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Hybridization of Castor Bean (*Ricinus communis* L.) in Morelos, México

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CONTENIDO

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Materiales y Métodos: Se especificará cómo se llevó a cabo la investigación, incluyendo el tipo de investigación, diseño experimental (cuando se traten de investigaciones experimentales), equipos, substancias y materiales empleados, métodos, técnicas, procedimientos, así como el análisis estadístico de los datos obtenidos.

Resultados y Discusión: Puede presentarse en una sola sección. En caso de presentarse de forma separada, la discusión debe enfocarse a comentar los resultados (sin repetirlos), en términos de sus características mismas, su congruencia con la hipótesis planteada y sus semejanzas o diferencias con resultados de investigaciones similares previamente realizadas.

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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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Economic impact of *Melanaphis sacchari* (Zehntner) on *Sorghum bicolor* (L.) Moench, and its management in the Southwestern of Puebla, Mexico

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ABSTRACT

Objective: To evaluate the economic impact of sorghum aphid (*Melanaphis sacchari*) and the sorghum crop profitability in Western Puebla, Mexico, considering the management practices application-index (IAPM), related to the control practices suggested by the State Plant Health Committee (CESAVEG).

Design/Methodology/Approach: Data on socioeconomic aspects of the producer and the production units were collected. The questionnaire was applied to producers affiliated to PROAGRO. Results are shown using descriptive statistics.

Results: The aphid infestation in sorghum had its most relevant effect on yield during 2014-2016. Income obtained from sorghum sales is decreasing due to a downward trend in the purchase price per ton. After the arrival of *M. sacchari,* the primary control strategy was to increase the number of insecticide applications, increasing production costs.

Limitations of the study/implications: Since producers' incomes do not depend solely on sorghum production, the effect of the pest on their economy was relatively minor.

Findings/Conclusions: The management practices application index indicates a moderate use of the recommended practices to manage this pest. The B/C ratio suggests that even after the establishment of *M. sacchari*, sorghum is still a profitable activity.

Keywords: Pest management, injuries, profitability.

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INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is one of the main crops in Mexico; it is a raw material for balanced feed for livestock industry (SAGARPA, 2012). 75.7% of the production of Puebla state is concentrated in 46 municipalities of the Southwestern region (Vargas, 2009; SIAP, 2017). Sorghum yellow aphid [*Melanaphis sacchari* (Zehntner)] represents a phytosanitary problem in this region. In 2013, this pest was detected for the first time in Mexico in the state of Tamaulipas, where infestation levels caused severe damages and losses ranging from 30 to 100%. It is currently present in all states where sorghum is sown (INIFAP-CIRNE, 2015). Damages caused by *M. sacchari* include desiccation, necrosis, delayed seedling growth and panicle appearance. If damage is severe, the plant dies. These damages have an impact on crop yield (Singh *et al*., 2004; Bowling *et al*., 2016). In addition, expenses on control tactics are associated with the application of insecticides (Oliveira *et al*., 2013).

Although there are strategies to control sorghum aphid, their implementation depend on the cultural, physical, biological, technical, social, and economic context in which the crop is grown (Rivas and Sermeño, 2004; Savary *et al*., 2006a, b).

Production costs have increased due to a greater number of insecticide applications used to control *M. sacchari*. In addition, there has been a continuous reduction in the price paid per ton of sorghum. Nevertheless, this crop is still sown in the region. It is necessary to know the strategies and modifications implemented in the production system to reduce damages caused by sorghum aphid, as well as to analyze the costs and benefits obtained from planting this grain in order to determine the reason for its continued use. For these purposes, the objective of this study was to assess the economic impact of *M. sacchari* and sorghum crop profitability in the Southwestern region of Puebla state, Mexico, considering the Management Practices Application-Index (IAPM) recommended by CESAVEG for sorghum production systems.

MATERIALS AND METHODS

Geographical Framework of the Study

The research was carried out in the Southwestern region of Puebla state, between parallels 18° 00′ and 19° 51′ N and meridians 97° 49′ and 98° 47′ W.

Sample Size

A questionnaire containing questions regarding socioeconomic aspects, production process and commercialization of sorghum was prepared. A sample (n) of beneficiary producers of the "PROAGRO PRODUCTIVO" federal program responded the questionnair. The sample was estimated with a maximum variance based on the following formula:

$$n=\frac{N\,Z_{\alpha/2}^{2}\,(.25)}{N\,d^{2}+Z_{\alpha/2}^{2}\,(.25)}$$

Where: N=1730 producers who are beneficiaries of "PROAGRO"; $Z_{\alpha/2}^{2}$=1.96 (value of normal distribution table); and α=0.05 (95% reliability).

The sample consisted of 91 producers producers were distributed as follows: Tepexco: 20, Izúcar de Matamoros: 19, Atzizihuacán: 14, Acteopan: 10, Tilapa: 8, Huehuetlán el Chico: 6, Xochiltepec: 7, Atzala: 5, Jolalpan: 1, and Huehuetlán el Grande: 1.

Economic Impact of *M. sacchari* on Sorghum Production

The following topics were covered in the questionnaire: producers' perception of the impact of sorghum aphid on sorghum yields, their knowledge of the damage it causes, the first cycle with infestation, the varieties planted, the insecticides applied, and the technical assistance received.

Changes Implemented into Agricultural System to Manage Sorghum Aphid Populations

Producers were sought to represent the changes in sorghum production system, and other activities developed to reduce losses due to sorghum aphid.

Management Practices Application-Index (IAPM, for its Spanish Acronym)

The IAPM, derived from the one proposed by Damián-Huato *et al*. (2019), was calculated, and applied to compare the recommendations set out in *M. sacchari* Management Guide by CESAVEG (2017), with practices implemented by producers. A value of 100 points was assigned to the total number of recommendations and these were weighed according to their impact on *M. sacchari* management: 10 points if they know how to locate and identify it, 5 points if they know the damage, 10 points if they identify beneficial fauna, 15 points if they eliminate infestation sources, 5 points if they use a certified seed, 10 points if they use seeds treated with insecticide, 15 points if they check the crop frequently, 10 points if they protect and allow beneficial fauna to act, and 20 points if they apply recommended products at the proposed dosage. Each weighted value was divided by two, where the first quotient represented the use recommended practice, and the second one to the practices actually carried out. The IAPM was calculated with the following equation:

$$IAPM = \sum_{i=1}^{k} \left[(pi)(PAPi / PGMi) \right]$$

Where: Management Practices Application-Index (IAPM); K=Number of Best Practices contained in Sorghum Aphid Management Guide prepared by CESAVEG (2017), where max K=9; Pi: Weighing given to the i-th element the recommendation; $PAPi$=Practices applied for the i-th recommendation element; i=1,2...k; where $\sum_{i=1}^{k} Ki = 1(pi) = 100$, i=1, 2... K; $PGMi$: Practices of the management guide for the i-th component of the recommendation; i=1,2... K, where ($PAPi/PGMi$)=Ratio of practices applied against those recommended.

Once the IAPM has been calculated, the typology of producers was prepared by grouping them according to the value obtained: low (<33.33) medium (33.34 to 66.66) and high (>66.66).

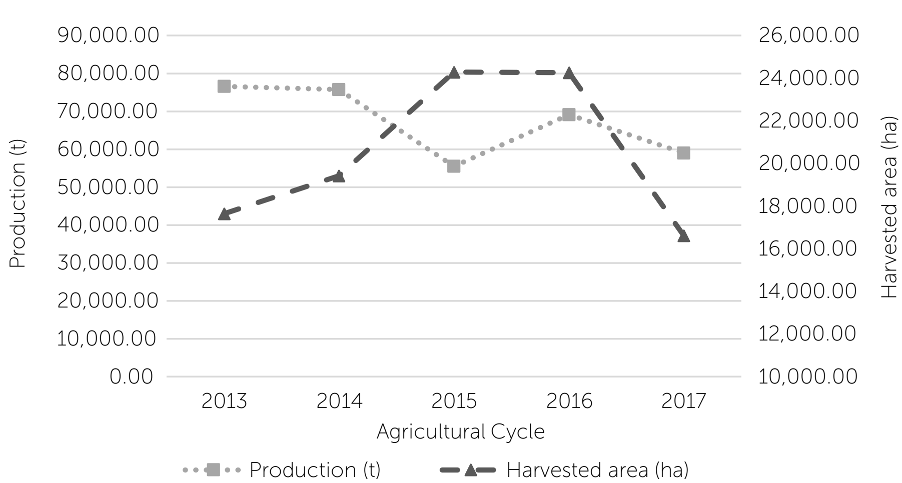

Figure 1. Sorghum production in the Southwestern region of Puebla state. (Prepared from SIAP data, 2019).

Crop Profitability both Under Traditional Farming and No-Till Farming Systems

Crop profitability was examined for 2017 cycle, under both systems implemented within the area: traditional farming and no-till farming. In both cases, production costs per hectare were determined based on the type of technology used by an average producer. Land preparation, inputs, contracted services, and indirect production costs were considered. Benefit-cost ratio was used as a profitability indicator, calculated according to Sobrado (2005):

$$C/BR = (SI)/(CH)$$

Where: C/BR=Cost-benefit ratio; SI=Sales Income; CH=Cost per hectare.

If the C/BR index is higher than 1.0, the portion in which it exceeds the unit will indicate the level of profitability of the crop.

RESULTS AND DISCUSSION

Impact of *M. sacchari* on Sorghum Production in the Southwestern Region of Puebla state

Majority (98.9%) of producers responded that their crops have been adversely affected by sorghum aphid. According to these producers, this pest causes the following issues: it dries up the plant (83.5%), lowering grain weight (13.2%) and growth of panicle (3.3%). Not all producers coincided with the initial infestation of the aphid: 56% of producers remember that it took place in 2015, but 44% said it was in 2014. The arrival of sorghum aphid to the region adversely affected crop yield: although 1775 additional hectares were sown in 2014 compared to 2013, the yield was 1.1% lower. This worsened in 2015, when production was 28% lower, although the area sown was larger. Besides the difference of areas sown between 2013 and 2017 is 1040 ha, the yield for the first cycle was 28.1% higher (Figure 1).

In the region, the average sorghum yield was 3.9 t ha^{-1} in 2014, and in 2015, 2.28 t ha^{-1}. These cycles were considered of greater infestation, with yields lower than those in 2013 (4.34 t ha^{-1}) (SIAP, 2017). In 2014 and 2015 nine varieties were sown (ACA506, ACA6001, ACA642, AMBAR, ANZU310, ARGOS, DEKALB, El CAMINO and GALIO). DEKALB, the variety sown to a greater extent (57.1 % of producers), is classified as a hybrid tolerant to *M. sacchari* (SAGARPA-INIFAP, 2017). The use of plant resistance is part of a strategy to reduce damages caused by sorghum aphid to grain sorghum crops (Haar *et al.*, 2019).

Table 1. Distribution of sorghum yields by 2014-2017 sorghum growing cycle.

Cycle	Yield (t ha^{-1})					
	< 1 t	1 a 1.9	2 a 2.9	3 a 3.9	4 a 4.5	NS
	Percentage of producers within range					
2014	14.28	31.87	49.45	1.10	3.30	0.0
2015	15.39	29.67	27.47	16.48	4.40	6.59
2016	0.0	7.69	31.87	36.26	21.98	2.20
2017	0.0	1.10	8.79	43.96	46.15	0.0

NS=Producer did not seed. Developed by author.

In 2014 and 2015 cycles, 87.9% of the producers applied insecticides. Imidacloprid (imidacloprid) was the most used product (84.1%), followed by Curacron (profenofos, 4.9%), Folidol (parathion, 3.7%), Disparo (chlorpyrifos-ethyl, 1.2%), and Malathion (malathion, 1.2%); while 3.7% of producers applied a mix of two or more of these insecticides and 1.2% applied alternative methods such as soap or ammonia. A low number (12.1%) of producers did not implement any control strategy, since they did not know the pest.

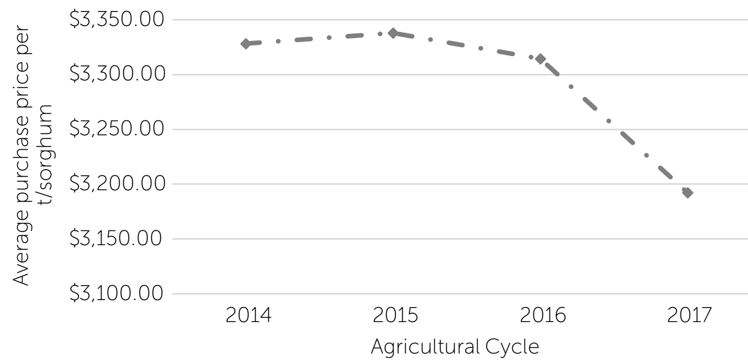

Figure 2. Average purchase price per ton of sorghum in the study region (Developed by author).

Yield distribution for 2014-2017 cycles is shown in Table 1. In 2014 and 2015 cycles, the yield observed is lower than 3 t ha^{-1} for a higher percentage of producers, as opposed to what was recorded in 2016 and 2017, when yields were higher than 3 t ha^{-1} for most of them.

Purchase price per ton has been falling in the region. In 2015, average purchase price was MX$3337.91, which was the highest price detected (Figure 2).

Due to a reduction in purchase price, combined with less production, revenues were lower than 2013, the cycle previous to the arrival of *M. sacchari* to the Southwestern region of Puebla state. The lowest income was obtained during 2014 and 2015 cycles (Table 2).

Changes Implemented into Agricultural System to Manage Sorghum Aphid Populations

The strategies implemented to control *M. sacchari* are an increased frequency of insecticide application (44%); crop inspection (21%); and change of insecticide (14%). Due to losses, 9% of producers did not seed in the next cycle, 10% sought advice, and and only 2% continued with the insecticide applied in the previous cycle. According to Aguilar (2005), intrusive species reduce crop yield, increase production costs, and the frequency of agrochemical use, which also was observed in this research.

In 91% of the cases, the effect of sorghum aphid on the producer's economy was relatively minor, since their income does not depend solely on sorghum profits. Their primary activities are: sugarcane sowing (35%), amaranth sowing (15%), peanut sowing (12%), corn sowing (11%), onion sowing (2%), stockbreeding (3%), aquaculture (1%); in addition to secondary activities, such as pottery (10%), as well as tertiary activities, such as their small businesses (2%) (grocery store and "huarache" shoe sale). The above agrees with that stated by FAO (2012): family farming represents the main source of income, but it can be supplemented with other non-

Table 2. Average sales revenue for 2013-2017 cycles in the study region.

Agricultural Cycle	2013	2014	2015	2016	2017
Data from SIAP	$12,558.65	$8,514.59	$6,070.97	$9,154.08	$11,621.12
Data from surveys	--	$6,161.57	$6,178.36	$9,910.19	$11,843.46

Prepared with data from survey and data from SIAP 2019.

agricultural activities. In this context, FAO (2001) stated that the effect of pests on producers' economy is mitigated by extra sources of income. However, this effect also depends on the producer's own adaptation, the reconsideration of the productive system, the availability of economic reserves, or even selling or pawning goods.

Management Practices Application Index (IAPM)

Two thirds (65.78%) of producers who use traditional farming showed a medium level in IAPM. In addition, most of the producers with no-till farming (85.7%) showed a medium level in IAMP (Figure 3). According to Damián-Huato *et al.* (2011), crop yield is the result of multiple factors, including the technological component, which should be used appropriately to be relevant. In both farming types, those with a higher IAPM also obtained a higher yield.

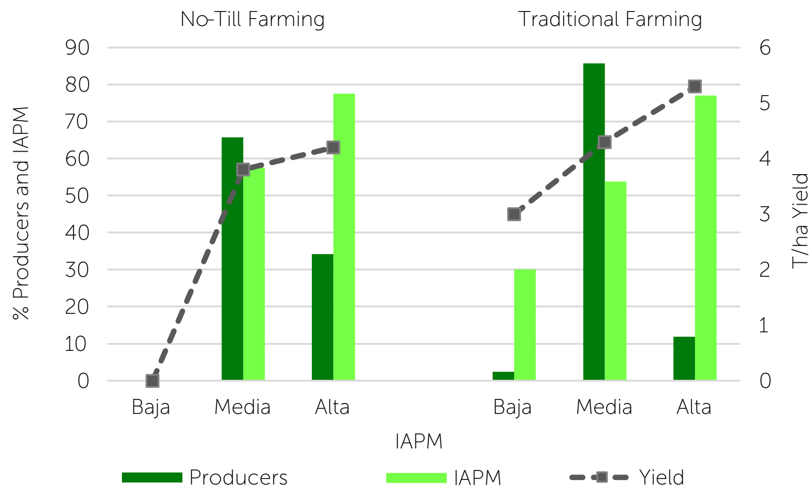

Figure 3. Percentage of producers and yield with respect to IAPM obtained in the Southwestern region of Puebla state.

Profitability of Grain Sorghum Cultivation

Production cost using traditional farming for 2017 was \$11,520.44 ha^{-1}. Land preparation represented 24.21% of production costs, supplies 41.48%, hired services

Table 3. Cost of sorghum production in the Southwestern region of Puebla state, 2017 cycle.

