 - 21.3 °Brix observed by Pereira *et al*. (2017), during the harvest of four sugarcane cultivars in Brazil. The °Brix increased from 13.94 at 330 DDS to 17.28 at 450 DAS, the latter value being slightly lower than 18 °Brix established as the minimum optimal value in sugar cane, according to Salgado *et al*. (2003). CP 72-2086 cultivar shows a slight drop in °Brix at 450 DAS sampling (Figure 1), although this was not statistically significant. The highest values of °Brix were observed in the 450 DAS sampling, reaching an average of 17.28 °Brix, similar to 17.15 and 17.86 °Brix reported by Salgado *et al*. (2017) for CP 72-1210 and MEX 69-290 with a supply of 120 and 180 kg N ha^{-1}, respectively. But they were lower than 20.3 to 22.35 °Brix described by Clemente *et al*. (2018) for three sugarcane cultivars at 402 DAS.

POL (%)

According to the multiple comparison test of Tukey, the POL (%) among cultivars is similar, since it found no statistic difference between its (Table 1). The percentage of POL fluctuated between 12.5 to 13.43, which is considered adequate for sugarcane juice with good quality (Salgado *et al*., 2003). Regarding the sampling dates, the highest percentage of POL (14.92) was observed in the sampling collected at 450 DAS, being lower than 18.53 to 19.75%

described by Clemente *et al.* (2018), for cultivars RB991536, RB011941 and RB92579 at 402 DAS.

The interaction between cultivars and sampling dates indicates that the percentage of POL was different between samplings at 330 and 390 DAS for MEX 69-290 and CP 72-2086, not finding differences between samplings at 390 and 450 DAS for those cultivars (Table 1). For MEX 79-431 a statistical difference was observed among three sampling dates, showing the highest percentage in the harvest, this can be explained by the sucrose accumulation process that occurs during the maturity stage of the sugarcane. The mean values presented by the cultivars, in the sampling at 450 DAS were 13.98% for CP 72-2086 and 15.62% for MEX 69-290 and MEX 79-431, which are higher than 12.0 to 13.4% reported by Islam *et al*. (2011) for six sugarcane clones.

The °Brix and POL (%) of CP 72-2086, showed a slight decrease between sampling at 330 and 450 DDS, although

Table 1. Analysis of variance and Tukey mean test of juice quality in three sugarcane cultivars, during the plant cycle in the ISRCH supply area.

Interaction Cv × DAS	DAS	MEX 69-290	CP 72-2086	MEX 79-431	Mean DAS†
°Brix	330	14.21 abc	14.17 ab	13.44 a	13.94 A
	390	15.57 bcde	16.32 cdef	14.84 abcd	15.58 B
	450	17.77 f	16.64 def	17.42 ef	17.28 C
	Mean Cv	15.23a	15.71a	15.85a	
POL (%)	330	11.84 ab	12.01 ab	10.51 a	11.45 A
	390	12.82 cd	14.17 cd	11.83 ab	12.94 B
	450	15.62 d	13.98 bcd	15.62 d	14.92 C
	Mean Cv	13.43b	13.39ab	12.5b	
Fiber (%)	330	11.99 ab	12.08 ab	11.42 a	11.83 A
	390	12.76 ab	12.99 b	11.83 ab	12.30 AB
	450	12.69 ab	11.48 a	12.73 ab	12.53 B
	Mean Cv	12.48a	12.18a	11.99a	
Purity (%)	330	83.24 abc	84.66 bc	78.13 a	82.01 A
	390	84.59 bc	84.57 bc	79.85 ab	83.0 A
	450	87.92 c	84.00 bc	87.41 c	86.44 B
	Mean Cv	85.25b	84.41b	81.80a	
Humidity (%)	330	82.9 b	81.24 b	83.68 b	82.61 B
	390	74.47 a	75.38 a	76.73 a	75.53 A
	450	74.52 a	75.48 a	73.37 a	74.46 A
	Mean Cv	77.29a	77.37a	77.93a	
Reducing sugars (%)	330	0.76 b	0.63 ab	0.76 b	0.72 B
	390	0.60 ab	0.55 ab	0.59 ab	0.58 A
	450	0.47 a	0.57 ab	0.53 ab	0.52 A
	Mean Cv	0.61 a	0.58 a	0.63 a	

	Probability of F for:			C. V (%)
	Cv	DAS	Interaction Cv × DAS	
°Brix	0.2424 NS	0.0001**	0.1850 NS	8.41
POL	0.0317*	0.0001**	0.0070*	10.24
Fiber	0.1726 NS	0.0176*	0.0099*	7.24
Purity	0.0016*	0.0001**	0.0027*	3.88
Humidity	0.5263 NS	0.0001**	0.0220*	2.65
Reducing sugars	0.6707 NS	0.0006**	0.4227 NS	26.66

†Cv=Cultivars, DAS= days after sowing, C. V.= coefficient of variation. Means with a letter in common do not present statistical difference (P≤0.05). Lowercase letters represent differences horizontally and uppercase letters do it vertically.

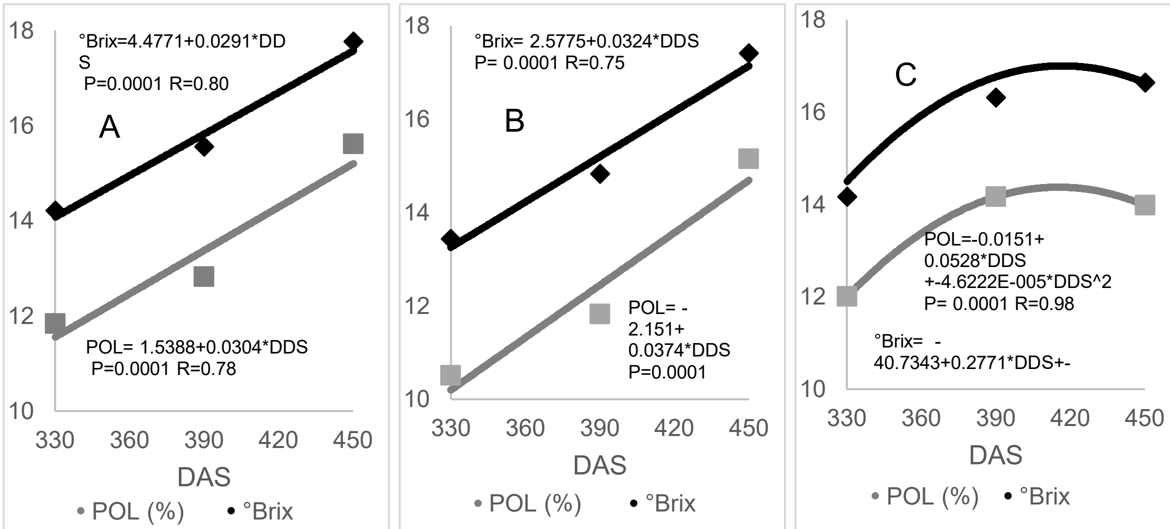

Figure 1. Accumulation dynamics of °Brix and POL (%) for sugarcane cultivars A) MEX 69-290, B) and C MEX 79-431) CP 72-2086 during the plant cycle in the supply area of ISRCH.

this was not significant. The trend line that was best adjusted for these variables in cultivar CP 72-2086 was quadratic polynomial (Figure 1), and indicates decrease in °Brix and POL in that cultivar; while for MEX 69-290 and MEX 79-431 a linear polynomial trend line was better adjusted, indicating that °Brix and POL values did not decrease. In this regard, Rodríguez *et al*. (2015), when evaluating 38 introduced sugarcane cultivars in Cuba, determined that the second-degree polynomial equation was the best fit to model the maturity of sugarcane cultivars during the evaluated harvest period.

Purity (%)

The cultivar MEX 79-431, presented the lowest percentage of purity (81.80%) compared to cultivars MEX 69-290 (85.25%) and CP 72-2086 (84.41%), between which there was no statistically significant difference. Values were lower than 87.45 to 88.45%, those found by Clemente *et al*. (2018). Regarding the sampling dates, between 330 and 390 DAS, there was no significant statistical difference, but there was for the sampling collected at 450 DAS, where the highest percentage of purity was observed (Table 1). Values observed for purity ranged between 82.01 and 86.44% at the sampling dates, which are slightly lower than the 85.5 to 87.5% observed by Xiao *et al*. (2017) in Guangxi, China.

In Figure 2, accumulation dynamics of the purity percentage of

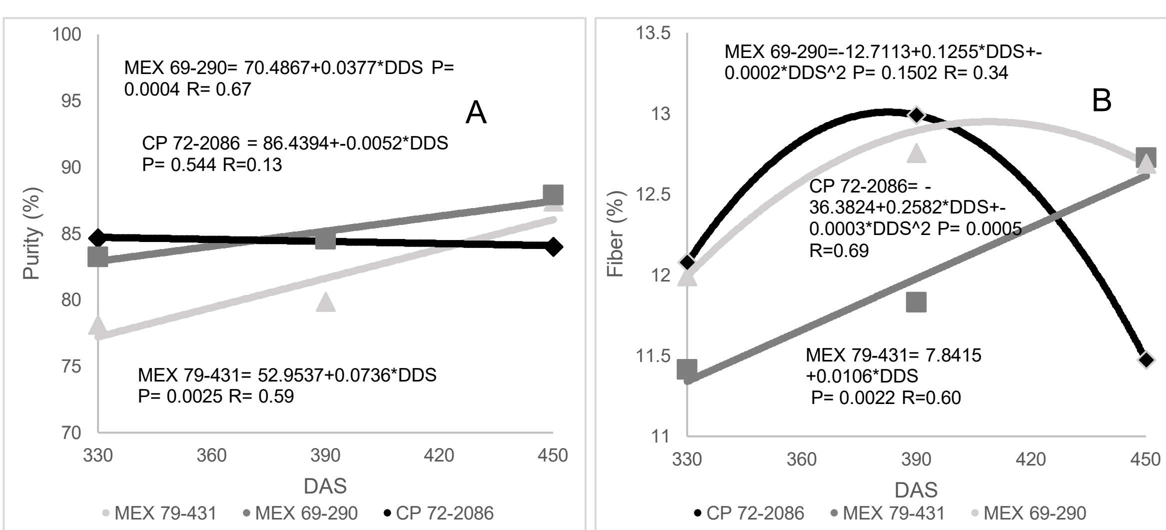

Figure 2. Dynamics of the percentage of (A) purity and (B) fiber of three cultivars of sugarcane during the plant cycle.

sugarcane cultivars can be observed throughout the maturity stage. The changing trend of purity (although without statistically significant differences) is clearly observed, expressing an increase from 330 DAS until harvest in cultivars MEX 69-290 and MEX 79-431.

The trend line that showed the best fit to the purity values (%) was a linear polynomial, although this was not significant for CP 72-2086 (Figure 2A). The mean purity values (%) observed in the sampling at 450 DAS for the three cultivars (84.00 to 87.92%), are slightly lower than those of 85.9 to 89.3% reported by Islam *et al*. (2011), for six sugarcane cultivars in Bangladesh.

Fiber (%)

For the fiber percentage, there was a statistically significant difference for the effect of the sampling date and for the Cv × DAS interaction (Table 1). The values registered for the cultivars were between 11.99 and 12.48%, which are lower than the 13.2 to 13.5% reported by Clemente *et al*. (2018). Regarding the sampling date, the highest percentage of fiber (12.53%) was observed in the sampling at 450 DAS, although it was not statistically different from the one performed at 390 DAS (12.30%). While the lowest value (11.83%) was observed in the sampling at 330 DAS, being less than 13.08 to 14.0%, those described by Salgado *et al*. (2017) for 10 sugarcane cultivars supplied with 0, 120 and 180 kg N ha^{-1}.

The Cv × DAS interaction for the fiber percentage shows that for the cultivar MEX 69-290 and MEX 79-431, the fiber accumulation dynamics was similar, an increase was observed as the harvest approached, although this was not statistically different. In the case of the CP 72-2086 cultivar, a different dynamic is observed, since the fiber percentage decreased significantly from the sampling at 390 to that collected at 450 DAS. The curve that fits the best for the fiber percentage values is a quadratic polynomial in CP 72-2086 and MEX 69-290, while for MEX 79-431, a linear polynomial was the better fit (Figure 2B).

Humidity (%)

The humidity content percentage was not significantly different among cultivars. However, for the effect of the sampling date and the Cv × DAS interaction, a statistically significant difference was observed (Table 1). The humidity percentage was very similar among the cultivars, with values of 77.29 to 77.93%, which are higher than those reported by Salgado-García *et al*. (2014) who reported humidity percentage of 69.79 and 70.14% for cultivars CP 72-2086 and MEX 69-290, respectively.

Regarding the samplings, the one performed at 330 DAS presented a higher value for humidity content (82.61%), decreasing in the subsequent samplings, although without statistical differences between 390 DAS (75.53%) and 450 DAS (74.46%). The dynamics of the humidity percentage of the evaluated cultivars showed a tendency to decrease as the harvest date approaches, reaching values between 73.37 and 75.78% at 450 DAS, which, according to Salgado *et al*. (2013), are considered adequate. The trend line that presented the best fit for the data of humidity percentage in stems was an inverse polynomial (Figure 3A).

Reducing sugars (%)

No statistically significant difference was found among the cultivars for the variable reducing sugars (%). Regarding the sampling date, it is observed that the reducing sugars decreased in the evaluated plantations (Table 1) as the harvest approached, being that at 390 and 450 DAS, when the lowest percentage of reducing sugars was registered (0.58 and 0.52% respectively); while the highest value (0.72%) for reducing sugars was observed at 330 DAS.

In Figure 3B it can be seen that reducing sugars are high when sugarcane is immature and low when it is ripe for harvest. These results are similar to those reported by Xiao *et al*. (2017) who mentioned that, during the period from growth to maturity of sugarcane, after the sucrose produced by the leaves is transported to the stems, the proportion of growth in the form of reducing sugars gradually decreases, and sugar reduction increases significantly when sugarcane is overripe, especially when juice quality tends to decrease.

Although the values of reducing sugars were not statistically different, for the cultivar CP 72-2086, a slight increase in the percentage of reducing sugars was observed in the sampling at 450 DAS, which indicates that this cultivar in plant cycle should be harvested after 330 DAS but before 450 DAS. This feature shows that CP 72-2086 is an early maturing cultivar. MEX 69-290 and MEX 79-431 showed a behavior as cultivars of medium-late maturity. The trend line that presented the best fit for the data on the percentage of reducing sugars was an inverse polynomial (Figure 3B).

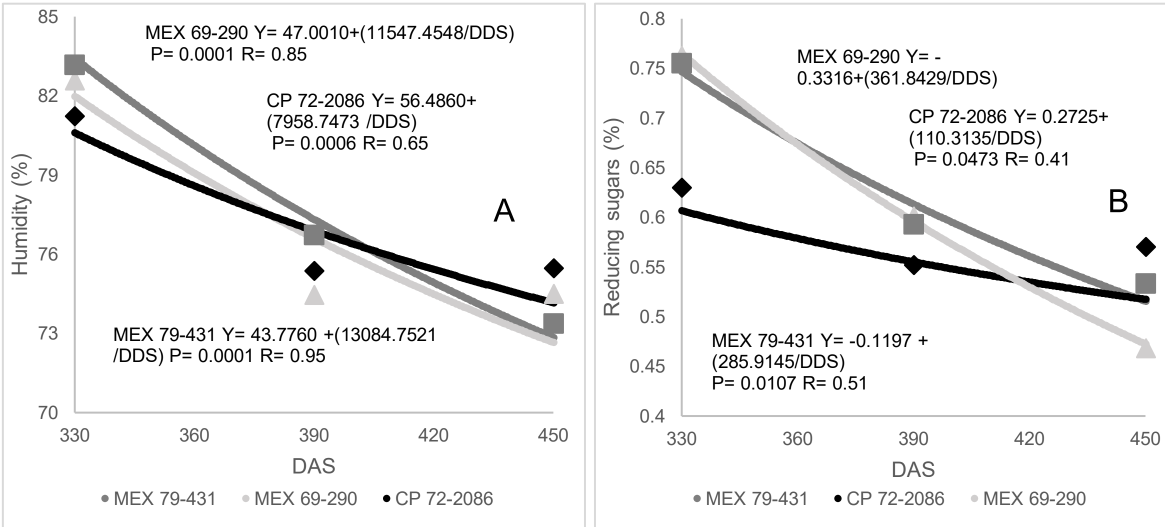

Figure 3. Dynamics of the percentage of (A) humidity and (B) reducing sugars, of three sugarcane cultivars during the plant cycle.

In Figure 1, it can be observed that the behavior of °Brix and the percentage of POL of the three evaluated sugarcane cultivars is similar, that is, as the °Brix increases or decreases, so does the percentage of POL and *vice versa*. This finding can be verified by the strong positive correlation presented between these variables (R=0.99 **; Table 2). Brix degrees presented a strong negative correlation with values of humidity percent and reducing sugars (R=−0.91 ** and R=−0.95 **, respectively), indicating that high °Brix values correspond to low values of humidity content and reducing sugars.

On the other hand, humidity percentage was strongly and positively correlated with the percentage of reducing sugars (R=0.91 **). In this regard, Salgado *et al*. (2016) observed that the lower the humidity in the stem, the less contents of reducing sugars.

CONCLUSIONS

Industrial quality of the evaluated cultivars only differed statistically in terms of the percentage of purity, with MEX 79-431 being the cultivar that presented the lowest value for this variable (81.80%); compared to MEX 69-290 (85.25%) and CP 72-2086 (84.41%) between which no statistically significant difference was observed.

In the sampling at 450 DAS, the highest value for °Brix (17.28), POL percentage (14.92%) and purity (86.44%) was observed. For the percentage of fiber, humidity and reducing sugars, no statistically significant difference was found between those samplings collected at 390 and 450 DAS. Values obtained in this study for the juice quality in the evaluated cultivars are within the range of standard values established in Mexico.

The trend line that best fitted the data for °Brix, POL and purity in MEX 69-290 and MEX 79-431 was a linear polynomial, while in CP 72-2086 it was a quadratic polynomial. Fiber percentage in CP 72-2086 and MEX 69-290 was best fitted with a quadratic polynomial trend

Table 2. Pearson's correlation coefficients (P≤0.05) between pairs of variables of juice quality (%) in three sugarcane cultivars during the plant cycle.