Activity	Traditional Farming			No-Till Farming (Zero)		
	Qty.	Cost ha^{-1}	Total (\$)	Qty.	Cost ha^{-1}	Total (\$)
Tasks			2789.42			911.76
Fallow	1	968.57	968.57			
Tracking	1	914.28	914.28			
Planting	1	906.57	906.57	1	911.76	911.76
Supplies			4778.83			5654.02
Gesaprim 90				2.5 L	182.15	455.37
Jornal				2	163.84	327.68
DEKALB	19 kg	30.96	588.24	18.9 kg	30.17	570.21
1st Fertilization	Included in planting		1511.03	Included in planting		1214.81
2nd Fertilization			749.21			1095.36
Jornal	2	162.81	325.62	2	267.77	535.54
Imidacloprid	0.379 L	686.22	260.70	0.585	691.67	404.62
Jornal	2	159.03	318.06	2	181.71	363.42
Gesaprim 90	1.81 L	188.02	340.31	2.52	127.41	321.07
Jornal	2	162.83	325.66	2	182.97	365.94
Hired services			1501.65			1639.76
Trilla	1	893.74	893.74	1	940.48	940.48
Freight	3.75 t	162.11	607.91	4.46	156.79	699.28
Direct Costs			9069.90			8205.54
Insurance	1	482.12	482.12	1	419.63	419.63
Financing			1968.42			1968.42
Indirect Costs			2450.54			2388.05
Total production cost			11,520.44			10,593.59

Developed by author.

13.03%, and indirect costs 21.27%. With this investment, an average yield of 3.75 t ha^{-1} is obtained. The cost for no-till farming systems was \$10,593.59 ha^{-1}, where 53.37% represent supplies, 15.47% hired services indirect production costs 22.54%, and land preparation only 8.60% (Table 3).

For traditional farming systems, benefit-cost ratio was lower than that obtained in no-till farming; in the first one, for every peso invested, the profit was only four mexican peso cents, while in the latter, the profit was 33 cents (Table 4). A similar pattern in B/C indicators was reported with 1.14 for traditional farming and 1.40 for no-till farming, indicating profitability (SAGARPA, 2014). With traditional farming, land preparation has a higher cost.

Table 4. Profitability (in mexican pesos) of sorghum cultivation in the Southwest of Puebla, 2017 cycle.

	Traditional Farming	No-Till Farming (Zero)
Yield (t ha^{-1})	3.75	4.46
Cost (\$ ha^{-1})	11,520.44	10,593.59
Sale price (\$ t^{-1})	3202.63	3,179.76
Sales Revenue (\$ ha^{-1})	12,009.86	14,181.72
Net income per ha (\$ ha^{-1})	489.42	3588.13
Net income per t (\$ t^{-1})	130.51	804.51
Cost-Benefit Ratio	1.04	1.33

Developed by author.

CONCLUSION

A lower sorghum yield in 2014-2016 cycles is a proof of the negative effects caused by *M. sacchari* attack. In addition to a lower yield, the income obtained from grain sales was increasingly smaller due to a downward trend in the purchase price per ton. More frequent insecticide applications were the main control strategy implemented against this pest, which increased production costs. However, the negative effect of *M. sacchari* on the producers' economy was relatively minor since producers have multiple jobs. A medium Management Practices Application Index (IAPM) was obtained for both types of farming types under assessment. However, the higher the IAPM, the higher the yield. Although profits with no-till farming are higher, sorghum cultivation is still considered a profitable activity for the Southwestern region of Puebla state.

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Analysis of Copra and Coconut Oil Markets in Mexico

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ABSTRACT

Objective: To assess the economic impact of the implementation of different production systems (real, traditional, intensive and organic) on the profits of copra-producing states and major coconut oil companies.

Design/Methodology/Approach: A linear programming model was formulated which considered the main costs and production revenues, and the transport costs of the copra and coconut oil market, in order to maximize the profit of copra producers and the oil industry simultaneously.

Results: The states that were most suitable in the distribution of copra were Guerrero and Tabasco, which proved to be the main suppliers of all the production systems evaluated; within production systems, the intensive system presented a higher level of profit in the scenarios raised.

Study Limitations/Implications: The model considered the sale of copra as the sole income of producers, leaving aside the marketing of other products and economic transfers, thus underestimating their total profit. Future research is required to help collect data on alternative sources of income for producers.

Findings/Conclusions: Increasing copra production without taking into account the installed capacity in the industry results in the creation of a copra surplus in most producing states, which would result in a fall in the prices of this product, therefore reducing the profit of most states.

Keywords: Spatial equilibrium Model, Profit Maximization, Production Planning.

INTRODUCTION

Copra is an agricultural product obtained from the drying of coconut pulp, which is used to produce a wide range of agroindustrial products on which a large number of industries depend, the most important of which is coconut oil (Granados and Lopéz, 2002). This crop is of special importance for the states of Guerrero, Colima and Tabasco, where more than 90% of the national production is concentrated, which in 2018 reached a value of 1,949.28 million pesos in those states (SIAP, 2019). However, during the last decades, national copra production has been negatively affected by different factors such as: advanced age of the plantations; diseases such as lethal coconut

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yellowing; low investment and use of inefficient agricultural practices, which have led to low yields in the plantations (INIFAP, 2019).

According to the United States Department of Agriculture (USDA, 2019), Mexico is the eighth largest consumer of coconut oil worldwide. This consumption, because of the low productivity of the copra-producing sector and the limited capacity of the agroindustry to produce coconut oil domestically, has meant that consumption has been satisfied thanks to imports that come mainly from the United States, which in 2017 reached 86,864 tons. In recent years, coconut oil imports have shown a growing trend due to increased demand and stagnation of domestic production (SIAVI, 2020). Although copra has a growing market (SAGARPA, 2017), the real price has stagnated at $6,638.00 pesos (MX) per ton during the period 2012-2017, so that many producers have decided to abandon or change the crop, putting at risk the agrifood and cosmetic industry that depends on this product. As a result, different organizations such as: Institutional Fund for Regional Promotion of Scientific, Technological and Innovation Development (Fondo Institucional de Fomento Regional para el Desarrollo Científico, Tecnológico y de Innovación, FORDECYT, 2018); the House of Representatives in conjunction with the National Council of Science and Technology (Consejo Nacional de Ciencia y Tecnología, CONACYT, 2015); the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación, SAGARPA, 2010); the National Institute of Forestry, Agricultural and Livestock Research (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, INIFAP, 2015); have set themselves the task of looking for alternatives that will have a positive impact on profits from producers, the main one being to increase production directly through the application of new techniques.

In order to solve problems related to production optimization, several studies have been carried out where spatial equilibrium models have been applied, for example: the study conducted to analyze the effects of the North American Free Trade Agreement on tomato exports from Mexico to the United States, and the impact that the application or elimination of foreign trade instruments such as tariffs would have (Garcia, Williams and Malaga, 2015); the work carried out to analyze the optimal temporal and spatial storage of sorghum in Mexico (Rebollar, García and Rodríguez, 2006); the study focused on the analysis of the bean market, in which the structure of the bean market in Mexico was determined through the application of a spatial equilibrium model (Torres and García, 2008); and the mathematical model to improve the distribution of prickly pear for Mexico through the minimization of costs of transportation routes from producing to consuming areas, obtaining the optimal distribution to market it (Ayllon *et al*., 2015).

The importance of copra cultivation lies in the large number of hectares dedicated to this crop, the byproducts obtained from its industrialization, and the jobs that depend directly and indirectly on the national copra-producing sector. The objective of this study was to evaluate how policies aimed at increasing copra production at the field level would impact the profits of copra producers and coconut oil companies, analyzing the functioning of the copra and coconut oil markets together.

MATERIALS AND METHODS

A linear programming model (Badole and Jain, 2012) was formulated for the distribution of the copra and coconut oil market, in order to analyze the coconut oil market and to determine how agents would respond to the proposed scenarios. The model takes into account the economic variables that determine the main revenues and costs of economic agents; it is a spatial equilibrium model (Takayama and Judge, 1971), similar to the linear programming model for the maximization of profits of prickly pear producers through optimization in the distribution network for the supply chain (Granillo-Macias *et al*., 2019). It seeks to optimize the profit of coconut producers and companies dedicated to coconut oil production, maximizing the income of copra producers and national oil companies simultaneously, and minimizing the value of the costs of copra production, oil processing, transportation, as well as the costs of acquiring and distributing coconut oil imports from the borders to the states of consumption.

The model considered four different types of technology in copra production: real, which is the one observed in official sources; traditional, which is the one that is carried out using few technical and technological advances; intensive, which uses advances in techniques and products, such as agrochemicals and improved palms; and organic, which uses improvements in agricultural techniques, but is free from the use of synthetic agrochemicals.

Formulation of the market profit maximization model

$$Max\ f(x) = \sum_{i=1}^{n} p_{ij}^{\alpha} x_{ij}^{\alpha} - \sum_{i=1}^{n}\sum_{i=1}^{n} t_{ij}^{\alpha} x_{ij}^{\alpha} - \sum_{i=1}^{n} c_{ij}^{\alpha} x_{ij}^{\alpha} + \sum_{i=1}^{n} p_{jk}^{\beta} x_{jk}^{\beta} - \sum_{j=1}^{n}\sum_{k=1}^{n} t_{jk}^{\beta} x_{jk}^{\beta} - \sum_{j=1}^{n} c_{j}^{\beta} x_{jk}^{\beta} - \sum_{l=1}^{n}\sum_{k=1}^{n} p_{lk}^{\beta} x_{lk}^{\beta} - \sum_{l=1}^{n}\sum_{k=1}^{n} t_{lk}^{\beta} x_{lk}^{\beta} \quad (1)$$

$$\sum_{j=1}^{n} x_{ij}^{\alpha} \leq x_{i}^{\alpha} \quad (2)$$

$$x_{j}^{\beta} = \sum_{j=1}^{n} x_{ij}^{\alpha} a_{i}^{\gamma\alpha} \quad (3)$$

$$x_{j}^{\beta} \leq x_{ij}^{\alpha} a_{i}^{\gamma\alpha} \quad (4)$$

$$\sum_{j=1}^{n} x_{jk}^{\beta} + \sum_{l=1}^{n} x_{lk}^{\beta} \geq y_{l}^{\beta} \quad (5)$$

Where:
p_{ij}^{α} purchase price of copra in the purchase zone; x_{ij}^{α} quantity of copra produced in *i* to be taken to *j*; t_{ij}^{α} transportation cost per ton of copra from production zone *i* to plant *j*; c_{i}^{α} copra production cost in the production zone; p_{jk}^{β} purchase price of coconut oil produced at the national level; x_{jk}^{β} quantity of coconut oil produced at production plant *k* that will be taken to state *k*; t_{jk}^{β} transportation cost per ton of coconut oil from production plant *j* to consumption center *k*; c_{j}^{β} cost of transformation of copra to coconut oil at plant *j*; x_{lk}^{β} imported quantity of coconut oil at border *l* that will be taken to state *k*; p_{lk}^{β} acquisition price of coconut oil at the border; t_{lk}^{β} transportation cost per ton of coconut oil from border *l* to consumption center *k*; $a_{i}^{\gamma\alpha}$ transformation rate from copra to coconut oil.

Assuming:
i=1,2...I=12 copra-producing regions; j=1, 2...J=7 coconut oil producing plants; l=1,2=2 ports of entry for coconut oil imports; k=1, 2...32=32 coconut oil consumption centers.

Equation (1) is the profit maximization function of the domestic market, which is obtained by subtracting the costs of production, processing and transportation from the income from the sale of copra and coconut oil produced in the territory; the cost of purchasing and transporting coconut oil from abroad was also considered.

The objective function is restricted by four equations described next:

Equation (2) establishes that the sum of copra shipments from the production zone to the oil processing plants should not be greater than their production; if the plants' demand is satisfied or it is not possible to produce more oil, the surplus production remains in these regions.

Equation (3) indicates that the amount of coconut oil that domestic plants offer is equal to the transformation coefficient (the amount of copra needed to produce one ton of coconut oil) multiplied by the amount of copra they demanded from copra-producing regions; this restriction implies that the plants cannot function as product warehouses.

Equation (4) establishes that the oil supply of the companies should be less than or equal to the installed capacity of the plants; that is, the plants cannot sell more coconut oil than they are able to produce on their own.

Equation (5) shows how coconut oil is distributed, the sum of the shipments of coconut oil produced in the companies at the national level and imported at the possible borders should be greater than or equal to the demand of each consumer state; this restriction shows that no demand should be left unsatisfied.

To feed the model, the quantities produced, different costs and prices during 2017 were considered. The quantities of copra produced were compiled from the main copra-producing states in Mexico, and were disaggregated by municipality in the case of Colima, since Tecomán is located in this state, which is the municipality with the largest production in the country. The model has 12 production regions; production for traditional, intensive and organic production technologies was obtained by multiplying the calculated yield of these technologies by the area of copra available in the state or municipality (Table 1).

According to data from the National Statistical Directory of Economic Units (Directorio Estadístico Nacional de Unidades Económicas, DENUE, 2019), in Mexico the leading companies in coconut oil processing are: Calahua (Lerma, State of Mexico); A de Coco (Armería, Colima); San Lucas (Iztacalco, CDMX); Campo Vivo (Colima, Colima); Soy de Aceite (Zapopan, Jalisco); DEICOCO (Tecomán, Colima) and ICOSA (Miguel

Table 1. Main copra producing regions (tons), period 2017.

Producer region	Real production	Trational production	Intensive production	Organic production
Campeche	354.57	655.11	831.75	676.51
Chiapas	805.10	3237.90	4110.97	3343.68
Armería	5439.00	20477.84	25999.51	21146.83
Coquimatlán	160.00	602.40	764.83	622.08
Ixtlahuacán	47.00	176.96	224.67	182.74
Tecomán	8794.00	33109.41	42037.08	34191.07
Guerrero	187963.90	314393.69	399167.25	324664.72
Jalisco	1317.64	3034.59	3852.84	3133.73
Michoacán	2872.65	10843.20	13766.98	11197.44
Oaxaca	8772.83	30383.55	38576.21	31376.16
Tabasco	10749.51	47144.50	59856.61	48684.68
Veracruz	1020.26	5677.62	7208.54	5863.10
Total	228296.46	469736.76	596397.26	485082.74

Source: Own elaboration with data from SIAP (2019), FIRA (2019), INIFAP (2019) and information from producers.

Hidalgo, CDMX), the first three being the most important because they concentrate most of the production. An installed capacity of between 30 and 21 thousand tons of oil was estimated for each, depending on their size. The transformation rate is .6 tons of oil per ton of copra, a transformation cost of 28,830 pesos per ton, which was calculated from a process of extraction by pressing, evaporation and filtering.

According to official information, there are 49 customs offices in Mexico: 19 on the northern border and 2 on the southern border, 17 maritime, 11 inland (SNICE, 2020); however, more than 95% of coconut oil imports transit through the customs offices located in Manzanillo (Colima) and Piedras Negras (Coahuila). The model made it possible to calculate the quantity of product, the destination and the routes to be taken by the imports derived from the different scenarios proposed.

To estimate the national demand for coconut oil, the 31 states and Mexico City were considered as separate consumer regions. Apparent consumption was obtained by multiplying per capita consumption by population using official data from the National Institute of Statistics and Geography (INEGI) for 2017; an apparent consumption of 222,700.26 tons of coconut oil at the national level was calculated.

Transportation costs were calculated, using the distance in kilometers reported between supply and demand regions by the Ministry of Communications and Transportation (Secretaría de Comunicaciones y Transporte, SCT, 2019), the costs of diesel, transport operator, toll booths and transport insurance. With this information, the transportation cost per ton of product between routes was calculated.

Regional production costs were calculated for the four types of production analyzed (real, traditional, intensive and organic), obtained by multiplying the total production of each region by the cost of producing one ton of copra. The production cost per ton reflects the prices of labor, organic and synthetic agrochemicals, and the machinery necessary for the application of agrochemicals. This information was compiled and analyzed using the methodology presented by the Agro-costs System of the Instituted Trust in Relation to Agriculture (Fideicomisos Instituidos en Relación con la Agricultura, FIRA); this methodology allows estimating agricultural production costs parametrically in a given area or region under a specific production technology (SADER, 2020).

Programming the model was carried out in the mathematical optimization package LINDO 18.0 (Cunningham and Schrage, 2004), and three scenarios were established for each technology: an increase for each state in the quantity of coconut oil demanded of 10%, an increase in copra production of 10% in each state, and an increase in the installed capacity of the companies of 10% for each.

RESULTS AND DISCUSSION

According to the table of total revenues from the market obtained by the LINGO software, the intensive production mode is the one that generates the largest profit in all the scenarios (Table 9). Tables 2, 4 and 6 show the result of the quantities shipped from the copra-producing states to the coconut oil production plants, the surplus in regional copra production, and the profit for each production region. It should be noted that it is natural to expect a negative value in regional profits, because the model only considers the profit from the sale of copra and discards income derived from the sale of byproducts, such as coconut fiber, coconut shell, among others; the model also does not consider government economic transfers such as support and subsidies, which increase the profits of regional producers. Tables 3, 5 and 7 are the results for the coconut oil market and show the total shipments from the producing plants to the consuming states and the profits they obtain, as well as the amount and cost of imports. Finally, Table 8 presents the total profits of each type of production given the scenarios presented.

The results for the base model (where demand and installed capacity reflect current data), indicate that the states with the greatest potential for copra distribution are Guerrero and Tabasco (Table 2). This is due to the low cost of transporting copra from these states to the coconut oil producing plants. According to the base model, if the state of Guerrero increases its copra production, it would be able to satisfy the demand of several coconut oil production companies; if this happens, the states geographically close to Guerrero (especially Colima and Jalisco) would not be able to place their production in the market, which would be counterproductive for them, due to the economic importance they represent.