	°Brix (%)	Humidity (%)	Reducing sugars (%)	Fiber (%)	Purity (%)	POL (%)
°Brix	1	**	**	**	**	**
Humidity (%)	−0.91	1	**	**	**	**
Reducing sugars (%)	−0.95	0.91	1	**	**	**
Fiber (%)	0.66	−0.47	−0.54	1	**	**
Purity (%)	0.79	−0.71	−0.73	0.84	1	**
POL (%)	0.99	−0.91	−0.94	0.71	0.86	1

** highly significant (P≤0.05).

line and in MEX 79-431 with a linear polynomial. For the data of humidity percentage and reducing sugars, the trend line that best fitted was an inverse polynomial. Brix degrees (°Brix) presented a strong and positive correlation with POL (R=0.99 **) and strong and negative correlation with humidity percentage and reducing sugars (R=−0.91 ** and R=−0.95 **, respectively).

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Protein Inputs of Animal Origin Used in the Substitution of Fish Meal in Aquaculture Feed

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ABSTRACT

Objective: To highlight some studies carried out with alternative protein sources from byproducts of animal origin to replace fish meal (FM) in the nutrition of aquaculture species.

Design/Methodology/Approach: A search for new protein sources of animal origin was carried out and experimentally evaluated with species of aquaculture interest, employing an information search methodology through the analysis of metadata kept in databases throughout the World Wide Web.

Results: Advantages and disadvantages of including byproduct flours of animal origin in the diet of aquatic organisms are pointed out. However, for worldwide aquaculture it is essential to emphasize that this protein exchange should not affect aquatic ecosystems but rather mitigate the effects of environmental impacts and promote the sustainability of aquaculture.

Study Limitations/Implications: The results of incorporating flours of animal origin in substitution of FM in the diets of aquaculture species are experimentally indicated, while specifying that there are no reports indicating the transcendence of such substitution in commercially balanced meals.

Findings/conclusions: Each of the dietary alternatives described here works at certain nutritional levels, decreases costs and increases the digestibility index, allowing for better water quality by disposing less nitrogen into the aquatic environment, without sacrificing the quality of the diets or the energy content of the final products.

Key words: aquaculture, proteins, diets, byproducts.

INTRODUCTION

There is environmental legislation in Mexico for sustainable development in the agriculture, livestock, aquaculture, and fishing sector which aims at moving towards good production practices. A strategy to achieve this is to generate exploitation of natural resources by promoting a culture of transformation and reutilization of byproducts from industries of the primary sector that can be used as protein substitutes in diets formulated for aquatic species, on the premise of being as efficient as commercial diets, in addition to showing

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a reduction in production costs (Aurrekoetxea and Perera, 2002). In this research, several studies with alternative protein sources are analyzed, based on byproducts of animal origin used to replace fish meal (FM) for the nutrition of aquaculture species, thus revealing the potential for their implementation and ecological benefits.

MATERIALS AND METHODS

A meta-analysis was carried out relying upon databases in the World Wide Web through Information Sciences (IS), Information and Communication Technologies (ICT), in addition to library resources and Open Educational Resources (OER) (Michán, 2011). A structured and systematic integration of the information about the topic was conducted through consultation of articles in scientific journals and libraries, carrying out the retrieval, translation, meta-analysis, interpretation, and drafting of the material (Tinto, 2009; Michán, 2011).

RESULTS AND DISCUSSION

Byproducts of animal origin can offer a wide range of raw materials that exist anywhere in the world and which, after aminogram and toxicity tests, can be included in the formulation of balanced meals for almost any aquaculture species. Some of these inputs are mentioned next:

Shrimp Head Flour (SHF)

Shrimp heads are discarded in shrimp farming at processing plants; this byproduct has an amino acid profile similar to that of soybean flour (*Glycine max* L.) and FM (Espinosa *et al*., 2015), with an average raw protein value of 50.72% (Belandria and Morillo, 2013), in addition to being a source of unsaturated fatty acids, minerals and carotenoids (Benitez, 2018). There are published studies about the physicochemical evaluation of oil obtained from shrimp heads where high concentrations of fatty acids were discovered, such as linoleic (C_{18}:2n_6), oleic (C_{18}:1n_9), and palmitic (C_{16}:0) acids, besides eicosapentaenoic (C_{20}:5n_3, EPA) and docosahexaenoic (C_{22}:6n_3, DHA) acids, with a mean astaxanthin content of 2.72 mg g^{-1}, which is a powerful antioxidant and nutraceutical agent (Núñez *et al*., 2011; Navarro *et al*., 2020). SHF also contains chemical-attractant molecules, thus allowing high palatability and being attractive for the consumer organism, managing to diminish FM from 5% and up to 30% when included in artificial food. This highlights that enriching a diet for shrimps with byproducts of the same shrimp industry allows for the improvement of the farm's efficiency, reaching greater survival and growth compared to the traditional ones (Benitez, 2018; Barbarito *et al*., 2009; Pelegrin, 2013). Espinosa *et al*., (2015) agrees that protein substitution of FM with SHF in the inclusion of feed for young totoaba (*Totoaba macdonaldi*) significantly improves the feed's digestibility with substitution levels of 30%.

Mollusk Entrails

Studies have been carried out with giant squid flour (*Dosidicus gigas*), to feed young marine fishes, such as Gulf corvina (*Cynoscion othonopterus*), showing high efficiency from obtaining greater yields in final weight and survival than in fish fed with the FM control diet (Madrid, 2014). In another experiment, Toyes (2016) developed diets based on scallop (*Pinna rugosa*) and giant squid (*D. gigas*) entrails to feed Pacific white shrimp (*Litopenaeus vannamei*). Its results demonstrated higher survival rates, between 18% and 21%, than those of the control diet, in addition to reporting a higher weight gain (35% and 50%) than the control diet, leading to the conclusion that incorporating flour of marine byproducts from cooked mollusks in the feed for shrimp as a substitute for FM increases consumption and growth in shrimps, in addition to decreasing the dietary condition factor (DCF). However, caution must be taken when using this kind of marine byproducts, since Benitez (2018) discovered that incorporating filtering mollusks such as the Catarina scallop (*Argopecten ventricosus*) in diets formulated for longfin yellowtail (*Seriola rivoliana*) had negative effects because the flour contained a marine toxin identified as okadaic acid, which affected the health of farmed fish and caused mortality. This toxin is produced by marine dinoflagellates of the genus *Dinophysis* spp and *Prorocentrum* sp, which accumulate in bivalve mollusks as a result of filtration and ingestion of these dinoflagellates in the ocean. If human beings consume these bivalves, affectations can be severe, given that the resulting pathology is diarrheic shellfish poisoning (DSP) caused by phycotoxins (Hernández, 2017).

Biological Ensilage

Biological ensilage is an affordable option that employs minimal technological infrastructure in its production; it is widely and mainly used with fishery byproducts (Salah *et al*., 2014). Fish processing produces between 50% and 60%

waste, the main ones being: head, backbone, fins, skin, and entrails, which are employed in the formulation of diets for several animal species (Calderón *et al.*, 2017). Delgado (2018) obtained 40% protein when using ensilage flour from the soft residues of Peruvian calico scallop (*A. purpuratus*), an input added in the ratio of between 2% and 10% to the diet of *L. vannamei* shrimp, thus discovering that these diets improve the organism's survival and weight gain. Carrasco (2016) used ensilage made of giant squid (*Dosidicus gigas*) entrails, tentacles and skin, concluding that it can be used as an alternative protein source to FM in diets formulated for *L. vannamei*. Cota (2018) designed a nutritional formula with giant squid (*D. gigas*) ensilage combined with soybean paste, coconut (*Cocus nucifera* L.) flour, and *Lactobacillus fermentum*, managing to obtain a nutritional profile of 44% protein, a meal which was evaluated in a bioassay with *L. vannamei* using a biofloc system. This author's results recorded greater growth in farmed shrimp, with more weight gain (39%), specific growth rate higher than 2.93% per day, 81% survival, and lower feed conversion of 1.5, thus concluding that this diet has strong viability to be applied in commercial farming.

Protein Hydrolysates

Enzymatic hydrolysis of proteins is the oxidation of organic matter to enzymatic degradation of different sized peptides. This process increases protein levels in diets, which will greatly determine their nutritional characteristics and use (Benítez *et al.*, 2008). The quality (source), origin (safety), and type of proteolytic enzymes are key factors in the production of protein hydrolysates (Li and Kittikun, 2010; Zapata and Castañeda, 2017). Inputs such as eggs, meat, blood, entrails, and cereals are the most commonly used, while yeast or casein hydrolysates are used as source of fermentation for the growth of microorganisms (Benítez *et al.*, 2008). Cárdenas (2014) indicated that fish hydrolysates show better nutritional and functional properties than those of whole fish or fish protein concentrate (FPC), without showing drawbacks such as elevated costs of protein raw materials used in fish diets, as well as FM scarcity in the international market (López, 2014). Carranza *et al.* (2018) researched the inclusion of hydrolyzed protein extract from tissues of weakfishes (*Cynoscion* sp.) and tilapia (*Oreochromis* sp.) in balanced meal for shrimp, where there was a favorable growth of 11% (weakfish hydrolysate) and 24% (tilapia hydrolysate). The greatest attraction was observed in shrimp fed with the balanced meal plus tilapia hydrolysate, in addition to having shown a specific growth rate (SGR) of 2.0% and a registered survival rate of 68% (with tilapia hydrolysate) and 71% (with weakfish hydrolysate), compared to the 52% survival rate obtained with balanced feed with FM. This demonstrated the effectiveness of including fish hydrolysates given the contribution of essential amino acids supplemented in diets for shrimp.