Regarding the coconut oil market, the base model (Table 3) shows that the principal brands are the ones that obtain a higher profit, and Campo Vivo and Soy Aceite de Coco are the ones that make the least shipments. It is remarkable that, when analyzing the traditional, intensive and organic technologies, all companies are able to produce at their peak, however, the quantities imported do not change even when there is enough copra to produce the demanded oil, so it is correct to assume that this limitation in the industry prevents the domestic coconut oil market from reaching its maximum potential.

The results for a scenario where the demand for coconut oil has a 10% increase at the national level, are very similar to those of the base model (Table 4). The states

Table 2. Results of the base model for the copra market; shipments and surpluses in tons, earnings in millions of Mexican pesos.

Copra market – Baseline scenario											
Region	Real		Traditional			Intensive			Organic		
	Shippings	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit
Campeche	354.6	−1.8	0.0	655.1	−3.3	0.0	831.8	−4.1	0.0	676.5	−4.5
Chiapas	805.1	−4.1	0.0	3237.9	−16.1	0.0	4111.0	−20.4	0.0	3343.7	−22.1
Armería	5439.0	−25.4	0.0	20477.8	−101.8	0.0	25999.5	−129.2	0.0	21146.8	−139.7
Coquimatlán	160.0	−0.7	0.0	602.4	−3.0	0.0	764.8	−3.8	0.0	622.1	−4.1
Ixtlahuacán	47.0	−0.2	0.0	177.0	−0.9	0.0	224.7	−1.1	0.0	182.7	−1.2
Tecomán	8794.0	−40.9	0.0	33109.4	−164.6	0.0	42037.1	−208.8	0.0	34191.1	−225.9
Guerrero	187963.9	−914.7	234522.2	0.0	−778.7	221810.1	87856.8	−1206.1	232982.0	2182.3	−1340.3
Jalisco	1317.6	−6.3	0.0	0.0	−7.4	0.0	3852.8	−19.1	0.0	3133.7	−20.7
Michoacán	2872.7	−13.6	0.0	9926.5	−51.5	0.0	13767.0	−68.4	0.0	11197.4	−74.0
Oaxaca	8772.8	−43.3	0.0	30383.6	−151.1	0.0	38576.2	−191.7	0.0	31376.2	−207.3
Tabasco	10749.5	−53.3	47144.5	0.0	−122.6	59856.6	0.0	−155.4	48684.7	0.0	−206.2
Veracruz	1020.3	−5.0	0.0	0.0	−14.4	0.0	7208.5	−35.8	0.0	5863.1	−38.7
Total	228296.4	−1109.5	281666.7	98569.6	−1415.4	281666.7	225230.1	−2044.0	281666.7	113915.6	−2284.5

Source: Own elaboration with results of the Lingo program.

Table 3. Results of the base model for the coconut oil market; shipments in tons, earnings in millions of Mexican pesos.

Coconut oil market – Baseline Scenario								
Company	Real		Traditional		Intensive		Organic	
	Shippings	Profit	Shippings	Profit	Shippings	Profit	Shippings	Profit
Calahua	30000	5129.61	30000	5129.62	30000	5131.49	30000	5131.49
A De Coco	29978	5122.65	30000	5127.79	30000	5126.47	30000	5126.13
San Lucas	25000	4274.22	25000	4275.32	25000	4272.14	25000	4272.14
Campo Vivo	5000	854.41	21000	3588.66	21000	3588.88	21000	3588.88
Soy Aceite De Coco	5000	855.84	21000	3593.74	21000	3593.69	21000	3593.03
Deicoco	21000	3588.00	21000	3587.93	21000	3589.08	21000	3590.09
Icosa	21000	3592.78	21000	3591.67	21000	3592.99	21000	3592.99
Total	136978	23417.51	169000	28894.73	169000	28894.74	169000	28894.73
Port of entry	Real		Traditional		Intensive		Organic	
	Shippings	Cost	Shippings	Cost	Shippings	Cost	Shippings	Cost
Manzanillo	39840.8	565.0	7818.7	110.0	7818.7	110.0	7818.7	110.0
Piedras Negras	45881.6	658.6	45881.6	658.6	45881.6	658.6	45881.6	658.6
Total	85722.4	1223.6	53700.3	768.6	53700.3	768.6	53700.3	768.6

Source: Own elaboration with results of the Lingo program.

of Guerrero and Tabasco turned out to be those that have priority in the distribution of copra according to the model; it is observed that shipments from the producing states to the companies did not increase despite the increase in demand for coconut oil, due to the limited capacity in coconut processing.

For the coconut oil market, a 10% increase in the demand for this product can be observed according to the model that all plants would work at their maximum capacity; however, domestic production would not be sufficient to meet this increase in demand, so it would be necessary to increase imports of coconut

Table 4. Results of the model for the scenario with a 10% increase in demand for the copra market; shipments and surpluses in tons, earnings in millions of Mexican pesos.

Copra Market – 10% increase in coconut oil demanda											
Region	Real		Traditional			Intensive			Organic		
	Shippings	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit
Campeche	354.6	−1.8	0.0	655.1	−3.3	0.0	831.8	−4.1	0.0	676.5	−4.5
Chiapas	805.1	−4.1	0.0	3237.9	−16.1	0.0	4111.0	−20.4	0.0	3343.7	−22.1
Armería	5439.0	−25.4	0.0	20477.8	−101.8	0.0	25999.5	−129.2	0.0	21146.8	−139.7
Coquimatlán	160.0	−0.7	0.0	602.4	−3.0	0.0	764.8	−3.8	0.0	622.1	−4.1
Ixtlahuacán	47.0	−0.2	0.0	177.0	−0.9	0.0	224.7	−1.1	0.0	182.7	−1.2
Tecomán	8794.0	−41.0	0.0	33109.4	−164.6	0.0	42037.1	−208.8	0.0	34191.1	−225.9
Guerrero	187963.9	−910.6	234522.2	79871.5	−978.2	221810.1	177357.2	−1429.3	232982.0	91682.7	−1563.5
Jalisco	1317.6	−6.3	0.0	3034.6	−15.1	0.0	3852.8	−19.1	0.0	3133.7	−20.7
Michoacán	2872.7	−13.6	0.0	10843.2	−53.9	0.0	13767.0	−68.4	0.0	11197.4	−74.0
Oaxaca	8772.8	−43.3	0.0	30383.6	−151.1	0.0	38576.2	−191.7	0.0	31376.2	−207.3
Tabasco	10749.5	−53.3	47144.5	0.0	−122.6	59856.6	0.0	−155.4	48684.7	0.0	−206.2
Veracruz	1020.3	−5.0	0.0	5677.6	−28.2	0.0	7208.5	−35.8	0.0	5863.1	−38.7
Total	228296.4	−1105.5	281666.7	188070.1	−1638.8	281666.7	314730.6	−2267.2	281666.7	203416.1	−2507.7

Source: Own elaboration with results of the Lingo program.

Table 5. Results of the model for the scenario with a 10% increase in demand for the coconut oil market; shipments in tons, earnings in millions of Mexican pesos.

Coconut oil market – 10% increase in coconut oil demand								
Company	Real		Traditional		Intensive		Organic	
	Shippings	Profit	Shippings	Profit	Shippings	Profit	Shippings	Profit
Calahua	30000.00	5130	30000	5131.16	30000	5131.16	30000	5131.16
A De Coco	29977.86	5122	30000	5126.07	30000	5126.07	30000	5126.07
San Lucas	25000.00	4279	25000	4271.98	25000	4271.98	25000	4271.98
Campo Vivo	5000.00	854	21000	3588.89	21000	3588.89	21000	3588.89
Soy Aceite De Coco	5000.00	856	21000	3593.09	21000	3593.74	21000	3593.09
Deicoco	21000.00	3588	21000	3589.69	21000	3589.03	21000	3589.69
Icosa	21000.00	3588	21000	3593.14	21000	3593.14	21000	3593.14
TOTAL	136978	23417	169000	28894	169000	28894	169000	28894
Port of entry	Real		Traditional		Intensive		Organic	
	Shippings	Cost	Shippings	Cost	Shippings	Cost	Shippings	Cost
Manzanillo	44659.4	633.6	12637.2	178.5	12637.2	178.5	12637.2	178.5
Piedras Negras	47132.0	676.6	47132.0	676.6	47132.0	676.6	47132.0	676.6
TOTAL	91791.3	1310.2	59769.2	855.1	59769.2	855.1	59769.2	855.1

Source: Own elaboration with results of the Lingo program.

oil, reducing the potential gain of the market (Table 5). When compared to the previous situation, the model indicates that an increase in the demand for coconut oil is detrimental in all scenarios, despite the increase in copra production resulting from the application of more efficient techniques.

According to the results of the model, with a 10% increase in the production capacity of coconut oil for each company in the market, the results show that: for the real production where the current situation is reflected, the results are the same as for Table 3. In the case of traditional technology, copra-producing states near the coconut oil companies manage to distribute part of their production, these being the states of Jalisco, Michoacán and Veracruz, because the states of Guerrero and Tabasco are unable to meet the demand for copra; for the other two technologies, it is observed that the

Table 6. Results of the model for the scenario with a 10% increase in the productive capacity for the copra market; shipments and surpluses in tons, earnings in millions of Mexican pesos.

Copra market – 10% productive capacity increase by the coconut oil industry										
Region	Real		Traditional			Intensive			Organic		
	Shippings	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit	Shippings	Surplus	Profit
Campeche	354.6	−1.8	0.0	655.1	−3.26	0.0	831.8	−4.1	0.0	676.5	−4.5
Chiapas	805.1	−4.1	0.0	3237.9	−16.10	0.0	4111.0	−20.4	0.0	3343.7	−22.1
Armería	5439.0	−25.4	0.0	20477.8	−101.82	0.0	25999.5	−129.2	0.0	21146.8	−139.7
Coquimatlán	160.0	−0.7	0.0	602.4	−3.00	0.0	764.8	−3.8	0.0	622.1	−4.1
Ixtlahuacán	47.0	−0.2	0.0	177.0	−0.88	0.0	224.7	−1.1	0.0	182.7	−1.2
Tecomán	8794.0	−40.9	0.0	33109.4	−164.62	0.0	42037.1	−208.8	0.0	34191.1	−225.9
Guerrero	187963.9	−914.7	314393.7	0.0	−778.66	311310.5	87856.8	−1206.1	322482.4	2182.3	−1340.3
Jalisco	1317.6	−6.3	3034.6	0.0	−7.42	0.0	3852.8	−19.1	0.0	3133.7	−20.7
Michoacán	2872.7	−13.6	916.7	9926.5	−51.55	0.0	13767.0	−68.4	0.0	11197.4	−74.0
Oaxaca	8772.8	−43.3	0.0	30383.6	−151.07	0.0	38576.2	−191.7	0.0	31376.2	−207.3
Tabasco	10749.5	−53.3	47144.5	0.0	−122.60	59856.6	0.0	−155.4	48684.7	0.0	−206.2
Veracruz	1020.3	−5.0	5677.6	0.0	−14.45	0.0	7208.5	−35.8	0.0	5863.1	−38.7
TOTAL	228296.4	−1109.5	371167.1	98569.6	−1415.4	371167.1	225230.1	−2044.0	371167.1	113915.6	−2284.5

Source: Own elaboration with results of the Lingo program.

states of Guerrero and Tabasco alone are capable of meeting this demand (Table 6).

Finally, for the coconut oil market, with a 10% increase in the production capacity of domestic companies, it is observed that for the scenarios where copra production increases in the states (traditional, intensive and organic production), the plants are capable of supplying the domestic market completely, eliminating the need to import coconut oil to satisfy domestic demand. This has resulted in an improvement of the situation of the copra and coconut oil market as a whole (Table 7).

When analyzing the total market revenues for each scenario suggested obtained by the LINGO software (Table 8), we observe that the highest value is reached when intensive production is used together with an increase in the installed capacity of the companies; and the lowest when demand increases under a base production. This is due to the fact that a greater amount of imports is needed to satisfy the demand, which implies a higher cost in its import and distribution. It is also notable that the best results are obtained when the productive capacity is increased, with the exception of the baseline situation, which does not show significant improvement.

CONCLUSIONS

The model determined that the most suitable states for copra distribution are Guerrero and Tabasco, due to their low transportation costs toward the coconut oil production plants; this is true for all scenarios and types of production.

Table 8. Total profit of the copra and coconut oil market; in millions of Mexican pesos.

Copra and coconut oil industry markets profits	
Baseline scenario - Real production	22 504.83
Baseline scenario - Traditional production	29 254.73
Baseline scenario - Intensive production	29 259.47
Baseline scenario - Organic production	28 794.97
Increase coconut oil demand - Real Production Increase	21 294.63
Increase coconut oil demand - Traditional production	29 167.55
Increase coconut oil demand - Intensive production	29 172.29
Increase coconut oil demand - Organic production	28 707.79
Productive capacity increase - Real production	22 508.3
Productive capacity increase - Traditional production	39 546.34
Productive capacity increase - Intensive production	39 559.5
Productive capacity increase - Organic production	38 948.42

Source: Own elaboration with results of the Lingo program.

Table 7. Model results for the scenario with a 10% increase in the productive capacity for the coconut oil market; shipments in tons, earnings in millions of Mexican pesos.

Coconut oil market - 10% productive capacity increase by the coconut oil industry								
Company	Real		Traditional		Intensive		Organic	
	Shippings	Profit	Shippings	Profit	Shippings	Profit	Shippings	Profit
Calahua	40000	6844.40	40000	6844.40	40000	6844.40	40000	6844.40
A De Coco	5000	854.46	40000	6835.19	40000	6835.19	40000	6835.19
San Lucas	35000	5983.04	35000	5984.56	35000	5984.56	35000	5984.56
Campo Vivo	5000	854.14	35000	5976.75	35000	5976.75	35000	5976.75
Soy Aceite De Coco	5000	855.84	22700	3883.56	22700	3883.56	22700	3883.56
Deicoco	21978	3755.70	25000	4270.58	25000	4270.58	25000	4270.58
Icosa	25000	4277.38	25000	4275.87	25000	4275.87	25000	4275.87
TOTAL	136978	23425	222700	38071	222700	38071	222700	38071
Port of entry	Real		Traditional		Intensive		Organic	
	Shippings	Cost	Shippings	Cost	Shippings	Cost	Shippings	Cost
Manzanillo	39840.8	565.0	0.0	0.0	0.0	0.0	0.0	0.0
Piedras Negras	45881.6	658.6	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	85722.4	1223.6	0.0	0.0	0.0	0.0	0.0	0.0

Source: Own elaboration with results of the Lingo program.

When comparing the results of the profit scenarios, a higher profit is obtained when the productive capacity of the industry is increased, and this is true for three scenarios suggested (base scenario, 10% increase in the demand for coconut oil, and 10% increase in the productive capacity of the national oil-producing plants). Therefore, the most efficient policies for maximizing market profit are technology transfer policies, focused on increasing the productive capacity of industries, either through modernization or the creation of new companies.

When observing the base scenarios and those where the demand for coconut oil increases, regardless of the type of production (real, traditional, intensive and organic), it is possible to note the creation of copra surpluses in most states, with the exception of the states of Guerrero and Tabasco. According to the results of the model, it is concluded that policies that result in an increase in copra production at the farm level will have as a direct consequence the creation of producer surpluses in most copra-producing regions, if conditions are not created to help expand the production capacity of the coconut oil industry; if an alternative market is not found, this surplus would cause a drop in copra prices at the national level, reducing the revenues of the copra sector in most of the states dedicated to this activity.

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Ecclesiastical strategy as a factor on territorial organization in Santa Ana de Guadalupe, Jalisco, Mexico

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ABSTRACT

Objective: The objective was to study the territorial organization strategy of local actors; church, government and population that influenced the evolution and current organization of the town of Santa Ana de Guadalupe after the canonization of the priest Toribio Romo.

Design/Methodology/Approach: The local development methodology was applied, through specific interviews with representatives of social partners; local church, government, and population.

Results: It was found that the infrastructure and equipment of the Saint's Temple, which receives more than 700 thousand visitors a year, shows potentialities, strengths and limitations at the locality. Analyzing the territory, through its economic, political, socio-cultural, and environmental axes, it was noted that local development is a process of growth and structural change in which the main interest of the town is to increase employment and meeting the needs and demands of religious pilgrims. As well as favor the appropriate use of the resources, and over-all potential of the locality in order to improve the standard of living of the population.

Limitations of the study/Implications: The strategies of cooperation and knowledge of the ecclesiastical agents in conjunction with the government and local population through joint organization contribute to the transformation of Santa Ana de Guadalupe.

Findings/Conclusions: It was observed that social partners (church, government and population) collaborate actively. Particularly in ecclesiastical activities to develop strategies (as organization and cooperation) to promote the local development.

Keywords: local development, social partners, religious activities.

INTRODUCTION

Complex processes are originated in the territory in different areas such as economic, social and environmental for solving problems. With the socio-economic actors in charge of developing alternatives to face these situations (Boisier, 2004; Rodríguez, 2009).

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Local development is a process of growth and structural change through the proper use of resources and potentialities of the territory (Arocena, 1995; Cardenas, 2002; In order to be feasible, local development should adopt more comprehensive visions *i.e.* analyzing the territory in the economic, political, socio-cultural and environmental axes (Armas, Tamayo and Santos, 2017). For example, in analysis of the spatial concentration of economic activities, they are not located in a uniform way on the territory, but tend to be located in certain areas, with the objective of taking advantage of the benefits that arise from being located close to other areas, or to those of demand generated by consumers (Arocena, 1995; Cárdenas 2002).