Livestock Industry

In the livestock industry there are meat processing byproducts, such as: bones, horns, hooves, tendons, some pieces of offal, blood and its constituents, all of which have a high nutritional value given their high protein content, complete profile of essential amino acids, and functional properties for the food processing industry (Barragán, 2013). There are studies showing their adequate implementation in aquaculture nutrition (Moutinho *et al.*, 2017), whether individually or combined with other nutritional sources, since they have amino acids such as: isoleucine, lysine, and methionine, which are paramount for the development of aquatic species (Márquez *et al.*, 2005). In this sense, blood meals (BM) have a greater potential given their high protein concentration, often higher than 85%. However, they have disadvantages for aquatic diets, since Villarreal *et al.* (2014), through studies conducted on the digestibility in diets for young *L. vannamei* based on several meat processing byproducts, determined that BM is the ingredient with most solubility in its amino acids in marine water, and it also has lower apparent digestibility coefficient of amino acids (65.3%), compared to that of FM (76.4%). Nevertheless, this raw material should not be completely dismissed, since it can be employed complementarily to the traditional diet and reinforced with fish oil, which in addition to having a high content of essential fatty acids, n-3 HUFAs, also enriches the diet and can reduce its lixiviation in marine water, thus creating a protective film on the feed particle as a stabilizing emulsion if it is used in larval diets for fish, crustaceans, or bull-frog tadpoles.

Poultry Industry

The poultry industry wastes most of the parts of the birds that are sacrificed, such as: carcasses, bones, legs, feathers, heads, and offal. Even when these byproducts are processed as poultry meal (PM) for flavoring or broth, they are not largely used as inputs in commercial diets for aquaculture species. Campos *et al*. (2017) conducted a bioassay with feather flour in young European seabass (*Dicentrarchus labrax*), managing to replace FM up to 76% with PM in its diets, thus concluding that there were no differences in growth or in survival from the fish fed with the control diet. Within tilapia farming, fermented poultry byproducts have managed to substitute FM from 20% to 80%, due to their kinetic characteristics, such as an increased activity in lipases and proteases, and due to their greater bioavailability and digestibility, in addition to a greater immune response (Dawood *et al*., 2020; Samaddar, 2018). Successful substitutions of up to 80% from FM by PM have been carried out in young *Oreochromis niloticus* (Hernández *et al*., 2010); however, when only chicken offal is used the final lipid content in the nutritional profile has increased, although the growth of young tilapia is lower than with the control feed based on FM (Alofa and Abou, 2019). Therefore, the additional implementation of essential fatty acids as a complement to the diets from these byproducts in various fish species is discussed (Barreto *et al*., 2016). Fish meal is the most commonly used input in dietary formulas for aquaculture, given the quality of its proteins due to the amino acid balance and concentration, combined with its high digestibility (Madrid, 2014). Obtaining raw material for its production has an environmental impact, because of overfishing of wild populations of sardines, herrings, and other forage and accompanying species that naturally appear as primary links in the trophic chains of marine environments, added to rising prices due to its growing demand and high operational costs of fishing and industrialization (Cota, 2018; Carranza *et al*., 2018). Commercial balanced meals for several aquatic species that are 100% manufactured on the basis of alternative sources to fish meal are not currently available in the market, which is why it is considered as an emergent market with high profitability index and necessary for the sustainability of aquaculture in Mexico. It is clear that when using byproducts as protein means, the environmental impact of otherwise wasted raw materials is reduced, so it is very important to promote a circular economy or "waste-free economy" in order to make the best use of byproducts branded as waste for the creation of new products and implementations. Mexico needs entrepreneurs with projects that are solely devoted to collecting all the waste of various food processing industries and its reconversion into diverse reusable inputs, not just for the food industry, but which can also be applied in the generation of biodiesel, biopolymers, and organic nano particles with different uses in various industries.

CONCLUSION

Each one of the dietary alternatives described here functions at certain nutritional levels, decreases costs, and increases the digestibility index. This allows improving water quality by disposing less nitrogen into the aquatic environment, without sacrificing the quality of diets or the energy contents of the final products.

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Evaluation of the consumption of two integral diets for psittacines in captivity in a wildlife rescue unit

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ABSTRACT

Objective: To evaluate the consumption of nutrients intake in a traditional and a proposed diet for parrots in captivity.

Design/methodology/approach: The study took place at Pachuca de Soto, Hidalgo, Mexico. Twelve parrots were assessed in captivity. The traditional diet (TD) provided to the birds was evaluated and a proposed diet (PD) was the alternative. The consumption and the amount of waste of each diet were recorded for five weeks. PD formula contained fruits, vegetables, and seeds. Data were analyzed with the Student's t-test at $p<0.5$ significance.

Results: TD lacked homogeneity in the ingredients offered during the five weeks evaluation. There were significant differences in the consumption between the two evaluated diets. The individual bird consumption was 349 g for TD and 314 g for PD. The TD was 41.87% fruits and 58.12% vegetables. The PD diet included seeds supplements. From the second to the fifth week of the evaluation PD had less waste.

Limitations of the study: The age, weight, sex and excreta collection from the parrots were not registered due to restriction rules in the conservation area.

Findings/conclusions: The PD offered the requirements that parrots need. It is necessary to train technical personnel on diet preparation. Feeding frequencies and food diversity stimulated consumption and waste decreased, improving the nutritional balance of the birds in captivity.

Keywords: Parrots, consumption, captivity, alternative diet.

INTRODUCTION

The Psittacidae (*Psittacidae*) are a family of birds of the order *Psitaciforme*. They include 86 genres with 353 species, most of which distribute in the tropics and are classified into three families: *Loriidae*, *Cacatuidae* and *Psittacidae* (Ravazzi and Conzo, 2008). These birds, commonly known as parrots and macaws, are characterized by their large hooked beaks and zygodactyl feet

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(fingers two and three forward and one and four back). *Psittacines* are a gregarious species, most of the time they are seen in pairs or large groups (Recalde and Vinueza, 2013). *Psittacines* are one of the taxonomic groups that have the greatest trafficking of species problem. These are generally extracted from their natural environments and if recovered, placed in rehabilitation centers or zoos, the management of these individuals in captivity are of vital importance.

Knowledge and implementation of adequate nutrition and feeding programs for *psittacines* is necessary to maintain or improve their well-being in captivity conditions (Jiménez, 2008). The amount of nutrients required by these birds depends on their metabolic demand for the maintenance of their body mass in relation to the physiological stage in which each individual is (Soto-Piñerido and Bert, 2011). Birds in free natural conditions, tend to expend excess energy, since they are constantly active, feeding and flying (O'Malley, 2007). In captivity, feeding is essential to maintain their usual body and physical processes according to their species. Supplying food, not containing or exceeding the amount of necessary nutrients, can predispose them to the appearance of nutritional disorders and diseases (Fowler and Miller, 2011). In Mexico, there are many *psittacines* under human care, for either research, rehabilitation, reproduction, conservation or exhibition (Engebretson, 2006). As an alternative response to their extinction threat, zoos and rescue centers must develop and implement conservation and feeding strategies in their available habitats (Collados, 1997). The objective of the present study was to evaluate the consumption of the nutrient intake in a traditional diet, compared to an alternative diet. The latter through the formulation and proper management of wild birds in captivity.

Figure 1. Alternative diet with fruits and vegetables in a plastic bucket.

MATERIAL AND METHODS

The study took place at the first "Unidad de Rescate, Rehabilitación y Reubicación de Fauna Silvestre, Endémica y Exótica de México" (Unit for the Rescue, Rehabilitation and Relocation of Wild, Endemic and Exotic Fauna in Mexico URRRFSM+), which shares public spaces with the "Parque Infantil Bioparque Convivencia" at Pachuca de Soto Hidalgo, Mexico. Located in the Central-Eastern part of Mexico, at an altitude of 2400 m (20° 06′ 59.6′′ N and 98° 44′ 45.1′′ W) and a mean annual temperature of 25.4 °C.

The URRRFSM contains 12 *psittacines* specimens of five species of undetermined sex. The *psittacines* enclosure is a closed place where all the specimens in the study are housed, its shape is rectangular measuring 4.30 m wide × 15 m long × 8 m high in its highest point and 6 m in its lowest.

Study design

The consumption and food waste of the traditional diet (TD) were evaluated for five weeks. After this period, a new ration, the alternative diet (AD) was formulated; the birds were adapted for a week to the new diet and from then on, the consumption and amount of waste were again recorded for another five weeks. The eating habits and routine during the TD offering period occurred daily. The birds were fed daily at 9:00 am in a feeder inside the unit. The AD was formulated with first quality fruits and vegetables, preserved in refrigeration. (Figure 1). Table 1 shows the content of both diets. The food was cut into homogeneous 2×2 cm pieces and placed in a plastic bucket.

Table 1. Diets provided to psittacine in captivity.

Traditional Diet (TD)*		Alternative Diet (AD)*	
Ingredient	g 100 g^{-1}	Ingredient	g 100 g^{-1}
Raw corn	33.10	Tabasco Banana	18.18
Banana	14.71	Papaya	13.64
Apple	13.57	Apple	13.64
Melon	13.57	Melon	13.64
Broccoli	10.13	Raw corn	22.72
Spinach	6.31	Beet	4.54
Celery	4.40	Spinach	4.54
Chard	4.21	Seed concentrate*	9.10

* .- wet base ** Seed concentrate (g kg^{-1}): oats 0.21, peanuts 0.08, sunflower 0.08, wheat 0.21, sorghum 0.21, millet 0.21.

During both diets preparation, all food was weighed with an Avery Berkel® DZ342 electronic scale with a 15 kg total capacity. The food supplied was weighed daily and during the morning of the next day, the excess food was collected, weighed and the daily consumption of the birds estimated. The leftover food was collected with a spare mesh placed on the cage floor, below the perches.

The nutritional value of the provided diets was determined with the UFFDA® software designed for formulation and estimation of nutritional requirements, specific for *psittacines*. Before the calculations, the dry matter content (AOAC, 1990) of the ingredients was determined, dehydrating it in an oven at 65 °C for 24 h. The obtained information was entered into the program to increase the precision of the nutritional requirements.

Figure 2. Alternative diet of seed concentrate offered at 1:00 p.m.

The AD included a complement with concentrated oat seeds in grain, peeled peanuts, sunflower seeds, wheat, sorghum and white millet. This mix was kept stored at the Nutrition Center, where the required daily portion was taken from. (Figure 2). The distribution of the AD was as follows: at 9:00 a.m. a portion of chopped fruits and vegetables and at 1:00 p.m. the portion of seeds. The percentage of the content of the ingredients in the AD was made up of 59.09% fruits, 31.81% vegetables and 9.09% seeds.

Statistical analysis

The data were grouped in a spreadsheet in the Excel software. The data analyzed with a T-Student test in the IBM-SPSS statistical software (V. 21). The means comparison was made between the TD *vs*. AD group of the same week or time with a 0.5 significance.

RESULTS AND DISCUSSION

The nutritional value of the diets is shown in Table 2. The *psittacines* requirements are limited. Jiménez (2008) mentions that the amounts of protein for maintenance, growth and reproduction ranges between 15, 19 and 20%, and the amounts of fat and fiber should not be greater than 5%. Regard mineral contribution, the phosphorus (P) in both diets is greater than calcium (Ca); however, it is important to mention that these birds are also fed a compact solid biscuit, which contains a high amount of calcium and some vitamins. The birds freely consume them and with it, balance the Ca: P ratio in a 2:1 ratio.

During the study, the TD lacked homogeneity of the ingredients offered during the day. Variations were recorded regarding the size and portion of the ingredients, due to the lack of technical-operational knowledge of the personnel who prepared the rations. These inappropriate practices are common when there is either ignorance or lack of training (Cisneros, 2006), providing quantities greater than that of daily needs. Table 3 shows the daily consumption recorded for the n=12 bird specimens kept in the enclosure. There were significant differences in consumption during the five weeks of study ($P<0.01$). The individual consumption of each bird was on average 349 g for TD and 314 g for AD as wet consumption.

The higher TD consumption was possibly due to its lower nutritional contribution compared to AD. Additionally, on some occasions one ingredient was increased instead of another, the justification been the lack of some ingredient. Likewise, a common criterion of

Table 2. Nutritional balances estimated using the UFFDA® software in two diets provided to psittacines in captivity.

Nutritional Requirements	Traditional diet	Alternative diet	Concentrated seeds	Unit
Balance	Amount			
E Metabolizable	4.6776	6.8960	4.2529	Mcal/g
Protein	18.53	16.76	15.0025	%
Fat	3.24	4.43	10.6530	%
Calcium (Ca)	0.25	0.26	0.0758	%
Phosphor (P)	0.36	0.61	0.4860	%
Vitamin A	1397691	5208520	0.5300	UI/Kg
Vitamin E	2556496	559100	0.0094	mg/Kg

The proposed diet analysis includes the added percentage of the seed concentrate.

Table 3. Registered behavior of the food consumed for two evaluated diets in captive *psittacines*.

Period (Weeks)	Traditional Diet (TD)		Alternative Diet (AD)		P
	Mean	SD	Mean	SD	
I	4.102	0.128	3.366	0.082	<0.01
II	4.306	0.059	3.770	0.166	<0.01
III	4.176	0.046	3.882	0.039	<0.01
IV	4.214	0.044	3.910	0.056	<0.01
V	4.144	0.046	3.898	0.030	<0.01

SD: standard deviation.

the caretakers included that if some ingredient was not palatable, was not included in the ration.

During the development of the study, the TD contained 41.87% fruits and 58.12% of vegetables. However, sometimes rations were modified due to each operational technician criteria; This attitude generated an imbalance in the nutritional content and increased food waste (Table 4). During the study, development vegetables were the ingredients most left by the birds. Most of these ingredients had problems in their reception and preservation, therefore, it was common that they are rejected during the offering and consumption. Lawton (1988) recommended the use of fresh ingredients, Noriega and Lozano (2008) suggest feeding the birds more than twice a day, to stimulate consumption and reduce confinement depression.

The AD included supplementation of a seed concentrate necessary for these species (Noriega and Lozano, 2008). The AD offered a feeding alternative, consisting of two times, in the morning fruits and vegetables chopped in pieces, and in the afternoon the seed concentrate. When the size of the ingredients is homogeneous, the birds tend to show a greater taste for certain foods. Therefore, taking care of the size of the feed avoids selectivity (Sciabarrasit, 2016). The birds had good acceptance and better welfare, as well as the good acceptance for the consumption of the offered portions, as mentioned by Noriega and Lozano (2008). During the week of adaptation to the AD, rejections were immediately registered; however, the gradual change led to the immediate adaptation of the animals (Recalde, 2013). It should be noted that *psittacines* are sensitive to diet changes and this should be gradually done. Most *psittacines* spend 50% of their time searching for food (Jiménez, 2008), which causes considerable energy expenditure. It is reported that they can spend from four to six hours a day foraging, traveling several kilometers looking for places to feed on different sources (Meehan *et al*., 2003). The practices of offering the same diet or different diets can affect or improve the provided food consumption, it is important to encourage the bird's well-being when these are in confinement (Dierenfeld and Graffam, 1996).

Table 4 shows the registered food surpluses. During the first week, there was higher wastage in AD (P<0.01), attributed to the sequelae of the adaptation to the new diet. However, from weeks two on, there was less waste, this behaviour is attributed to a greater adaptation to the food and palatability of their ingredients.

The factors involved in the consumption and food refusal are diverse, mainly due to stress, the environment, and the freshness and variability of the food. Studies of *psittacines* in free life, indicate the ability of these birds to discriminate differences in the nutrient's concentration, allowing them to choose between fruits from different plants (Matson and Koutsos, 2006). While, in captivity, they do not exhibit this ability to select the ingredients of their diets, showing a notable preference for food with high energy content (McDonald, 2006). The recorded surpluses in the AD indicate that it is the best way to offer the food. The birds were kept busy feeding for a longer time and the surpluses percentage decreased. The results in this research allow visualizing that the AD decreased ingredients selection and facilitated their intake. *Psittacines* in captivity are characterized for choosing what to eat based on individual preferences for a certain food, regardless of its nutritional value (Recalde, 2013).

Table 4. Recorded surpluses of two diets evaluated in twelve psittacines birds in captivity.

Period (Weeks)	Traditional Diet		Alternative Diet		P
	Mean	SD	Mean	SD	
I	0.455	0.144	0.524	0.082	<0.01
II	0.380	0.055	0.326	0.169	<0.01
III	0.428	0.049	0.271	0.039	<0.01
IV	0.441	0.053	0.264	0.044	<0.01
V	0.527	0.058	0.263	0.032	<0.01

SD = Standard deviation.

CONCLUSIONS

It is important to evaluate the diets offered in the places where birds are kept in captivity, considering that these provide the needed daily requirements. It is necessary to train operational technical personnel in the preparation of the diets and involve behavioural studies in the birds to avoid feeding-related problems. Feeding frequencies and the diversity of the food such as vegetables, fruits and seeds, stimulate the consumption, reduces waste and improve the nutritional balance of birds in captivity.

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AGRO PRODUCTIVIDAD

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Fisheries discard as an alternative for agricultural feed in the state of Campeche, Mexico

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ABSTRACT

Objective: To determine the incidence of non-target fishing species, in riparian fishing, as a dietary alternative for the agricultural sector in the state of Campeche, Mexico.

Design/methodology/approach: The ports surveyed in the state of Campeche: Champotón, Seybaplaya and Campeche. A total of 89 questionnaires were applied at random and at the free will to participate to coastal fishermen. The obtained data were analyzed with the R vr 3.4.4 statistical software.