The aim is to understand, tending towards local development processes, linked to the trust that already exists among social partners in the community, to those behavioral norms and levels of association ability. The strengthening of relations among social partners is an aspect of great importance for the territory (García, 2008; Aurajo, 2016).

The actors establish the organization of the modes of appropriation, cooperation and knowledge of common problems. Such strategies are decisive for local development (Cárdenas, 2002; Balente-Herrera, Díaz-Puente and Parra, 2012). Religious activities appear as critical in the development of human beings, as well as agent in the transformation of common territory.

The impact of canonization of the Saint Toribio Romo in the town of Santa Ana de Guadalupe allowed the development of different activities, as well as various types of concentrations related to religious phenomena (Aguilar, 2016). The objective of this research was to study the territorial organization strategy of local social partners; church, government and population, that affected the current local evolution at Santa Ana de Guadalupe town, after canonization of the priest Saint Toribio Romo.

MATERIALS AND METHODS

Study area. Santa Ana de Guadalupe is located at kilometer 0.9 of the Jalostitlán-San Miguel el Alto State Highway (Figure 1). The town belongs to the municipality of Jalostitlán in a region called Los Altos de Jalisco. Santa Ana de Guadalupe is administratively considered just as a settlement, because it has a small rural population, with 151 men and 160 women (INEGI, 2010).

The local development methodology was used (Arocena, 1995; Boisier, 1999, 2004; Cepal 2012). Specific interviews were applied to representatives of

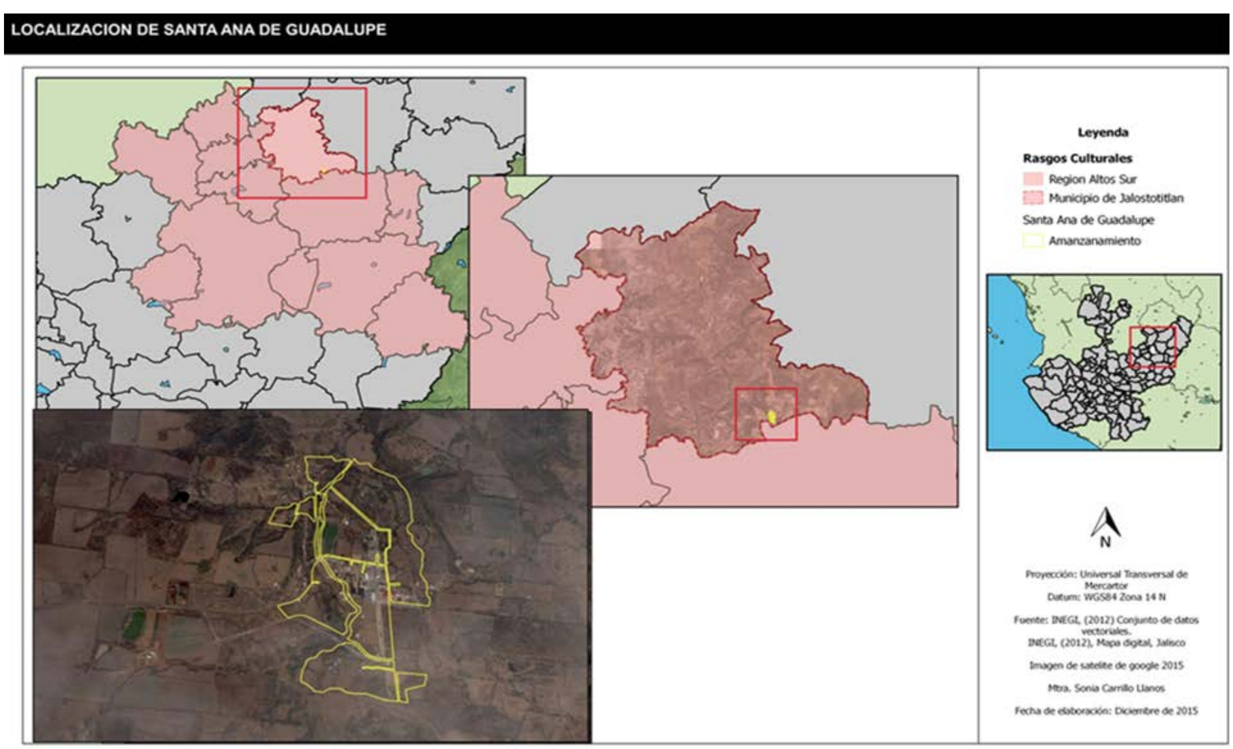

Figure 1. Location map of Santa Ana de Guadalupe territory (Jalostitlan, Jalisco, Mexico).
Source: Own elaboration with information from INEGI (2012).

social partners: church, government, and population, designing a partner-specific type of interview for each partner type. Also, we used a questionnaire known as Ethno survey (University of Princeton and University of Guadalajara, 2012), as well as fieldtrips.

RESULTS AND DISCUSSION

Based on the field trips and interviews, it was observed that at the locality of Santa Ana de Guadalupe, in Los Altos de Jalisco, a popular holiday of the saint Toribio Romo is being developed (Fábregas, 1986; Meyer, 1994). This saint was born at the town; and the holiday started as a family-matter and a regional network, making news to extend it. His canonization was an important factor as an ecclesiastical strategy, because shortly after the canonization, a temple was built for their devotion, which is one of the most visited at the national scale (Table 1).

Visitors counting both, pilgrims, and merchants, is greater than 750 thousand a year (Martínez, 2009), thus generating great economic resources income for the town. De la Torre (1992) mentions that it is difficult to understand the success of the holiday of Santo Toribio; as he is one of the youngest Catholic Saints, canonized as a martyr priest in 2000 (Archbishopric of Guadalajara, 2014).

Such an ecclesiastical strategy was of paramount importance to the development of Santa Ana de Guadalupe, despite being a small rural town, in a short-term it generated local and regional sources of employment, because businesses occur not only at the locality, but in the nearby municipalities. And there arrive also merchants from other states of the country.

Regarding the regional production process that presented different transformations throughout its history, it evolved from a subsistence economy with family labor to an open process of regional market relations intermediaries, these activities impact on territory transformations.

On the other hand, infrastructure (Figure 2) of the town, in order to house the influx of people coming to visit the Saint Toribio is basic (water, electricity, drainage, etc.) Therefore, if this influx of pilgrims continues, it will require bigger services (hotels, public parks, etc.) and instruments must be created that allow sustainable use of resources for local development.

Regarding the socio-territorial problem, it was found that the effect on the territory generated various facilities and infrastructure, but there is no solid territorial organization based on planning. Due to people influx to the area, it is essential to timely rectify incipient situations of contamination, pilgrims, agglomeration, demand for services, so that the location would progress efficiently and sustainably.

CONCLUSIONS

It was observed that social partners (church, government, and population) actively collaborate, specifically in ecclesiastical activities for the development of strategies (as organization, and cooperation) in order to satisfy the needs and demands of pilgrims, and to promote local development at Santa Ana de Guadalupe.

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Table 1. Influx to the main religious temples in Mexico.

Temple	Condition	Location	Space	Annual influx
Guadalupe's Virgin	Mexico City	Federal District	Urban	15 million
Our Lady of San Juan de los Lagos	Jalisco	San Juan de Los Lagos	Urban	6 million
Virgin of Zapopan	Jalisco	Zapopan,	Urban	3 million
Virgin of the Rosary of Talpa	Jalisco	Talpa de Allende	Rural	3 million
The Christ of Chalma	Mexico state	Chalma	Rural	3 million
The Holy Child of Atocha	Zacatecas	Silversmiths Fresnillo Zacatecas	Urban	1.5 million
Saint Toribio Romo	Jalisco	Santa Ana de Guadalupe Jalostotitlán	Rural	750 thousand
Virgin of Juquila	Oaxaca	Juquila	Rural	500 thousand
The Lord of Mercy	Jalisco	Tepatitlán de Morelos	Urban	More than 200 thousand

Source: Own elaboration with information from Martínez (2009).

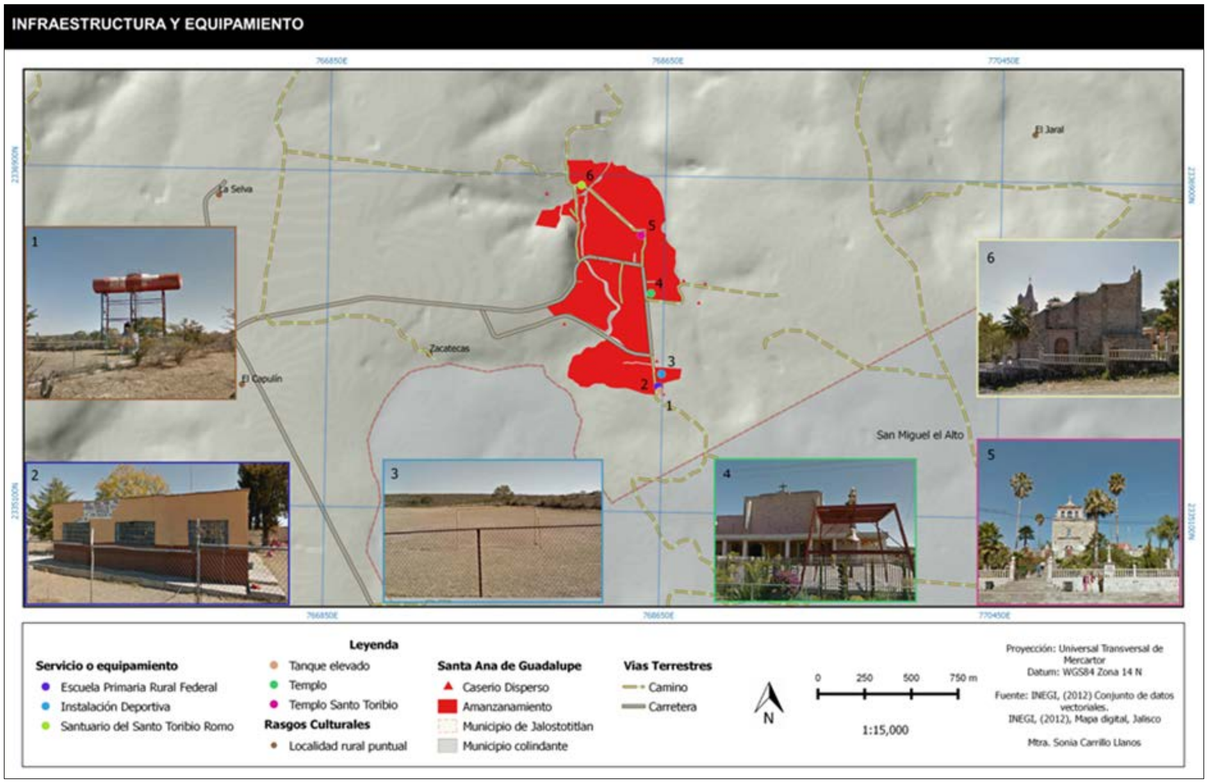

Figure 2. Map of infrastructure and equipment of Santa Ana de Guadalupe (Jalostitlan, Jalisco, Mexico). Source: Own elaboration with data from INEGI (2010, 2012).

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Conservation of the Tropical Rainforest in the Usumacinta Canyon Flora and Fauna Protection Area in Mexico

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ABSTRACT

Objective: To study the conservation status of the tropical rainforest in the "Cañón del Usumacinta" Flora and Fauna Protection Area in Mexico, through an analysis of the change in land use and vegetation (1997, 2009 and 2016).

Design/Methodology/Approach: Vegetation and land use shapefiles at 1:250,000 scale (national continuum) corresponding to 1997 (series I), 2009 (series IV), and 2016 (series VI) were downloaded. Finally, a spatial analysis was generated with calculation of exchange rates, using the Land Change Modeler between 1997-2009 and 2009-2016.

Results: During 1997-2009, the tropical rainforest occupied 31.2% and the greatest impact of the period seen was a change rate of 7.4%. Subsequently, between 2009 and 2016 there was a great decrease in the land use change rate in the forest (0.8%), due to its decree as a federal Protected Area in 2008, as well as natural regeneration and the promotion of ecological restoration programs.

Study Limitations/Implications: Absence of geographic variables to analyze factors driving change in land use.

Conclusions: It is essential to promote the sustainable management of the Usumacinta Canyon based on what is established in the land use planning program and the management plan, and to redouble efforts to implement actions for restoring ecosystem services and the continuous monitoring of change in land use.

Keywords: Biological conservation; Protected areas; High Evergreen Forest; Territorial Ecological Planning.

INTRODUCTION

The Usumacinta Canyon Flora and Fauna Protection Area contains unique biotic characteristics, as it is the entrance to the Petén department of Guatemala and to the Mesoamerican Biological Corridor, which spans from Mexico to Central America and constitutes the second most extensive mass of tropical rainforest after the Amazon (Arriaga *et al.*, 2000; DOF, 2008;

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Mifsut and Castro, 2010; Hernández-López *et al*., 2013, Mercedes Castillo, Barba-Álvarez, and Mayorga, 2018). One of its most characteristic traits is the presence of high evergreen rainforest, which is the most exuberant vegetation as well as the richest and most diverse of all the plant groups, according to Rzedowski and Huerta (1994). The most representative species of the reserve are chicozapote (*Manilkara zapota*), zapote (*Pouteria sapota*), breadnut (*Brosimum alicastrum*), guapaqué (*Dialium guianense*), and canxán (*Terminalia amazonia*) (Figure 1; DOF, 2008).

Until the 1960s, accessibility conditions kept the Usumacinta region practically unpopulated, registering during this period the establishment of the first population nuclei, with anthropic activities and devastating practices for the region's rainforest (Isaac-Márquez *et al*., 2005; García and Soares, 2017). In this same decade, ecosystems in the Usumacinta and Chontalpa regions turned out to be the most impacted in the following watersheds: the Grijalva-Usumacinta due to the start of plans for directed colonization and productive modernization; the Chontalpa and Balancan-Tenosique, which influenced the dynamics of the population and territory (Isaac-Márquez *et al*., 2005; Zavala and Castillo 2007; García-Morales *et al*., 2014).

By 1970, the high evergreen rainforest represented 81.3% of the Usumacinta Canyon (Palomeque-de la Cruz, 2008). However, the livestock farming conversion process that was initiated in the previous decade arrived with particular strength for Tabasco in the mid-seventies. In this decade, the state of Tabasco became the top beef producer for Mexico City, which signified an increase in pastureland through the occupation of lands with high evergreen rainforest cover (Tudela, 1992; Manjarrez-Muñoz, 2007). The consolidation of traditional extensive cattle farming contributed to the deterioration of more than 95% of the high evergreen rainforest in all of the Grijalva-Usumacinta watershed territory (Isaac-Márquez *et al*., 2005; Zavala and Castillo 2007; García-Morales *et al*., 2014).

During the eighties, the government of Tabasco developed the first studies to identify ecosystems in good state of conversion, as part of a strategy to mitigate the impact of the productive activities of the Chontalpa Plan and the Balancán-Tenosique Plan (SEMARNAT, 2015). It wasn't until 2005 that the Official Journal of the state published the Protected Area decree with state jurisdiction, designated as the Usumacinta Canyon State Park (Periódico Oficial del estado de Tabasco, 2005). Three years after the state decree, the federation released a decree that included the Usumacinta Canyon within the category of Flora and Fauna Protection Area (DOF, 2008).

In the Usumacinta Canyon, there are still important high evergreen rainforest areas in corridors and fragments, but their full extent and current state of conservation are unknown. This information is essential to support ecological land use planning (Velasco-Tapia, 2010). Thus, Balvarena (2012) and Jiménez-Sierra *et al*. (2014) consider it necessary to study the dynamics of high evergreen rainforest covers due to the influence that they have on the presence or decrease of ecosystem services like climate regulation, carbon storage, water regulation (increase in infiltration and evapotranspiration), water quality, erosion, landslides, and flood control, among others.

Figure 1. Rainforests and wetlands in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: System of Public Research Centers CONACyT (2017).

For this reason, the objective of this study was to evaluate the impact on natural vegetation as a result of livestock activities in the Usumacinta Canyon Flora and Fauna Protection Area, by analyzing the change in land use and vegetation in the periods between 1997-2009 and 2009-2016.

MATERIALS AND METHODOLOGY

Study Area

The Usumacinta Canyon Flora and Fauna Protection Area (Area de Protección de Fauna y Flora del Cañón del Sumidero, APFFCU) covers an area of 45,243 ha. The APFFCU is located between coordinates 17° 14' 00'' and 17° 28' 00'' North latitude, and 91° 32' 00'' and 90° 56' 00'' West longitude, in the southern part of the Tenosique municipality of Tabasco, bordering the Republic of Guatemala (Figure 2). It borders Chiapas to the west along the Usumacinta River for 33 kilometers; the Tenosique municipality to the north; and it borders Guatemala to the south in what is known as the physiographic province of the Sierra Madre de Chiapas and Guatemala, a sub-province of the El Petén lowlands (SEMARNAT, 2015). The predominant climate is warm-humid with year-round rain, and the average annual temperature is 26 °C with a precipitation range of 1,500 to 2,500 mm annually (INEGI, 2015).