Results: The results showed that the coastal fishing catch is 760.1 kg on average/week, and fishing discards of 30.42 kg/week. Of the bycatch, 68.8% is discarded and the rest sold at a low price (US $ 0.2). Among the waste products, 34 species stand out, but seven represent the 58.7% of maximum incidence, mainly Bosh *Ariopsis felis*, Chac-chi *Haemulon plumierii*, Cojinuda *Caranx crysos*, Ixpil *Upeneus* sp., Macabi *Elops saurus*, Postà *Bairdiella chrysoura* and Sardina *Herengula jaguana*.

Delimitations/implications: There is a wide variety of species of which their potential as a protein source is unknown, which can be used as input in feed.

Findings/conclusions: Registered fishing discards are made up of more than 30 non-target species and according to their incidence can be considered as inputs in feed manufacturing for the agricultural sector.

Keywords: artisanal fishery, source of animal protein, feed ingredient.

INTRODUCTION

On the global scale, fishing is an activity that substantially contributes to job creation, poverty alleviation and food security; mainly by small-scale or artisanal fisheries in coastal areas of developing countries (Bené *et al*. 2007). The *per capita* fish consumption was 3.2% (20.5 kg), surpassing beef consumption, sheep and pork (2.8%), except for poultry which represents 4.9% (FAO, 2018). Fishing

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in Mexico takes place both in the Pacific and Atlantic oceans where the main sought species are shrimps, oysters, coastal and oceanic pelagic fish (grouper, mullet, sardine), which are of high commercial value and higher consumption. The Campeche coastline has a length of 523.3 km, where three municipalities and twelve coastal communities are located, with a fishing discharge of 407,889 t (SEPESCA, 2019). Nevertheless, fishing activity is at its maximum exploitation limit (FAO, 2018). As a result of this, aquaculture activities have been generated as a source of animal protein, based on the cultivation of marine and freshwater species, from the management of reproducers, maintenance of fry, juveniles and adults, their feeding, management and harvesting (FAO, 2019).

In recent years, aquaculture faces problems related to water consumption, excessive cost of electricity and feed. The latter depends on the protein added to the feed, its efficiency depends on its high concentrations of fish meal (protein) and fish oil (lipids) obtained from forage fish (Hua *et al*., 2019). The main input in the manufacture of balanced feed is the anchovy species (*Engraulis ringens*), which produces between 25 and 30% of the fishmeal and fish oil in the world for the pharmaceutical, livestock, aquaculture and poultry industries (Samamé-Panta, 2019).

This species provides a concentrated source of high-quality protein, omega-3 fatty acids, DHA and EPA that intervene in animals' growth (Valenzuela *et al*., 2012). The livestock sector directly depends on feed as the main input for production, to meet this requirement, incorporation of protein of animal origin is required. Various ingredients have been evaluated as a feed alternative based on seaweed (Beneitez and Rincones *et al*., 2008), insect meal, seeds, fruits, meat by-products (blood meal and bone meal) and microbial proteins (Gasco *et al*., 2016) designed for the agricultural sector. However, few studies report the usage of artisanal fishing by-products as an alternative ingredient for feed preparation and manufacture. For this reason, the objective of this research was to determine the incidence of non-targeted fishing species, in coastal fishing, with no commercial value but that can be a protein source in manufacturing commercial feed for the agricultural sector in the state of Campeche, Mexico.

MATERIALS AND METHODS

Between September and December 2019, coastal fishermen from three ports with economic importance were surveyed: Champotón, Seybaplaya and Campeche, located at the north and central coast of the state. The ports were selected taking into account their geographic location, the discharge volume and the characteristics of their fishing fleet (riverside). A total of n=89 questionnaires were applied to fishermen. The questionnaires were applied at random and at the free will of the participants. The questionnaire was structured in three sections, the first collected general information about the interviewees, while the second and third sections focused on obtaining information on the captured organisms (species) and social and economic aspects that include the weekly total weight, the amount from it for self-consumption, the species caught and those discarded for its low commercial value. The data were analyzed and descriptive statistics performed with the R vr 3.4.4 statistical software.

RESULTS AND DISCUSSION

The results showed that fishing is the main source of employment for the populations near the coast, which concurs with Carranza (1967), who emphasizes this activity in Campeche has a long tradition due to its social and economic impact. In this region, the fishing production chain is made up of permit holders, fishermen, private companies, and commercial fishing that send their products to local and regional markets. The foregoing also coincides with Gutiérrez-Zavala and Mancilla (2012) who show that the direct actors of the activity are fishermen, permit holders, wholesalers and retail fishing distributors.

The fishing activity in the state of Campeche is carried out by people 48.5 years mean age (n=77±14.64). Results also indicated that the persons who engage in fishing are mostly mature, which also coincides with that reported by Vidal (2013) and Gravez *et al*. (2009) who mentioned that the workforce in fishing cooperatives in Mexico is integrated by people aged between 40 and 49 years, and in other countries, between 41 and 46.7. Likewise, 49.3% of the fishermen reported at least 30 years of experience in the activity; 49.2% of them have primary school level and 2.8% have university studies. These also concur with Vidal (2013), who reported that fishermen have basic academic degrees, as a result of the fact that fishing is carried out for most of their lives.

Fishermen are dedicated to catching snail, crab, scale, shrimp, octopus and crab. According to Guerrero and Martínez (2020) the activity is carried out with fishing permits, this being the scale the most common, which groups species horse mackerel, snook, grouper, blondes, chac-chi, snapper, octopus and sharks. Authors such as Guerrero and Martínez (2020) highlight that fishermen distinguish two fishing groups, the first relate to commercially important fishing (octopus and conch), the second, to marine scale fishing of low and medium economic value.

The mean scale catch per week was 628.8 kg (n=67±0.93), 115.3 kg of *Octopus maya* (n=21±149), 10 kg of *Callinectes sapidus* crab (n=1) and 6 kg of *Menippe mercenaria* moro crab (n=1). Scale species represent the largest catch, and are generally made up of demersal species, elasmobranchs, crustaceans, and mollusks. Of the total catch, a mean of 4.3 kg (n=73±4.37) is destined for the fisherman's family, who consume it 2.5 times per week (13.1%), data comparable with that reported by Cifuentes-Lemus *et al*. (1990), who mention that the catch volume is divided into two types, subsistence fishery, which satisfies the needs of the fisher's family, and the commercial one, which generates profits and goods, and includes community members (other permit holders).

Thirty-four point one percent of fishermen commercialize their catch in local markets or nearby towns. Twenty-six percent sell it to packers, and 12.3% sell it to freezers. Seventeen point seven percent of that sold to packers or freezers are destined for national sale, and only 1.3% is sold to the national market directly. Also, the results indicated that most of the catch is destined to the local community or surrounding areas, and a minimum amount (1.3%) is destined for national commercialization; these commercialization differences are compared with those reported by Fischer and Espejo (2004), who propose four channels or levels of distribution for consumer producers; where hearty fishermen meet levels 1 and 2 of the links in the distribution chain. According to Arias de León (2014), the small-scale or artisanal fishery requires labour and the participation of the owners to intensify capital through modern techniques; it also indicates that the exploited resource by the fishermen is integrated into society for self-consumption, distributors, or processing, which commonly occurs on the same day in a weekly manner, as presented here, where it is emphasized that 76% of the participants sell their product the same day, 21.3% sell it weekly, and 2.6% sell it every two weeks. The non-targeted fishing catch is 30.42 kg average / week (n=56±47.16), which represents 4.8% of the total catch.

Of the non-targeted catch, 68.8% is discarded, the rest is used with a low commercial value, and in some cases, more than 50% is thrown back into the sea (Pitcher and Chuenpagdee, 1994).

Fishermen in the region use this waste as bait for crab or octopus, as well as for the production of Macabi (*Elops saurus*) ground meat for hamburgers; however, there is no use of the non-target fishery as a source for fishmeal. In this regard, Bowzer *et al*. (2014) propose the production of flour-based on invasive fish species such as the Asian carp (*Hypoph-thalmichthys* sp.) and largemouth bass (*Micropterus salmoides*). Abarra *et al*. (2017) determined that knifefish (*Chitala ornata*) meal, a non-target species, contributes to growth with a good feed conversion factor and weight gain in Nilotic tilapias (*Oreochromis niloticus*).

The fishery for non-targeted species is not bought by the final consumers, in some cases, the fishermen give it away (6.5%). Some sell this discard at a low price ($ 0.2 to $ 0.5 US) and represents 70% of these sales, the rest access better prices that range between $ 1.00 to $ 3.00 US after filleted, as is the case for macabi *Elops saurus* meat. However, skeleton and skin waste is not accounted for. According to Stevens *et al*. (2018) between 50 and 70% is made up of viscera, heads, skin, bones and blood, which could be used as an alternative protein source. According to the obtained data, there are at least seven recurrent species (58.7%) in the three fishing ports of the state, which are: Bosh (*Ariopsis feliz*), Chac-chi (*Haemulon plumierii*), Cojinuda (*Caranx crysos*), Macabi (*Elops saurus*), Postà (*Bairdiella chrysoura*), Sardina (*Herengula jaguana*) and *Dorosoma anale* (Table 1).

At Campeche and Champotón ports, more than 22 non-targeted species were reported, compared to the Seybaplaya port that registered less than 15. This difference may be due to the way fishes are captured and non-selective fishing gear used during the process, which originates the incidental species dragging. This agrees with that reported by Alverson *et al*. (1994) who estimated that worldwide there is a fishing discard of up to 27 million tons per year, where the excessive use of non-targeted fishing gear stands out.

Table 1. Incidence of bycatch species from three fishing ports at the state of Campeche, Mexico.

Common name	Scientific name	Total		Seybaplaya	Champotón	Campeche
		Incidence	Incidence (%)	Incidence (%)	Incidence (%)	Incidence (%)
Anchoa	*Cetengraulis edentulus*	1	0.4	-	0.4	-
Armado	*Orthopristis chrysoptera*	6	2.8	-	-	2.8
Bandera	*Bagre marinus*	2	0.9	0.4	0.4	-
Balá	*Hypanus americanus*	1	0.4	-	-	0.4
Bonito	*Euthynnus alletteratus*	4	1.8	-	-	1.8
Bosh	*Ariopsis felis*	25	11.7*	4.7	1.8	5.1
Carito	*Scomberomorus regalis*	1	0.4	-	0.4	-
Cazón	*Rhizoprionodon terraenovae*	3	1.4	-	1.4	-
Chac-chi	*Haemulon plumierii*	24	11.3*	2.8	5.6	2.8
Chambo	*Baliste capriscus*	5	2.3	1.8	-	0.4
Chucha	*Rhinoptera bonasus*	5	2.3	-	0.4	1.8
Cochinita zimarura	*Balistes capriscus, Balistes vetula*	1	0.4	-	0.4	-
Cojinuda	*Caranx crysos*	14	6.6*	1.4	4.2	0.9
Cordoba	--	4	1.8	1.8	-	-
Coronado	*Seriola zonata*	1	0.4	-	-	0.4
Curvina	*Cynoscion nothus*	9	4.2	-	1.8	2.3
Huachinango	*Lutjanus campechanus*	1	0.4	-	0.4	-
Iguana de mar	*Synodus foetens*	1	0.4	-	-	0.4
Isabelita	*Pomacanthus arcuatus*	4	1.8	1.8	-	-
Ixpil	*Upeneus sp.*	13	6.1*	4.2	-	1.8
Jurel	*Caranx latus*	2	0.9	-	0.4	0.4
Macabi	*Elops saurus*	13	6.1*	0.9	-	5.1
Pargo	*Lutjanus analis*	9	4.2	0.4	2.8	1.4
Payaso	*Epinephelus adscensionis*	2	0.9	-	0.4	0.4
Pegador	*Remora* sp.	1	0.4	0.4	-	-
Picuda	*Sphyraena barracuda*	1	0.4	-	-	0.4
Postá	*Bairdiella chrysoura*	17	8.0*	2.8	0.4	4.7
Pulpo	*Octopus* sp.	1	0.4	-	0.4	-
Sábalo	*Megalops atlanticus*	1	0.4	-	-	0.4
Sardina	*Harengula jaguana, Dorosoma anale*	19	8.9*	5.1	3.8	-
Sargo	*Archosargus probatocephalus*	2	0.9	-	0.4	0.4
Sierra	*Scomberomorus maculatus*	6	2.8	0.4	0.9	0.4
Xpu´	*Sphoeroides testudineus*	1	0.4	-	-	0.4
Charal	*Chirostoma* sp.	12	0.56	0.4	-	5.1

* Higher fishing incidence.

CONCLUSIONS

The non-targeted fishing discards in the state of Campeche are made up of more than 30 species that can be valued as protein inputs for the manufacture of feed for livestock and aquaculture. Fishermen in ports indicate that these resources could represent another source of employment and wasted added value.

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Quality Seal for Artisanal Chorizo in Valle de Toluca: Keys to Obtaining a Collective Brand

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ABSTRACT

Objective: To identify the socioeconomic and cultural conditions necessary for obtaining a quality seal for artisanal chorizo in Valle de Toluca, Mexico.

Methodological Design: A qualitative approach was made from the perspective of Localized Agrifood Systems, for the analysis of an artisanal food. The participative approach, observation, and semi-structured interviews were useful tools to carry out the research.

Results: Valle de Toluca has a traditional food that identifies it, as is the case of chorizo in its red and green versions, around which there is the possibility of implementing a quality seal for its differentiation and protection.

Limitations: The study was limited to the work carried out with the chorizo producers belonging to Valle de Toluca; in this sense it is necessary to assess the implementation of a differentiating seal for a traditional food which faces disloyal competition, both from the producers' trade union and from the food industry, consisting in the elaboration of generic products that have the same name, although their quality is not the same.

Conclusions: It is necessary to develop a participative and territorial perspective.

Keywords: quality seals, artisanal sausage, protection, collective action.

INTRODUCCIÓN

Local foods, of artisanal manufacture, are in a constant struggle to stay current: disloyal competition inside the home turf itself, industrialized analog products and, sometimes, the lack of a generational replacement are only some of the factors that threaten the continuity of these products.

The agrifood industry has been directed toward immediacy in the selection and purchase of products, which corresponds to the needs of the accelerated rhythm of contemporary life. However, some consumers attempt to acquire products with characteristics associated to the geographical place of origin, the traditional guarantee in the

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elaboration process, the environmental care of those products that generate a fair economic retribution for small-scale producers, among others (Oyarzún, 2005).

The paradigmatic example of the European Union accounts for the existence of specific policies for the protection of food products, which are fruit of tradition and production in a specific region, which can be certified through seals such as Certificate of Origin, Protected Geographical Indication and Traditional Speciality Guaranteed, to cite the most frequent. This translates into a legal protection framework strongly directed at the consumer, ensuring good production and elaboration practices, as well as giving the producer a commercialization tool, which gives its product a competitive advantage (Oyarzún *et al*., 2002; Oyarzún, 2005).

National Food Control Systems are an essential condition for the protection of consumers, and they are also fundamental to ensure the quality of food products; however, it should be taken into account that the quality of a food is the result of a process that implicates the entire productive and commercial chain (Oyarzún *et al*., 2002).

In Latin America the demand for products with differentiated quality is still incipient, although the knowledge and the interest of an urban consumer for these quality characteristics of the foods have increased. In turn, this represents a small market niche, which leads to the conformation of organizations directed at the protection of their product, through a quality seal, which is also a commercialization tool (Oyarzún, 2005; Velarde, 2012).

The study carried out in Mexico by the Mexican Institute of Industrial Property (*Instituto Mexicano de la Propiedad Industrial*, IMPI), focused on the protection of traditional products, is still deficient because often the normativity represents an insurmountable access barrier for small-scale producers who wish to carry out a certification process for regional products that are part of their tradition (Linck *et al*., 2006).

According to the IMPI (2020), there are two protection figures for products originally from a particular region: they are Collective Brands (CB) and Certificates of Origin (CO), and each has its particularities.

According to the IMPI (2020), a brand is understood as a set of visible signs that distinguish the products or services from others of the same kind or class in the market. The fulfillment of the following conditions must be considered to be judged as CB: i) only the associations or partnerships of legally constituted producers, manufacturers or providers of services can request it, ii) applying for the collective brand registry serves to distinguish the products or services of their members in the market, from the products or services of third parties, iii) it cannot be object of a transmission of rights or license of use, since its use is reserved to the members of the association or partnerships, iv) the use will be subject to the rules that the association or partnerships determine.

On the other hand, CO is understood as the name of a geographical region of the country that serves to designate a product originally from it; achieving this legal protection must be carried out officially, that is, the IMPI must issue a petition to achieve this goal.

Although both figures represent a legal protection for specific products which belong to a unique geography, the substantial difference lies in that the CB belongs to a partnership or association of producers, while the CO belongs to the State, so the benefits are distributed differently (Linck *et al*., 2006).

Performing projects focused on revitalizing the patrimony requires integrating a multidisciplinary team, which can help a group of producers in different ways, in order to achieve an adequate productive, organizational, legal and commercial process.

In this sense, the objective of this document was to identify the socioeconomic and cultural conditions necessary for obtaining a quality seal for artisanal chorizo in Valle de Toluca. This document presents the study performed with chorizo producers to achieve the socioeconomic valuation of chorizo through a CB, from the collective construction of Rules of Use, required to integrate the documentation of a registry application of the brand at the IMPI.

MATERIALS AND METHODS

Between the year 2010 and 2012, a group of students and researchers ascribed to the Master's Program in Rural Agroindustry, Territorial Development and Agrifood Tourism of the Universidad Autónoma del Estado de

México, began a project to achieve the certification by IMPI for chorizo from Valle de Toluca (VT) (Ovando, 2016). Through a research-action methodology directed by the approach of Localized Agri-Food Systems (LAFS), it was sought to promote collective action through two interconnected paths: i) structural collective action, related with the creation of a group of producers; and ii) functional collective action, which aims at gaining access to a territorialized resource such as a Collective Brand (CB), in this case for artisanal chorizo (Boucher and Desjardins, 2005; 17).

From a participative approach, work meetings were carried out with the chorizo producers from Valle de Toluca, which are focused on the tasks to attain a distinctive seal for their artisanal manufacture (Ovando, 2016), and in this way, to achieve a process of differentiation and protection in face of industrial chorizos and those from other parts of the Mexican republic.