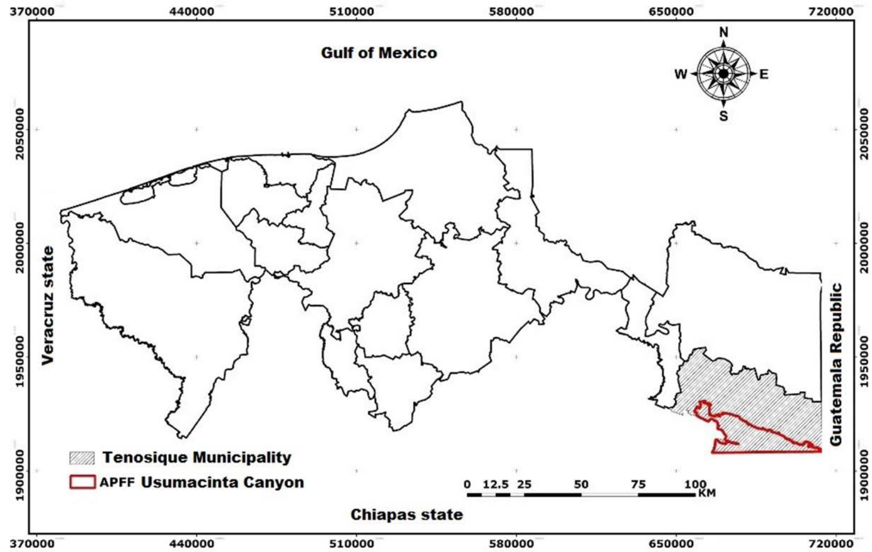

Figure 2. Geographic location of the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: self-made.

Database Procurement

Three shapefiles of vegetation and land use were downloaded at 1:250,000 scale (national continuum), corresponding to 1997 (series I), 2009 (series IV), and 2016 (series VI). The three shapefiles were obtained from the CONABIO geographic metadata catalogue with the geographic coordinate reference system UTM Zone 15 N, using the DATUM WGS84 parameters.

The shapefiles were converted to raster format with a size of 10 meters per pixel, with 7280 columns and 7541 rows, using the RASTERVECTOR command of the IDRISI Terrset software. Later, they were reclassified using the RECLASS command of the IDRISI Terrset software with the following categories: (1) rainforest, (2) secondary vegetation, (3) wetland, (4) farmland, (5) pastureland, and (6) urban (Figure 3).

Analysis of Changes 1997-2009-2016

With the Land Change Modeler module of the IDRISI Terrset software, a change matrix was generated with raster images that varied in the number of study dates; that is to say, in more than two periods of time (Pontius *et al*., 2004). In this analysis, cross-referencing of the raster images from 1997 and 2009 generated a matrix with a statistical κ=0.6444, while the images from 2009 and 2016 generated a matrix with a statistical κ=0.9088. These statistics that are close to 1.000 are reliable for the study of the spatial and temporal dynamics of the ecosystems in two time periods (Eastman, 2012).

Calculation of Change Rate

The change rates were calculated using the Palacio-Prieto *et al*. (2004) formula:

$$Td = [(S2/S1)(1/n) - 1] * 100$$

where: *Td*=annual change rate (%), *S*1=Covered area at start of period (ha), *S*2=Covered area at end of period (ha), and *n*=Number of years in period.

RESULTS AND DISCUSSION

Change in Land Use 1997-2009

During 1997 to 2009, losses of 21,870 ha of rainforest were detected, with a negative change rate of 7.4% (Table 1). This is very high compared to the deforestation rate at the regional level (0.90%) during 1993 and 2007 in the Grijalva-Usumacinta watershed (Kolb and Galicia, 2012).

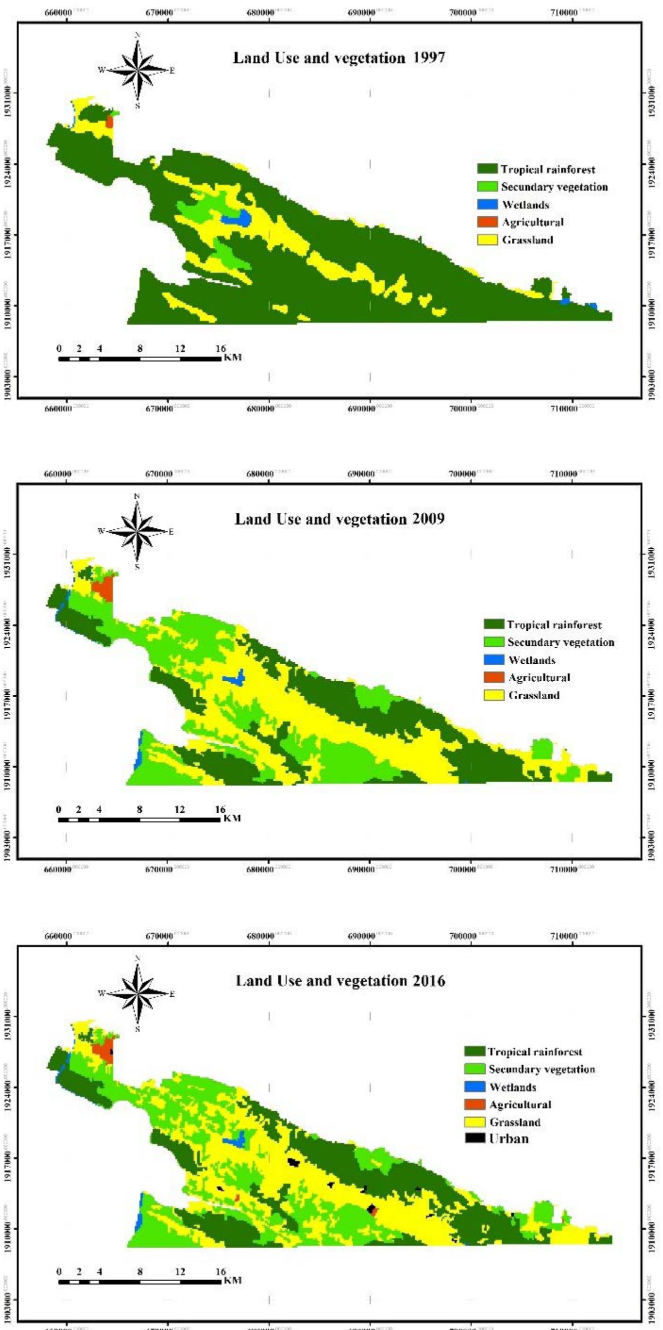

Figure 3. Maps of land use and vegetation 1997a, 2009b and 2016c in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: self-made.

Even though Tabasco is not a completely cattle-farming state, it sends large amounts of fattened livestock to the north of Mexico. Thus, cattle farming and agriculture are the dominant activities in the rural setting, both with a high degree of environmental deterioration. In the case at hand, deforestation of the high evergreen forest begins with the establishment of maize (*Zea mays*) plots that make up a significant part of the country's diet, and which are then transformed into pastureland (Galindo-Alcántara *et al*., 2006, Mifsut and Castro, 2010; Velasco-Tapia, 2010). The environmental impact generated by these farming systems is high; for cattle farming, because it is based on the transformation of natural vegetation with extensive grazing practices in pastures with low rates of summer pasture; and for agriculture, because the old slash-and-burn system continues to be maintained (Galindo-Alcantara, 1999).

The above shows that deforestation of the rainforest is not solely connected to population growth, but also to farming activities and external uses (Velasco-Tapia, 2010; Gallardo-Cruz *et al*., 2019).

At the start of the new century, deforested areas were rising due to the creation of programs supporting livestock ranches, such as PROGAN. This program aided 2,126 projects in Balancán and Tenosique between 2003 and 2005. In contrast, the program for rainforest restoration (PRODEFOR) only benefitted between 17 and 28 projects during 2004 and 2005 (Manjarrez-Muñoz *et al*., 2007). Notably, during 2000-2012, the municipality of Tenosique supplied between 20 and 40% of the total hectares of lost tree vegetation per year in the lower Usumacinta watershed (Gallardo-Cruz *et al*., 2019).

Conversely, the areas of succession or secondary vegetation (acahuales) increased by 13,682 ha, with a growth rate of 19.5 % (Table 1). This increase is generally the result of a recovery process within abandoned

Table 1. Quantification of land use and vegetation change 1997-2009 in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

Category	1997	%	2009	%	Losses	Gains	Net change	Exchange rate
Tropical Rain forest	35,696	78.9	14,121	31.2	−21,870	295	−21,575	−7.4
Secondary vegetation	1,611	3.6	13,682	30.2	−929	13,001	12,071	19.5
Wetlands	416	0.9	419	0.9	−268	270	2	0.0
Agricultural	81	0.2	374	0.8	0	293	293	13.6
Grassland	7,439	16.4	16,648	36.8	−1,490	10,699	9,209	6.9

farming and pasture zones due to loss in soil fertility in the case of farmland, or to meat market prices that push farmers to sell their animals (Galindo-Alcántara *et al.*, 2006).

Change in Land Use 2009-2016

In the 2009-2016 period, rainforests showed losses of 1,163 ha, therefore the negative change rate was at 0.8%, less than that registered during 1997-2009 (Table 2). This decrease in the rate of deforestation is attributed to the high evergreen rainforest and fragmented rainforest having undergone reversal processes in their vegetation cover (Arreola-Muñoz *et al.*, 2011). In Tabasco, the reversal of tree vegetation has occurred naturally and induced: naturally as a result of abandoned farming activities, and induced due to the growth in the number of reforestation programs for forestry activities and payment for ecosystem services (Alejandro-Montiel *et al.*, 2010; Gallardo-Cruz *et al.*, 2019). Particularly, the conservation of high evergreen rainforest during 2009-2016 coincides with the decree of the Usumacinta Canyon as a Federally Protected Area in 2008 (DOF, 2008).

Currently, the federal program Sembrando Vida ("Planting Life") could be a catalyst for environmental conservation, as it is driving agroforestry projects and Tabasco is one of the benefitted states (De la Barrera *et al.*, 2019, Secretaría de Bienestar, 2020).

During the 2000 to 2016 period, the lower basin of the Usumacinta River has been the region with the lowest rainforest deforestation rates, compared to the middle and higher region. This condition could be influenced by the extension of the protected areas in the middle and lower basin. For example, the extension of Montes Azules is much greater than the area of the Usumacinta Canyon, so that by volume the area lost in the former is greater than in the latter (DOF, 2008; Gallardo-Cruz *et al.*, 2019).

During 2009-2016, the deforestation rate notably decreased. Despite this, farming activities in the APFFCU continue to be unsustainable because they are organized in a traditional extensive farming system that combines agriculture and cattle ranching with low economic reinvestment and high use of local natural resources, resulting in significant pressure on the high evergreen rainforest (Nuncio *et al.*, 2001). However, there are currently other strategies that are contributing to the reforestation of these spaces. Such is the case with the Sembrando Vida program, which fosters recovery through the introduction of timber-yielding and fruit trees to the natural forests that include recently abandoned parcels (De la Barrera *et al.*, 2019).

To restore and conserve the last remnants of high evergreen rainforest and control the impact of farming activities, proposals have been elaborated with a focus on land zoning that consider at least two premises: the incorporation of tree cover into cattle ranching surface areas using silvopastoral systems, and the use of species and technologies in the cattle farming units that decrease the use of natural resources (Manjarrez-Muños *et al.*, 2007). Also available is an ecological zoning model where land use designation is based on the condition and vocation of the natural resources, and which integrates socioeconomic, productive, environmental, legal, and administrative aspects in order to face existing environmental conflicts and induce the integral management of the Usumacinta Canyon, organized in Environmental Management Units (Unidades de Gestión Ambiental, UGA) (Arreola-Muños *et al.*, 2011) (Table 3).

Among other actions, implementing monitoring of the principal patterns in land use and vegetation change is recommended, by way of current remote sensing techniques and Geographic Information Systems, in order to identify the chief conditioning factors of these impacts and to map future scenarios. Studies measuring ecosystem services are also important, with the objective

Table 2. Quantification of land use and vegetation change 2009-2016 in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

Category	2009	%	2016	%	Losses	Gains	Net change	Exchange rate
Tropical rainforest	14121	31.2	13322	29.4	−1163	365	−799.0	−0.8
Secondary vegetation	13682	30.2	13817	30.5	−2365	2500	135.0	0.1
Wetlands	419	0.9	420.8	0.93	−11	14	2.0	0.1
Agricultural	374	0.8	432	0.95	−16	74	59.0	2.1
Grassland	16648	36.8	16990	37.6	−2734	3076	342.0	0.3

Table 3. Environmental Management Units (UGA) for the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

Land use	area (ha)
Rural human settlements	963,79
Rainfed agriculture	445,14
Fruit tree	83,28
Holistic Semi-Intensive Livestock	7.750,21
Plantaciones Forestales	7.364,10
Productive restoration	1.654,33
Agroforestry systems	1.362,76
Silvopastoral System	9.790,17
Environmental Rehabilitation	14.232,16
Ecoturism	360,3
Xate and Motusay plantations	11,04
Research work	11.966,89

Source: Arreola-Muñoz *et al*. (2011).

of avoiding or reverting disturbance and conserving the original remains of the high rainforest, soil, and natural water flows that all maximize the provision of ecosystem services, since it is recognized that the Usumacinta rainforests are carbon sinks with relevance in America (Mifsut and Castro, 2010).

CONCLUSIONS

The study of the state of conservation in the high evergreen rainforest of the Usumacinta Canyon Flora and Fauna Protection Area determined that between 1997 and 2016, a total of 23,033 ha of rainforest were lost. Notably, the greatest negative change rate of rainforest was recorded in the period from 1997 to 2009, which it decreased in 2016 possibly as a result of the decree of the Protected Area and the implementation of programs driving ecological restoration. Since the decrease in natural cover entails the loss of other organisms from habitat loss, including silvopastoral systems in farming units is recommended, as well as the use of new technologies that lower the use of natural resources. Even the Sembrando Vida program could play a fundamental role in the development and conservation of the area. In addition, execution and follow-up of the policies established in the land zoning model is recommended, as well as the promotion of permanent monitoring of changes in land use and of ecosystem services.

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Sociocultural aspects of nourishment and the use of the plot in the rural community of Bandera de Juárez

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ABSTRACT

Objective: To analyze sociocultural aspects related to human nourishment and the use of family plots in the community of Bandera de Juárez, Veracruz, México.

Methodology: A literature review, together with open interviews and on-field participative observations, knowledge exchange workshops and life storytelling were made.

Results: The celebration of the feasts of San Isidro Labrador and All Saints Day were identified as moments for the re-creation of identities and strengthening of links that constitute social networks. They represent major occasions for understanding different productive and sociocultural uses of plots. In these phenomena nourishment is an essential factor. The family plot agroecosystem as a space of social importance sets a socialization and identity development process.

Implication: The process players generate awareness on the value of traditional nourishment, the nutritional quality thereof and the rescue of their cultural identity.

Findings: The importance of how nourishment "feeds" cultural processes is outlined. Some useful concepts, both for understanding sociocultural aspects of nourishment, the handling and uses of the plot, as well as the justification for the choice of the research method are discussed.

Keywords: traditional foodstuffs, identity, socialization.

INTRODUCTION

Human nourishment is a social activity: the manner of production of foodstuffs, distribution and consumption patterns are historical processes that show cultural features, according to specific temporary and spatial contexts (Harris, 2011). The diet of persons is defined by foodstuff access factors, social appraisal by some and individual taste; also, this is related to weather and social phenomena, such as speculation or ritual-religious matters. The analyses of nourishment patterns or cultural nourishment identities refer to this. Cultural phenomena for these habits, customs and practices are addressed by food anthropology (Ortiz *et al.*, 2005). What, when and how much is produced in the plot are

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questions that relate to biophysical and sociocultural factors. In this research, such factors are addressed from the society-nature metabolism idea (Toledo, 2013); *i.e.* the determinations given in such relationship are mutual. Studying the plot is fundamental for understanding the development of agriculture, as its handling has assumed domestication and genetic improvement. It is an "farming lab", where a good result allows the appropriation of a species the replication of which is attained in the plot. Plots used as agroecosystems are found in several latitudes, assume features in form and use, according to specific biophysical and sociocultural contexts (Mariaca *et al*., 2010). Biophysical and social aspects were researched (Bello & Estrada, 2011). The concepts of plot, yard or orchard are varied. For this research, the authors define a plot as a vital space, a place where activities for the social reproduction of families are performed, from the attainment of comforts such as foodstuffs to the exchange of goods and knowledge. Therefore, the objectives for this research were: 1) to analyze sociocultural aspects intervening significantly in the constitution of family plots; 2) to study the relationships between the plot productive calendar, cultural calendar and food cultural identity; and 3) to characterize the sociocultural functions that meet family plots in Bandera de Juárez, Veracruz, Mexico.

MATERIALS AND METHODS

Bandera de Juárez us a town that belongs to the Municipality of Paso de Ovejas, Veracruz, Mexico (19° 12' 01.25'' N, 96° 25' 19.37'' O). The methods used in the research have the "participative action research" (IAP) precepts as an integrating axle in concordance with the management model proposed by Álvarez *et al*. (2011). The work was performed in four stages.

1) Motivation: Municipal and local authorities were contacted, and they invited families from the community to take part in the work in turn. A motivational workshop was made at the Learning and Knowledge Exchange Center (CAIS) of Colegio de Posgraduados, Veracruz Campus, where knowledge about regional construction materials, crops (vegetables, fruits, legumes, medicinal, aromatic and ornamental herbs) and ecotechnologies were shared: This activity allowed motivating ten families the work was performed with.

2) Diagnosis: The socioeconomic situation in Bandera de Juárez was found in the census made by INEGI, (2010). The health diagnosis was made with the support of students from the School of Nutrition of Universidad Veracruzana, Veracruz Campus; the body mass index (IMC) from 42 persons attending the community's Health Center was obtained. The plots were characterized based on cropped vegetable biodiversity and animal breeding that the relation thereof with nourishment (López-Armas *et al*., 2017).

3) Community development. Training through knowledge exchange workshops was performed in family plots, with women who normally handle the management thereof, as this situation occurs derived from social gender roles. At the workshops, human nutrition was dimensioned with the feasibility of family production (plot and parcel) to meet their food needs. Participative research was performed through life storytelling about nourishment in Bandera de Juárez both as a historical, social and cultural phenomenon; a participative observation and open interviews were performed and this allowed approaching cultural features of the social group (García *et al*., 2008); the lessons learned from the participation were validated in exchange workshops and community inputs were acknowledged.

4) Assessment: each phase was assessed in order to feedback the process. The information obtained was analyzed and systematized and a joint reflection and analysis exercise that supported result socialization was performed.

RESULTS AND DISCUSSION

Socioeconomic Diagnosis. Bandera de Juárez has an approximate population of 733 inhabitants, 357 men (48.70%) and 376 women (51.30%). The average education years account for 4.83 years, 5.02 years in average for men and 4.73 years for women. 654 persons (89.22% of the population) are Catholics; 19 (2.59%) stated practicing another religion and 42 (5.72%) practice no religion. 211 households, of which 163 (77.25%) are led by a man and 48 (22.75%) are led by a woman. Households with earth floor covered with materials account for 184 (87.20%); 202 (95.73%) have electric power. The drinking water utility is present in 151 households (71.56%) and 185 have bathrooms (87.67%). 189 households (89.57%) have a television and 153 (72.51%) have a refrigerator. The census performed in this work showed that 626 persons do not have access to health services (85.40%); 69 persons (9.37%)

quote in the Mexican Social Security Institute (IMSS) and only one person quotes in the Social Security Institute at the Service of State Workers (ISSSTE-Veracruz); on the census year, the People's Insurance (SP, terminated in the present) had 20 affiliates (2.73 %).

Health Diagnosis. 24% of the population has normal weight, 48% is overweight, 19% have type I obesity, 2% have type II and 7% have type III obesity. Sánchez-Castillo *et al*. (2004) documented a sample of 11 730 men, of whom 41.3% reported overweight and obesity issues (SPO); although the results obtained from Bandera de Juárez are higher. 30% of these persons have type II Diabetes mellitus, which is associated to a poor diet and the intake of refined sugars (Sanz *et al*., 2013). This matches the statement of Sánchez-Castillo *et al*. 2004, who mentioned that the SPO increases morbidity for type II Diabetes mellitus and cardiovascular disorders, among others.

Diagnosis of Family Plots in Bandera de Juárez. The fact that an edible, condiment or medicinal species is present in the plots does not only respond to the season (adequate conditions for its development); this is also associated to the decisions shaped by taste and feasibility of uses given to species. These plants satisfy nourishment, ornament, medicinal use, construction, lumber and shadow, among others. The decision on what to grow and what food to eat and the manner of preparation thereof has sociocultural conditions, such as the insertion of persons in a social network and life experiences.

Food production is the most important function of plots; in average, 63.6% of species found have such purpose. Upon adding condiment species, the importance of obtaining inputs for preparing meals in decisions made on the management of the plot is evidenced. Taste is a factor that determines the presence-absence of species; Figure 1 shows the classification of use for species found in plots in Bandera de Juárez.

Among species, Barbed-wire cactus (*Acanthocereus* sp.) stand out and they provide food during the dry season and used as well as living fences. Among fruit species, banana (*Musa* sp.), lemon (*Citrus limon*) and sapodilla (*Manikara zapota*) stand out. Medicinal species used more frequently are aloe vera (*Aloe* sp.) and arnica (*Arnica* sp.). Most vegetal species produced in plots are for self-consumption; nevertheless, there are persons who trade hoja santa (*Piper auritum*) leaves; French beans (*Phaseolus* sp.); banana leaves (*Musa* sp.) and tamarind pulp (*Tamarindus indica*). Major local feasts are good moments to trade some inputs produced at the plots, as they are required for meals and/or rituals. As an example of high demand, banana leaves, hoja santa leaves or marigolds (*Tagetes erecta*) are used as ornaments for offerings for the departed and graves during the feasts of November. Figure 2 reports the percentage of relevant species in studied plots.

The management of the plot (orchard) is minimal. Main tasks are weeding or trimming and irrigation; rain seasons are short, and the water supplied via pipes is scarce and supplied through a well and a pump; therefore, it is common that "gray water coming from cloth and floor washing" are used for irrigating the plot. The participation of women is underlined in plot management tasks. This is conditioned in part by gender-related matters. Although the 2010 Population Census (INEGI) states that more than 85% of the economically active population is men, this refers to gender roles, in which man appears as a provider and who usually leaves his home in order to work either in parcels, as a laborer, workman or in the service sector.

Women address domestic labor: preparing meals, raising children and looking after the plot. Nevertheless, due to changes in the social structure, the number of women performing as providers is increasing, either for themselves or as a support for their partners, which assumes changes in the management of the plot. Also, systematizing information with respect to the plot management is still pending albeit positive, some results

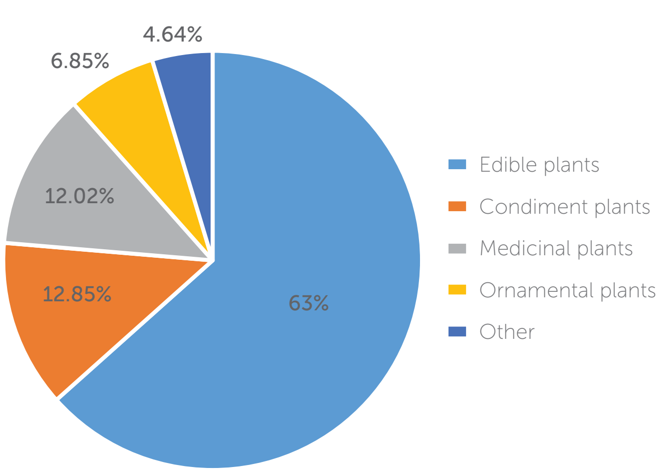

Figure 1. Classification of species according to their use in studied plots.

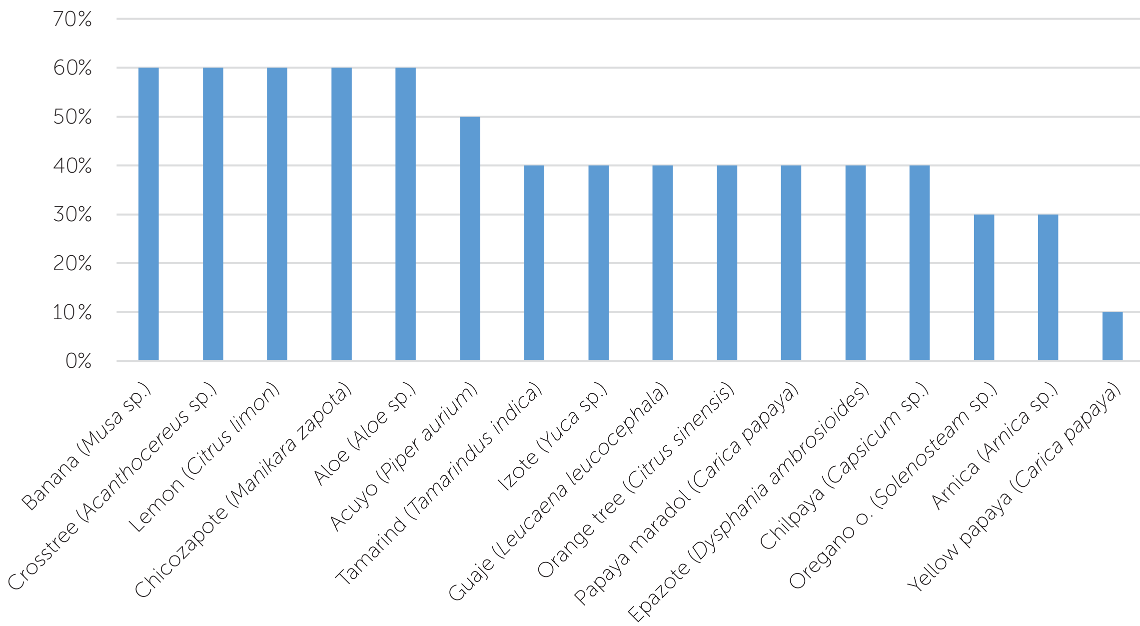

Figure 2. Significant species found in the 10 backyards of the rural community of Bandera de Juárez, Veracruz, Mexico.

appear to be accidental, as they are not replicated in an orderly fashion.

Table 1 shows work performed at the ten plots of study. Animals bred at the plot are pigs (*Sus scrofa domesticus*), turkeys (*Meleagris gallopavo*) and hens (*Gallus gallus domesticus*), which are destined to self-consumption or the sale thereof. Hens are consumed regularly; turkeys and pigs are destined to the market or prepared as a meal during a celebration (baptism, wedding, birthday, San Isidro Labrador or All Saints Day). In order to breed and feed animals, food waste, corn and purchased balanced food are used. The handling of the plot incorporates external inputs related to technology packages for farming production. For example, apart from using droppings as fertilizer, agrochemicals are used as well in plots. Table 1 shows activities and persons responsible thereof in the plots in study.

The territory appropriation also utilizes regional biodiversity through gathering or hunting, which reflects an ancestral knowledge on species and their use. An interviewer stated: "Armadillo (*Dasypus* sp.), rabbit (*Oryctolagus cuniculus*), green iguana (*Iguana iguana*), everything is well prepared here; even the raccoon (*Procyonlotor* sp.) is delicious as barbacoa; armadillo is prepared with marinade".

Community Development

Nourishment in Bandera de Juárez is a particular expression of syncretism. The food inheritance

Table 1. Activities carried out and those responsible, in ten study backyards in Bandera de Juárez, Veracruz, Mexico.

Family	Pruning	Weeding	Irrigation	Loosen the soil	Fertilization	Responsible
1	Yes	Yes	Yes	No	No	Ms. (of the house)
2	Yes	Yes	Yes	No	No	Mr. And Ms.
3	Yes	Yes	No	No	Yes (compost they use on corn)	Ms.
4	Yes	Yes	Yes	No	No	Ms.
5	No	No	Yes	Yes	Yes (donkey manure)	Ms.
6	No	Yes	Yes	Yes	Compost	Mr. And Ms.
7	No	Yes	No	No	No	Mr. And Ms.
8	No	Yes	Yes	No	No	Ms.
9	Yes	No	Yes	No	No	Ms.
10	No	No	Yes	Yes	Yes (compost they use on corn)	Ms.

Source: Self preparation.

of the Mesoamerican civilization-building process that justifies the preparation of meals with corns in several forms is notorious. In Bandera de Juárez, cuisine and meal preparation continue to be a female space and work; a strong social role division emanating from gender matters is persistent. Women know about meal preparation, food and condiments. There are some exceptions to the rule: "He, with one uncle, would go to the river to fish shrimp; he says that, when he was a boy, he would take up to one week at the river and then they would cook whatever they wanted, shrimp dishes." The scientific names of both species located in the region are (*Macrobrachium acanthurus* and *Macrobrachium carcinus*). Men cook when they go fishing in groups, without female company.

In Bandera de Juárez, agriculture loses weight as an economic activity as paid work in the industry or services gains terrain. Among factors that influence the devaluation of farming work as an activity that assures family reproduction (in a wide sense), there are the low cost-benefit ratio, excessive work for attaining good production, the uncertainty of the result, dependence on environmental and market factors, the proximity of the port of Veracruz and its industrial zone as a development pole and its paid labor offer. Changes in the society-nature relationship are important as economic activities transform. Urbanization is the path to the improvement life conditions. Services have been recent transformation processes present among the inhabitants. A participant states that now women do their work more easily. She remembers when she had to go get water from the river: "women have turned lazy now." These changes simplify activities. Currently, most of the population have drinking water and electric energy services. With the arrival of electricity, the use of appliances that changed the manner of preparing and preserving food began. The urbanization process is usually related to wellbeing in this town. In part, this is due to the simplification of some works and the influence of messages that associate an urbanized and modern lifestyle to success and/or comfort.

There are foodstuffs that may be associated to a poverty condition; for some, it is proper to consume them privately and indoors regularly and off the sight of others. Nevertheless, the situation changes when there is a ritual, feast or shared dinner is involved (weddings, baptisms, or even funerals). Especially, both feasts continue being important for most of the population in Bandera de Juárez: May 15, San Isidro Labrador, feast of the patron saint of the town, and November 2, All Saints Day. The economic contingency may mark the presence of a species in the plot; for example, during "All Saints Day:" An interviewee stated: "Ever since I remember, my mother always prepared mole for the feast (May 15), mole for "All Saints Day", for weddings, sweet fifteen and baptisms. It is rare to know about someone who chooses not to prepare mole. It's delicious". "It's not the same to make it on May 15 for someone who can offer a banquet for his guests than making it for someone who barely knows what's going on that day; and neither is it to offer stuffed peppers instead of barbacoa tamales". This is also a moment of social distinction, a visualization of power relations: Those who had a good year, successful in financial terms are separated stand out; those who gained benefits or whose salary allows them to have a little extra and share food with others.

Television may be a symbol of financial wellbeing and modernity. As children are the most vulnerable public before advertisements, they associate food products with ideas of wellbeing. The impact of this has been an increase in children obesity and associated chronic degenerative conditions of no benefit whatsoever for the development of capacities in the population (Luján-Carpio *et al.*, 2015). Advertisements do not promote a balanced diet based on fruits and vegetables; they mostly promote sugar beverages, candy and cereals with added sugar, with greater content of calories, fats and carbohydrates. Among adults, a rooted habit is to quench the thirst or drink bottled soft drinks during the meal. Coca-Cola is the most popular, as it is consumed since childhood. Nevertheless, the idea that soft drinks different than cola do not affect health that much is popular. Rivera *et al.* (2018) state that overweight and obesity issues are due mainly to a high intake of calories, ultraprocessed foods rich in calories (refined sugars and flours), fats and sugar drinks, the result of which is an overconsumption of energy and, therefore, chronic degenerative conditions.

The diet of inhabitants in Bandera de Juárez is varied. Despite the fact that food has social and family determinants, individual taste also determines the choice of a person on his/her intake when there are options to choose from. Food scarcity situations leave no options on nourishment options. Thus, nourishment reflects both personal taste and power relationships within the social structure (Toledo, 2013).

CONCLUSIONS

Changes in social, structure, with more women as providers, assumes changes in the management of the plot. The community urbanization process, changes in economic activities and the idea of associating urbanization with wellbeing are determinants on how families allocate resources to the family plot as this space fulfills a social function in identity and bond strengthening processes. Significant knowledge of family experiences are transferred to younger members. This knowledge is touched by the insertion of the family in social networks. The plot's productive function is influenced by celebrations; there are temporary biophysical conditions about what is planted; although the use of the crops is a human decision that has incidence on the agroecosystem. In Bandera de Juárez, nourishment is a reference of identity. Its inhabitants define themselves facing others with the food that they consume and forms in which they prepare meals. The feasts of San Isidro Labrador and All Saints Day are a framework of community and identity bonds.

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Cocoa (*Theobroma cacao* L.) harvest and postharvest in Tabasco, Mexico

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ABSTRACT

Objective: To characterize the harvest and postharvest of the cocoa management system at La Chontalpa, Tabasco, Mexico.

Design/methodology/approach: The study took place in the towns of Francisco Trujillo Gurría and Ernesto Aguirre Colorado de Huimanguillo, Tabasco, Mexico. The study was descriptive and accounted for 51 producers and those responsible for the cocoa profit centers. Producers were chosen through targeted sampling. A survey on their harvest and postharvest was applied, in addition to direct assessment in plantations and profit centers.

Results: The cocoa harvesting is manual. The producers cut the ripe and almost ripe fruits, do not store and 58.8% of them do not make "quebraderos" with the fruits. With a "machete" cut the fruit in half and manually extract the grains. The fresh grains are sold at a profit. The cocoa is then fermented in wooden boxes, dried artificially, natural, or in a combined way, and packed in "yute" bags for sale. Profit centers do not keep track of their grain origin and make no selection or determine product quality.

Study limitations/implications: All producers harvest in the same way, but the processes during post-harvest could differ at different collection centers.

Findings/conclusions: The harvest of cocoa fruits at different maturity and the lack of storage causes a heterogeneous fermentation. The humidity level during the drying process is empirically determined.

Key words: Harvest, cacao, fermentation, drying.

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INTRODUCTION

The harvest and postharvest, in addition to the cocoa genotype (*Theobroma cacao* L.) determine the quality of the cocoa beans (Jiménez, 2003). The harvest consists of cutting, opening of the fruit (pods) and extracting their grains. Postharvest handling includes the fermentation, drying, classification, packaging and storing the cocoa beans in collection or profit centers (Moreno and Sánchez, 1989). The fermentation and drying of the grains constitute the step previous to its commercialization and industrialization. Fermented and dried cocoa is easy to transport, store and of better-quality product (Jiménez, 2003).