In this sense, through team work, municipalities were identified that maintain an active production of chorizo and the approximate total of people who are devoted to this artisanal activity in Valle de Toluca (Map 1). Later, the working lines were defined to begin with the collective action, which were centered on: i) the conformation of a group of producers, ii) the development of an improvement plan for hygienic management, iii) the creation of a strategy for brand promotion and design, and iv) the identification of the requirements for obtaining the quality seal (Ovando, 2013).

Obtaining information for the conformation of a file was carried out through plenary meetings with chorizo producers and through the application of 10 semi-structured interviews, from a total of 30 participants, to understand their testimony regarding the process of elaboration of the sausage (Aprile-Gniset, 2012; Guber, 2015), and in this way to integrate documentation with the adequate characteristics to carry out the CB application at the IMPI.

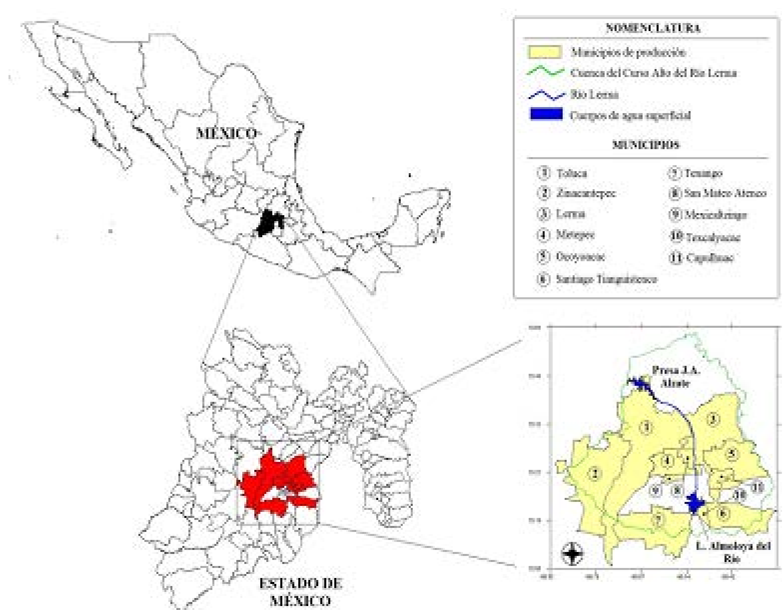
RESULTS

The production of artisanal chorizo in the study zone can be understood within the logic of a Localized Agri-Food System, because it has the following characteristics: i) it has a local concentration limited by a valley, where there are specific resources and assets, ii) it is part of traditional know-how, and iii) it has a reputation of its own, where the characteristics of the territory gave origin to an emblematic sausage that is part of the cultural-gastronomic heritage of the zone (Boucher *et al.*, 2011).

The study performed had the goal of making the territory more dynamic, through the revitalization of the cultural-gastronomic heritage, derived from obtaining a quality seal; unfortunately a monetary value cannot always be assigned to the benefits generated by these activities. Protecting traditional know-how, obtaining quality ingredients, improving the living conditions of producers, consolidating a CB, researching and educating about regional products, are clear benefits in the execution of the project, although they cannot be valued in exclusively economic terms (Linck, 2008).

The first studies stemmed from a small group of producers who showed interest and trust in the project, contributing the first steps to consolidate the actions proposed. Regarding the conformation of the CB application before the IMPI, the first approaches took place in the sense of understanding the ingredients, taking into account the differences between producers, and trying to obtain a range within which the traditional sausage would not lose this characteristic (Table 1).

However, when writing the rules, it is necessary to understand the custom of elaborating chorizo, or in



Map 1. Municipalities that produce artisanal chorizo in Valle de Toluca (Prepared by authors).

Table 1. Characterization of artisanal chorizo in Valle de Toluca.

	Ingredients	Preparation	Variations
Red chorizo	• Pork Meat • Spices (pepper, cumin, cloves, nutmeg) • Dried chilies • Ginger • Garlic • Onion • Coriander seeds • Vinegar • Lard • Pork tripe	Grind chilies, garlic, onion and reserve. Dissolve the spices and salt in the vinegar, add to the chili mixture, place the meat and let it pork tripe. Place in the gut, tie every 10 cm and hang	Currently there are almond chorizo, with raisins, special (they contain other spices). The greatest variation of this chorizo is the one that occurred in the 70s, due to a rise in the prices of chili peppers, this is how the green chorizo was born
Green chorizo	• Pork Meat • Spices (pepper, cloves, cumin, cinnamon, oregano) • Coriander seed • Ginger • Chile cuaresmeño • Coriander • Tomato • Lettuce • Chile poblano • Parsley • Garlic • Onion • Vinegar • Lard • Pork Tripe	Devein and grind the chilies, garlic, onion, coriander, tomato, lettuce, poblano pepper and parsley, reserve. Dissolve the spices and salt in the vinegar, add to the previous mixture. Incorporate the meat in the liquid and let it rest for 3 days. Place in the pork tripe, tie every 10 cm and hang	This chorizo has few variations (only in the ingredients) and this depends on the region where it is made, avocado, pumpkin seed, spinach, chili peppers like chile de arbol are added to it as well as some nuts such as almonds, peanuts, raisins, pine nut, walnut.

other words, trying to convert the tradition into a rule, granting chorizo a unique legal character with which the Producers' Association can be endorsed and differentiated, through particular ways in which they have produced their chorizo throughout time.

From meetings with the producers (Photo 1), a short definition of chorizo was also determined; this, with the aim of achieving a unification criterion in terms of the artisanal product that they elaborate. It was concluded that chorizo is a sausage made from pork meat, chili peppers and spices; elaborated manually; prepared, tied and dried with the traditional recipe; and which is part of the history and tradition of Valle de Toluca.

Since there was already a characterization of the sausage and a first definition of it, the remaining steps consisted in: defining the name for the CB, establishing the rules of use, and presenting the application, not without first attaining the consolidation of the Association of Chorizo Producers in Valle de Toluca, since it is an essential requirement to achieve each of the steps. Therefore, the constitution of the name had to do with the region so the working team proposed the CB Chorizo del Valle de Toluca Región de Origen (Chorizo from Valle de Toluca Region of Origin), taking as a paradigm the case of the Queso Cotija Región de Origen, first food elaborated artisanally that was granted a CB by the IMPI in 2005 (Barragán, et al. 2018).

Photo 1. Meetings with producers (Photograph by Pedro Ovando, 2013)

However, the proposed name –despite the background– was inviable because within the industrial property law endorsed by the IMPI, in 2012, certain words could not be used, such as Valle (valley), Toluca or chorizo, due to their generic character; this was before the law's actualization –carried out in 2018–

where the name of a known geographical zone can be registered to identify the product as native, defining its quality and reputation (IMPI, 2020).

Despite the setback's efforts continued, so that in order to achieve integrating the documentation, they started by establishing the rules of use for artisanal elaboration of chorizo, which had as reference the rules of use proposed for the CB Queso Cotija Región de Origen (Álvarez *et al*., 2010).

In the rules for the elaboration of artisanal chorizo in the traditional manner, just as the producers described, a description was found of the geography referencing the limits of the Valle de Toluca where the authentic chorizo could be manufactured; the procedure for packing, tying and aerating is also detailed, complemented with the amount of the ingredients and the range of each product. An example of this is the proportion between meat and fat that could be used, which was established at between 15% and 20% fat, and 80% and 85% meat, to be able to be considered chorizo from Valle de Toluca.

Although the aim of the project was attaining the CB to support the tradition and quality of the chorizo, it was also sought to motivate the creation of the association of producers and to involve the public institutions and

Figure 1. Poster from the fair (Ovando, 2013: 91).

the academy, so that the support network could provide continuity in the process and certain aspects could be favored. These aspects were: i) improving the economic welfare of producers, ii) strengthening producers' organizations, iii) promoting relationships between producers, public and private actors both in the territory and the country, and iv) possibilities of promoting other processes of artisanal manufacture within the region.

Likewise, some challenges about the implementation and the use of a quality seal were discerned: i) drive of promotion and commercialization, ii) conformation of a self-regulating organization of the CB, iii) projection of the promotion of a slaughterhouse where meat from the region could be obtained for the product's elaboration, iv) participation of intermediaries in the process, with the aim of reinforcing the circuit of traditional character.

In this sense, the promotion of the first Fair of Artisanal Chorizo from Valle de Toluca was achieved through participative work (Figure 1), where in addition to the participation of the producers with which work was being done, some others joined, accounting for the chorizo-making tradition found in the valley.

CONCLUSIONS

The study to be carried out with the producers of a traditional food, for it to acquire value, is enrichening and ought to take place constantly and consistently. In the case of this proposal, obtaining a brand for artisanal chorizo in Valle de Toluca has still not been consolidated, an aspect that translates into a series of economic, management, educational and organizational challenges that must be navigated in face of the socioeconomic transformation of the territory where this emblematic food is produced. Without a doubt, what we present here is an antecedent that collective work has benefits that can be consolidated gradually. It is necessary to take into account that achieving a collective action that advances adequately is a long and sinuous path because, on the one hand, there is scarce participation of the producers' trade union, but also because there is a large chain of institutions to gain access to a quality seal that allows differentiating and protecting a traditional food such as chorizo in Valle de Toluca.

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