The quality of the cocoa produced in Mexico is not high (not cataloged as "fine" or "aroma cocoa"). In the 1930s, high-quality creole cacao (ICCO, 2012) grown in Mexico, was replaced for lower-quality more productive varieties. Currently, these are no longer as productive, due to age, disease and poor agronomic management.

Only ripe pods should be cut for harvest. Maturity can be indicated by the color, which is yellow or orange-yellow depending on the genotype. The harvest of overripe pods with germinated grains produces chopped grains, susceptible to the fungi attack, affecting their commercialization, the flavor of the chocolate produced with them and overall puts its innocuity at risk (Enríquez, 2004). Harvesting immature pods affect postharvest because undeveloped grains do not contain enough pulp and sugars for fermentation (Enríquez, 2004). The fermentation and drying of cocoa beans during post-harvest handling determine their flavor and aroma characteristics, which are the basis of the quality established by the international market (González *et al*., 2012). Variations in fermentation and drying result in differences in the final quality of the product (Ortiz de Bertorelli *et al*., 2009). With that in mind, the objective here was to characterize the harvest and postharvest management in two cocoa profit centers.

MATERIALS AND METHODS

The study took place at Francisco Trujillo Gurría and Ernesto Aguirre Colorado towns (Villages C-32 and C-40 respectively) of Huimanguillo, Tabasco, Mexico.

The study was descriptive and included the producers and managers of cocoa processing centers. The producers included in the study were chosen through a sample directed among those attending an assembly called by the Ejidal Commissariat (local authority) and the President of the Local Association of Cacao Producers (ALPC) of each community. Two surveys were used as a research technique. One on regard the field harvest (n=25 C32 producers, and n=26 C40 producers), directly in the plantations and during the harvest time. The questionnaire covered, from how cocoa is cut and the cocoa beans extracted, to the way it is sold and its destination.

The post-harvest survey was applied to the Presidents of the ALPCs directly at the cocoa processing centers. The questionnaire ranged from the general characteristics of the benefit in terms of the date of establishment, number of workers and area of influence, to aspects of the quality control and destination of the obtained grain. In addition to the surveys, the obtained data were complemented and corroborated by direct assessment of the plantations, facilities, process conditions and product handling.

RESULTS AND DISCUSSION

Harvest

Producers harvest cocoa with knives and machetes (Figure 1a). They cut the fruits at physiological maturity and those near to it, colloquially called "sazones". 41.2% of the producers have "quebraderos" (Figure 1b), identified as sites within the plantation where the harvested cocoa is collected before the extraction of the beans. In these quebraderos, producers with the help of a machete cut the fruit in half and extract the cocoa beans by hand without detaching the funicle. 100% of the producers mentioned that, to obtain a kilo of fresh cocoa, 10 to 13 fruits are needed, and that a bucket full of cocoa beans (Figure 1c) weighs between 20 and 23 kg. 41.2% of the visited producers have their trees numbered and can identify those most productive and disease resistant. Also, they record the fruits per plant at the time of harvest. This is important because a participatory genetic selection program could be emplaced (Alonso-Baez and Aguirre-Medina, 2009).

Once the slimy cocoa beans (fresh) are extracted theses are taken to the collection center of the local Association (ALPC). Sometimes producers sell to intermediaries because the Association might not have the cash to pay for the product at the time of delivery (Córdova-Ávalos *et al*., 2008).

Figure 1. a: Usage of a blade (luco) to harvest cocoa. b: "Quebradero" of cocoa fruits. c: Preparation of a bucket of cocoa for sale.

From the interviewed producers, 41% report testing the scales. That it is, the producers test them by weighing themselves before their cocoa. 47% of the visited plantations obtain a dry cocoa production of 395.3 kg ha^{-1}, 47% obtain less than 232.5 kg ha^{-1} and 6% obtain up to 837.2 kg ha^{-1}. These yields are high compared to the 372 kg ha^{-1} reported by Díaz *et al*. (2013) for six municipalities in Tabasco and five in Chiapas. However, if we consider that the average cocoa production in Tabasco is 460 kg ha^{-1} (SIAP, 2019), the average production (464.9 kg ha^{-1}) for the assessed towns is within the state average.

With regard to technification, only 2% of the plantations are installing drip irrigation; the rest is seasonal. 23.5% of the visited producers organically manage their plantations, compost and implement 70 to 80% of the management recommended by Alonso-Baez and Aguirre-Medina (2009) for cultivation: pruning, discarding diseased fruits, diseased branches, apply copper sulfate to ease moniliasis (*Moniliophthora roreri*), and manually control weeds.

The productive period of cocoa plantations has been estimated to be between 25 to 30 years (Yao *et al*., 2015). In this study, 88% of the plantations are over 30 years old, and therefore some producers are trying to renew their plantations through government support programs or their means. These producers are planting new cocoa varieties to renew and rehabilitate their plantations. The rehabilitation of plantations was indicated by Díaz *et al*. (2013) as the highest priority measure to reactivate cocoa production in Mexico.

The discouragement of the producers during the harvest is usually due to the theft of fruits, the misalignment of prices, pests and diseases. The theft of fruits cannot be controlled and causes the cocoa to be harvested immaturely and not at the "quebraderos" as it was used to. Immature cocoa fruits affect the final quality of the product because it does not adequately ferment. The absence of quebraderos affects plantation sustainability. After the extraction of cocoa beans, the shell and funiculus remained there, which accounted for up to 80% of the cocoa fruit. The husk and funiculus already decomposed (cascarilla) were incorporated as fertilizer in the plantations.

The cocoa price mismatch was observed because in the evaluated harvest season (2016-2017) the price per kilogram of fresh cocoa varied by 26% in relation to the final price. Córdova-Ávalos *et al*. (2008) reported a 25% fluctuation in the initial and final price of a kilogram of fresh cocoa for the 1999-2000 harvest in Huimanguillo, Tabasco. This means that the price mismatch in cocoa is a constant every year and that it is not the leaders of the associations and the UNPC who determine the price of fresh cocoa, as stated by Córdova-Ávalos *et al*. (2008).

Pests such as squirrels and birds (*Melanerpes aurifrons*) cause direct and indirect damage. No methods for bird control were applied. Hunters are hired to control squirrels who charge US $ 2.00 per hunted squirrel. These mammals feed on the grain, exposing fruit residues (Figure 2) that serve as an inoculum for fungal diseases such as monilia and black spot (*Phytophthora palmivora*). These diseases have caused the abandonment of plantations by reducing their production by up to 80%,

Figure 2. Cacao fruit damaged by squirrels (left) and birds (right).

making the crop unaffordable. As mentioned by Díaz *et al*. (2013) from 2000 to 2011, cocoa production in Mexico decreased 43.7% due to the attack of moniliasis, among other factors.

Postharvest and cocoa collection center characterization

The post-harvest of cocoa begins in the fields and ends in the ALPC collection centers. Postharvest begins the moment the cocoa pods are removed from the tree. It ends when the grain is dry and ready for sale or industrial processing. Postharvest includes the fermentation and drying processes, which largely determine the quality of chocolate.

In the present study, the producers do not pre-condition the cocoa pods, and once they are cut from the tree, they are split with a machete and their grains are extracted by hand. Afoakwa (2011) recommends splitting the cocoa pods with a wooden pillar or a machete. Preconditioning is the storage of harvested cocoa pods for a period before pod opening and bean fermentation (Afoakwa *et al*., 2014). The storage of the cocoa pods before its opening and grains extraction influences their fermentation (Kongor *et al*., 2013) and improves the quality of chocolate produced with it (González *et al*., 2012). The fermentation, drying, selection, packing and storage of the cocoa bean for sale, constitute the benefits process of the cocoa bean. The characteristics and infrastructure of the profit centers are shown in Table 1.

In relation to the type and material of construction, both profit centers are closed cement buildings. This is important because the fermentation process requires constant climatic conditions. Likewise, these profit centers have office areas and equipment, but do not have hygrometers or a guillotine to test grain cutting. This test and moisture determination are essential to assess the physical quality of the fermented grain. Regarding the type of cocoa received, both profit centers receive fresh cocoa (Rodríguez *et al*., 2012).

Characteristics of the fermentation, drying and storage of cocoa

At the profit centers, once the fresh beans are received, they are transferred to wooden boxes for fermentation (Figure 3). Fermentation takes place for 8 d. The fermentation of cocoa beans in boxes has been classified as a low uniformity method since it results in an incomplete use of sugars and a high presence of defective beans (Guehi *et al*., 2010). The fermentation process in these centers is inadequate since the producers do not classify the grains before their fermentation, which does not favor a homogeneity of the fermented grains. On the other hand, the lack of instruments for moisture determination and cutting tests makes it difficult to know if the beans are well fermented.

The drying of cocoa consists of the loss of moisture from the grains that go from 60% to <8% for their safe storage (Afoakwa *et al*., 2014). At the C40 Town, only artificial drying is used, in C32 it is combined with natural drying (Figure 4). However, in the latter, the drying capacity is lower. In both profit centers, dry cocoa is packed in 50 to 60 kg jute bags and stored until marketed.

Quality control and regulatory aspects

Both centers have no certification to process cocoa, do not classify the beans, and do not perform cutting tests. The beans are sold without information of their origin. There is no process for packaging and tracking the grains (the bags does not keep information of the batch from the producer, fermentation, drying and packaging). A traceability system allows the chocolate industry to know how the beans were processed (Saltini *et al*., 2013).

Table 1. Characteristics of postharvest cocoa handling in two towns of The Chontalpa Plan, Tabasco, Mexico.

Collection center characteristics	Town	
	Francisco Trujillo Gurría (C-32)	Ernesto Aguirre Colorado (C-40)
Foundation year	2005	1940
Type of bought cocoa	Fresh	Fresh
Working months	Nov-Jan y April-Jun	Nov-Jan y Feb- April
Construction type	Closed	Closed
Construction material	Concrete	Concrete
Office supplies	Furniture and files	Furniture and files
Moisture meter and guillotine	No	No
Balances	Si	Si
Incorporation as a company	No	Si
Collection center capacity		
Number of workers	10	14
Installed capacity to ferment *	50	140
Used capacity to ferment *	10	15
Installed drying capacity *	10	32
Used capacity for drying *	4	32
Cocoa received *	18	35
Producers served	70	170
Average area per producer (ha)	1.5	1.5
Fermentation		
Do you ferment your cocoa?	Yes	Yes
Fermenters type	Wooden boxes	Wooden boxes
Days to ferment	7	8
Drier type in use		
Natural drying	Yes	No
Time (days)	3	
Turning frequency	2 h	
Artificial drying	Yes	Yes
Time (hours)	12 a 16	24 a 36
Daily drying capacity (ton)	1.5	4
Storage		
Do you store your product?	Yes	Yes
Infrastructure type	Concrete	Concrete
Do you classify grains and do cutting test?	No	No
Each bag keeps the lote information from the producer, ferment, drying and packaging?	No	No
Regulatory aspects		
Are you certified to benefit cocoa?	No	No
What company does the certification?	AMCO **	-
Final product and its destination		
Standard type?	Yes	Yes
Who do you sell your cocoa to?	Agroindustry (AMCO)	NUCP ***
Product destination	National market	National market

* t sem^{-1} per week; ** Agroindustrias Unidas de Cacao S.A. de C.V.
*** National Union of Cocoa Producers.

According to the Mexican standard for quality control of cocoa beans (NMX-FF-118-SCFI-2014), both centers produce "First-class fermented and dried" cocoa. The characteristics of top-quality cocoa are a minimum of 60% well-fermented beans, humidity of less than 8% and the absence of atypical odors such as smoky or moldy (Fowler and Coutel, 2017).

Figure 3. Fermentation of cocoa in wooden boxes.

Commercialization and destination of the grain

The profit center of the ALPC of town C32 sells the dry cocoa to the Agroindustrias Unidas de Cacao S.A. de C.V. company (AMCO), that at the C40 town sells to industry and the UNPC. The UNPC sells the grains to national and foreign agro-industrial companies. It was determined that the price of the kg of fresh cocoa varies from US$ 0.50 to US$ 0.75, the profit centers in turn sell the kg of dry processed cocoa between US$ 2.20 to US$ 2.40.

CONCLUSIONS

At the assesses localities the cocoa harvest is manual. Producers harvest ripe fruits and due to cocoa theft, seasoned (immature) fruits are also harvested. Producers do not precondition (store) their fruits prior to the manual extraction of the cocoa beans. Immature fruits and a lack of preconditioning affect cocoa fermentation. The fermentation of the grain takes place in wooden boxes and is not homogeneous. Drying is artificial, natural or combined. The dry, unsorted grain is packed in jute bags for sale. Profit centers do not keep a record of the origin of the cocoa beans, nor do they perform cutting or moisture tests on the grains to determine the quality of the product. The centers are limited regard the adoption of methods and technologies to optimize the fermentation and drying processes. However, its physical spaces are convenient to carry out these processes.

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Amaranth Microgreens as a Potential Ingredient for Healthy Salads: Sensory Liking and Purchase Intent

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ABSTRACT

Objective: To identify liking, acceptability, and purchase intent of salads prepared from amaranth microgreens in a mixture with lettuce and carrots.

Design/Methodology/Approach: Seven formulations of amaranth microgreens, lettuce, and carrots were evaluated. The study was conducted through a centralized location consumer study. The level of liking was measured with a 9-point hedonic scale. Acceptability and purchase intent were measured with a binomial scale.

Results: In general, consumers indicated they liked salad samples within a range of 6 (liked slightly) and 7 (liked moderately). Formulation 7 (with the highest proportion of carrot) was liked by consumers in aftertaste, flavor, and overall liking. Formulation 3 (a balanced mixture of its three ingredients) was liked in its attributes: colors, texture, appearance, and smell. Overall liking had a significant impact on purchase intent.

Study Limitations/Implications: Study results represent only the segment of the surveyed population, most of which were young people between 18 and 25 years old (60%).

Findings/Conclusions: Amaranth aroma can impact the liking of amaranth microgreen-based salads without causing rejection. The use of carrots in combination with amaranth microgreens can improve the acceptability of salads. Salad formulations with amaranth proportions of 22 to 33.3% have more opportunity in their purchase intent.

Keywords: amaranth, microgreens, consumers, acceptability, purchase.

INTRODUCTION

Microgreens are immature plants that have completely developed cotyledons and can have or not their first true leaves. They generally measure between 2.5 and 7.6 cm in height, and they are usually harvested between 7 and 14 days after germination (Xiao *et al*., 2016). They represent an alternative for food consumption with functional properties (Xiao *et al*., 2015). In addition, a small portion of microgreens can provide around 89% of the daily required intake of vitamins (Kou *et al*., 2013). Amaranth cultivation in Mexico is primarily directed toward grain production for different processed products, and although the crop is

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Imagen de Luisella Planeta Leoni en Pixabay consumed as a plant in rural areas, it is not common to find these products in supermarkets with similar packaging to other leafy vegetables such as lettuce. The cultivation of amaranth for the production of microgreens could be a diversifying option for the crop, to be used in nutrient-rich foods with functional properties. In order to accomplish this goal, it is necessary to identify the reactions of consumers regarding the use of microgreens, to successfully introduce them into the market. A consumer study will allow the determination of key sensory attributes that impact the level of liking, acceptability, and purchase intent in salads formulated with amaranth microgreens.

Various studies have demonstrated that there is a direct correlation between vegetable consumption and a reduction in the development of chronic illnesses, such as cardiovascular diseases and cancer (Slavin and Lloyd, 2012). It has been found that microgreens generally contain more phytonutrients (such as ascorbic acid, α-tocopherol, and β-carotene) than mature plants, and are excellent sources of vitamins and carotenoids (Chloe *et al*., 2008). On the sensory side, microgreens can provide intense flavors, vivid colors, and specific textures, while also being able to function as a decorative element in salads or as a new ingredient. In general, the quality of fresh products is related to various sensory attributes such as appearance, texture, and flavor (Xiao *et al*., 2015). Among all the quality attributes, appearance is the initial attribute that attracts consumers and affects their choice to buy for the first time. However, other characteristics play a crucial role in consumer satisfaction and repeating purchases. To date, there is no information from studies published in the literature about the integration of amaranth microgreens in salads evaluated by consumers.

The use of amaranth microgreens in salads could represent a strategy for diversifying the application of the amaranth crop. Nonetheless, a lack of awareness of this use in consumers can be a limitation. The objective of this study was to identify the liking level, acceptability, and purchase intent of salads prepared using amaranth microgreens mixed with lettuce and carrots.

MATERIALS AND METHODOLOGY

The study was conducted in the Sensory Testing Laboratory of Colegio de Postgraduados, Córdoba Campus, located on km 348 of the Córdoba-Veracruz Federal Highway, in Amatlán de los Reyes, Veracruz, Mexico.

Plant Material

For the production of amaranth microgreens, seeds of the Areli variety were used, which were planted in the municipality of Xayacatlán de Bravo, Puebla. The soil used consisted of 60% loam, 25% sand, and 15% compost. The seeds were sprinkled evenly, covered lightly with soil, and fully moistened. They were watered twice a day: morning and afternoon. After 5 days, the seeds began to germinate. By the seventh day after planting, the watering schedule was modified: in the morning, around midday, and in the afternoon. This procedure was maintained for 11 days, which was the time it took for the plants to reach the height and characteristics required for cutting. The microgreens were harvested using previously disinfected scissors by cutting the stem approximately one centimeter above the soil. The plants were placed in a plastic container and stored in refrigeration at 4 °C to avoid oxidation or darkening.

The carrots and romaine lettuce were purchased the local market one day before conducting the consumer study.

Mixture Design

The design of the salad mixtures was based on a simplex triangle where the total proportions of each ingredient (amaranth microgreens, lettuce, and carrots) in the salad were adjusted to sum 100% according to Table 1. As constraints, a maximum of 80% and a minimum of 10% were set for all the ingredients.

Salad Preparation

Before preparing the salads, the ingredients were selected to verify the absence of physical damage, contamination, or undesirable materials. All the ingredients were washed and disinfected in a 1% sodium hypochlorite solution for 3 to 5 min. The lettuce and carrots were cut into long segments of approximately 5 cm × 1 cm, adequate for the salad presentation. The

Table 1. Percentages of ingredients used for salads formulation.

Formulation	Lettuce %	Amaranth %	Carrot %	Total %
F1	80.0	10.0	10.0	100
F2	56.0	22.0	22.0	100
F3	33.3	33.3	33.3	100
F4	22.0	56.0	22.0	100
F5	22.0	22.0	56.0	100
F6	10.0	80.0	10.0	100
F7	10.0	10.0	80.0	100

amaranth microgreens were only trimmed of excess stem. Given that salads are usually eaten with dressing, a neutral dressing of lime and honey (1:1) was used in all the formulations. The dressing selection sought one that was simple, easy to prepare, and appropriate for the mix of ingredients while having the lowest impact on salad taste.

All the ingredients in the formulations presented to the consumers were weighed individually to guarantee proportions according to the mixture design. Weighing was done using a Scout ®Pro (Ohaus Corporation, 194 Chapin Road NJ07058, USA) analytical scale. The ingredients were manually placed and mixed on disposable plates. The total weight of the amaranth microgreens, lettuce and carrots that was presented to the consumer was 30 g, and as a final step, 5 ml of dressing was added.

Consumer Study

The study was conducted with consumers in a central location modality. The evaluation was carried out at Córdoba Campus of Colegio de Postgraduados. To collect the answers, a questionnaire was used with three sections: 1) consumer demographic data; 2) evaluation of salad liking for 7 sensory attributes (appearance, color, aroma, mouth feel or texture, flavor, aftertaste, and general liking) on a 9-point hedonic scale (1=Extremely dislike, 5=neutral, 9=Extremely like); and 3) evaluation of the "acceptability," "purchase intent," and "purchase intent after knowing that the salad contains amaranth microgreens" on a binomial scale (yes/no). All the panelists were instructed to rinse their mouths with water between each sample to minimize the effect of the order of presentation. Participation was voluntary and the consumers were informed about the ingredients, and the use of the hedonic scale with respect to the 7 attributes.

In total, there were 63 consumers. Their ages were within a range of 18-24 years old in around 59% and between 25-34 years old in 29%. Among the consumers, 59% were women and 41% were men.

Statistical Analysis

Given the total quantity of formulations (7), a balanced incomplete block design was used ro reduce consumer fatigue. With this statistical design, each consumer evaluated only 2 formulations according to the plan 11.2a (t=7, k=2, r=6, b=21, λ=1, E=0.58; Cochran and Cox, 1957). The design was repeated 3 times. For the analysis of liking data collected from the hedonic scale, a balanced incomplete block design was used ro reduce consumer fatigue with a significance level of 0.05. For means comparison among formulations, Tukey's test was applied. To identify similarities among formulations considering all the attributes simultaneously, Principal Components Analysis and Cluster Analysis were used. To identify the critical attributes for acceptability and purchase intent, a multiple logistic regression analysis was used (Prinyawiwatkul and Chompreeda, 2007), where the significance of each of the coefficients associated to each attribute was determined according to the following model:

$$\ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 Appearance + \beta_2 Color + \beta_3 Aroma + \beta_4 Texture + \beta_5 Flavor + \beta_6 Aftertaste + \beta_7 Overall\ Liking$$

To identify the effect of providing additional information to the consumer (the use of amaranth microgreens in the salad ingredients) on the purchase intent, the McNemar test was used. The R software version 4.0.2 was used with the integrated development environment of RStudio 1.3.959.

RESULTS AND DISCUSSION

In the variance analysis of the liking level for sensory attributes, no significant difference was found among the formulations for attributes of color, texture, flavor, aftertaste, and overall liking. In general, consumers indicated that they liked the salad samples in a range of 6 (like slightly) and 7 (like moderately). These results suggest that even with different proportions of ingredients in the formulations, consumers liked most of the attributes of the salads, and adding amaranth microgreens had no significant impact on consumer liking. A significant difference was found for the appearance and aroma attributes in a range of 5 (neutral) and 7 (like moderately). In the case of appearance, the lowest value was for formulation 4 (lettuce 22%, amaranth 56%, and carrot 22%), which was one of the formulations with the highest proportion of amaranth. Paakki *et al*. (2019) studied the impact of color intensity and color contrasts in mixed salads. These authors found that salads with more contrast in their colors were more attractive to consumers since they were associated with freshness, variety, and complexity. In the case of aroma, the lowest values were for formulations 4 and 6, both with the highest proportions of amaranth microgreens. This suggests that the aroma of amaranth microgreens could impact the level of liking, but not at a level that causes rejection. According to Kyriacou *et al*. (2016), microgreens usually have more intense flavors than sprouts. In general, the liking values for the attributes studied were similar to those found by Senevirathne *et al*. (2019) in salads prepared with different species of microgreens (Table 2).

The multivariate analysis of the results from the principal components and cluster analyses is shown in Figures 1 and 2. The formulations were projected in the first two principal components: AXIS1 (which explained 74.47% of the total variability) and AXIS2 (which explained 13.04% of the total variability), for a total of 87.51%. The formulations were projected along this line, where the closest were the most visually similar between them according to the values (on the hedonic scale) that they were assigned in their attributes. Formulation 7, with the highest proportion of carrot, was pleasant to the consumer in its aftertaste, flavor, and overall liking attributes, as was Formulation 3 in its color, texture, appearance and smell attributes, with an even balance in its three ingredients. Formulations 1 and 5 were at an intermediate level, while formulations 2 (with a high proportion of lettuce), 4, and 6 (with high proportions of amaranth microgreens) were at the lowest level. Caracciolo *et al*. (2020) found that although visual appearance is important, acceptability is determined by flavor and texture. Cluster analysis allowed two groups to be visualized, clearly separating formulations 2, 4, and 6 from the rest.

The multiple logistic regression analysis is presented in Table 3. In this analysis, the coefficients for each attribute in the estimated model for acceptability were not significant. This indicates that no single attribute had a significant impact on the acceptability of the salads. Regarding purchase intent, only overall liking had a significant impact (P=0.0005), indicating that consumers

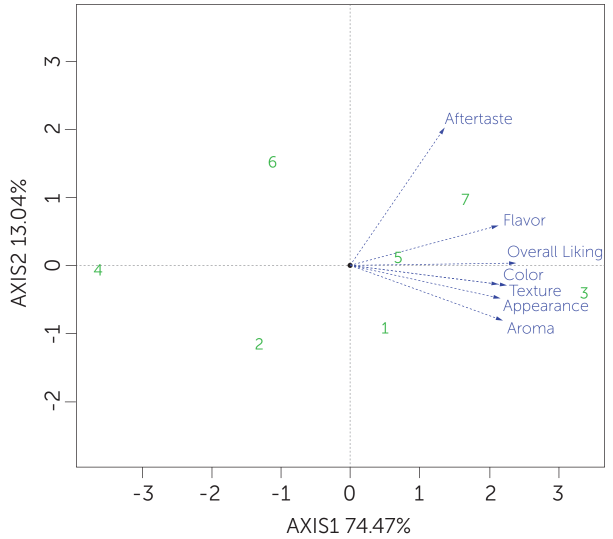

Figure 1. Biplot constructed with liking values plotting formulations and attributes in two dimensions.

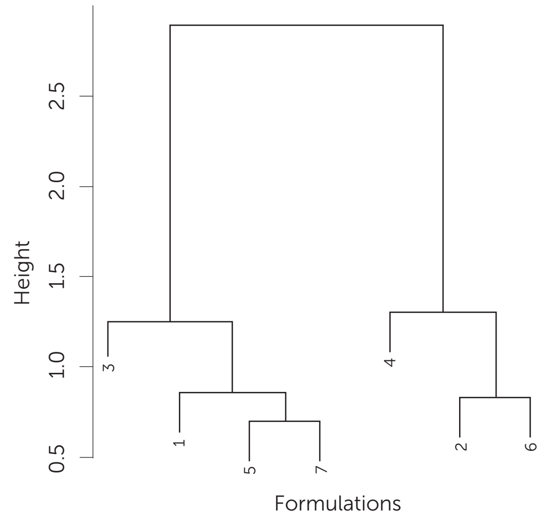

Figura 2. Dendrogram showing two groups of formulations with similar levels of liking.

Table 2. Liking levels for attributes of the seven salad formulations*.

Formulation	Appearance	Color	Aroma	Texture	Flavor	Aftertaste	Overall Liking
1	6.50±0.99ab	6.89±1.13a	7.11±1.08ab	7.11±1.37a	6.94±1.43a	6.22±1.40a	6.94±1.11a
2	6.83±1.04ab	7.06±0.94a	6.22±1.35ab	6.22±1.83a	6.50±1.29a	6.11±1.71a	6.78±1.17a
3	7.39±0.92a	7.44±1.15a	7.28±1.13a	7.33±1.08a	7.33±1.24a	6.44±1.46a	7.33±0.97a
4	5.94±1.26b	6.28±1.60a	5.89±1.49b	6.28±1.49a	6.44±1.54a	6.17±1.20a	6.33±1.53a
5	6.72±1.45ab	7.11±1.02a	6.67±1.33ab	6.89±1.02a	6.67±1.37a	6.44±1.46a	7.17±0.86a
6	6.83±1.04ab	6.72±1.07a	6.00±0.97b	6.44±1.95a	6.78±1.56a	6.56±1.42a	6.78±1.31a
7	6.83±1.10ab	7.22±1.35a	6.72±1.36ab	6.83±1.50a	7.33±1.41a	6.56±1.42a	7.11±1.18a

* Mean values ± standard deviation. Means with the same letter in the same column are not significantly different according to Tukey's test at α=0.05.

relied on the combination of salad attributes to determine purchase intent. Formulation 4 was rated with the lowest acceptability and purchase intent (50%) and Formulation 5 with the highest (100%). Michell et al. (2020) found that familiarity with microgreens, cost, availability, and shelf life are also key factors in determining purchase intent of microgreens.

In general, the results of the analysis of variance, Principal Components Analysis, and Multiple Logistic Regression Analysis suggest that salad formulations that are balanced in their ingredient proportions and those with a slightly higher proportion of carrots were the best rated by consumers (Formulations 3 and 5).

The result of McNemar's test was not significant, indicating that informing consumers that the salad contains amaranth microgreens does not change their purchase intent, which was generally favorable for most formulations. Renna *et al*. (2017) emphasize that the culinary promotion of microgreens has great potential to integrate these ingredients into international gastronomy and foster the use of local edible species.

Table 3. Coefficients for the multiple logistic regression model for acceptability and purchase intent.

Attibutes	Acceptability		Purchase Intent	
	Estimated	Pr (>|z|)	Estimated	Pr (>|z|)
Appearance	0.2678	0.7135	0.3688	0.2211
Color	1.2512	0.1058	−0.1120	0.2211
Aroma	−0.2982	0.6160	0.0195	0.9458
Texture	0.0515	0.9165	−0.0552	0.8458
Flavor	0.8699	0.2461	0.5406	0.1282
AfterTaste	−0.0722	0.9096	0.0016	0.9956
Overall Liking	0.6879	0.3679	1.3909	0.0005

Pr (>|z|) values smaller than 0.05 indicate a significant impact of the attribute on salad acceptability or purchase intent.

CONCLUSIONS

The aroma of amaranth can impact the level of liking of salads prepared with this crop's microgreens without reaching rejection. The use of carrots in combination with amaranth microgreens can improve the acceptability of salads. Salad formulations with amaranth proportions of 22 to 33.3% have more opportunity in purchase intent. In general, salads with amaranth microgreens were well received by consumers and represent an alternative for the diversification of the crop.

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Agricultural credit use in papaya agroecosystems in the central region of Veracruz, Mexico

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ABSTRACT

Objective: To analyze the use of agricultural credit and the profitability of their papaya agroecosystem.

Design/methodology/approach: A survey was applied using a questionnaire to 114 producers in seven municipalities in the central area of Veracruz, Mexico.

Results: 75% of papaya growers do not know about formal sources of credit that support their productive activity. Only 22.8% have used some type of financing, and only 2.6% came from formal credit sources, even though, 97.4% used semi-formal and informal financing options. 77.2 % of growers use their own economic resources for papaya production. This generates a great heterogeneity on production costs and crop management (level of technology) that reflects the final yield. Even under these conditions the crop is profitable.

Limitations of the study/implications: Information from public or private credit institutions, does not reach potential users. The few farmers who have accessed a formal credit, have had bad experiences, such as embargoes and legal actions due to special situations that made them not paying on time, that discourage growers from using this type of credit.

Findings/Conclusions: Lack of knowledge of the growers about financing sources. Low use of agricultural or other formal private credits, as 77.2% of growers used their own economic resources, which generates great heterogeneity in production costs associated with the level of technology, that is reflected in the crop yield, even so the papaya crop still is profitable.

Keywords: *Carica papaya*, farmer credits, production costs, yield, profitability.

INTRODUCTION

Commercial agriculture depends on technology packages, which include technical advice and credits for the purchase of machinery, seeds, fertilizers, irrigation systems, herbicides, pesticides and other inputs, although this agriculture has negative effects on the environment and human health from the ecology viewpoint, their contribution to world food production cannot be denied (FAO, 2009).

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In Mexico, the banking system comprises the multiple banking system and development bank system. As of 2002, the creation of Bancos Asociados a Cadenas Comerciales (BACC) was authorized. It was considered to be a multiple banking institution (SHCP, 2012). As of late 2002 to early 2014, as a de-centralized body of the Federal Public Administration, Rural Financing (FR) is the Federal Government's official agency that encourages agriculture and livestock raising, forest, fishing and all other activities linked to the rural environment, as well as the formation of first-floor financial intermediaries (SHCP, 2009).

According to Carranza (2007), financing sources by which agriculture and livestock raising producer get resources from may be classified as domestic and foreign, as well as formal (banking and non-banking), semi-formal (cooperation, producer organization) and informal (local lenders, loan sharks and usurers), credit from agents from inside the production chain (input producers, final product purchasers) and friend and family credit.

As papaya is a fully commercial crop, completely addressed to the market, it shows certain technical demands for its production process in order to reach performance and quality required by the market. Small producers in the state of Veracruz try to incorporate innovations such as fertilization and pests combat, which represents strong amounts of money for their purchase and application; also, the fruit's growth requires a major amount of contracted labor. These items mean major expenses for the producer who does not have access to financing sources, with amounts, periods and interest rates adequate for their activity.

Mexico falls on fifth place as a papaya producer at a world level, with a production of around 961,768 t in year 2017; it is also one of the main exporting countries with around 168 mil t, 99% of which are bound for the US. In order of importance, exporter countries that follow are Brazil, Belize, Malasia and India (FAOSTAT, 2017). The Agroalimentary and Fishing Information System (SIAP) reports that there is papaya production in 20 states of Mexico, of which Veracruz, Michoacán, Colima, Oaxaca, Chiapas and Guerrero stand out by their sown area, which concentrate more than 73% of sown surface with 19,845 ha, with a production volume of 1,093,487 t of fruit (SIAP, 2017; SIAP, 2019).

The Maradol papaya has a Cuban origin and was introduced in Mexico in 1977. It had an extended growth in the state of Veracruz in the last 20 years and currently prevails in the national market. Its features are productivity, post-crop handling strength and fruit quality. Nevertheless, it is prone to acquiring the Papaya ringspot virus (VMAP or PRSV-p) (FPS, 2009; Semillas del Caribe, 2017).

By the end of 2019, the state of Veracruz leads the national statistics as a main papaya producer; with a sown surface of 3,455 ha, an average yield of 32,759 t ha^{-1}, and a production of 112 mil t; followed by Michoacán and Colima, with yields greater that, in some occasions, outweigh the national average that amounts to 43.45 t ha^{-1} (SIAP, 2010; SIAP, 2019).

The production cost for the placement of this crop is not smooth. Variability depends on the country zone involved and financial resources the producer has for technology management. 76% of production in the state of Veracruz is focused on the municipalities of Cotaxtla, Isla, Tierra Blanca, Soledad de Doblado and Tlalixcoyan, located mainly in the central region. The objective was to analyze the use of agricultural credit and the profitability of their papaya agroecosystem in the central region of the state of Veracruz.

MATERIALS AND METHODS

Research was made in the municipalities of Cotaxtla, Tierra Blanca, Tlalixcoyan, Soledad de Doblado, Manlio Fabio Altamirano, Puente Nacional and Actopan, Veracruz, Mexico. The first four are located between the first papaya producers, with 60% of production and 48% of the surface grown in the state (SIAP, 2017).

A mixed research was made with qualitative and quantitative variables through a poll, for which a semi-structured questionnaire that considered open and closed questions, with Likert scale and multiple choice dichotomous-type answers, was applied. Questionnaire sections were: i) general producer aspects, ii) property features, iii) financial culture, iv) access to credits, v) crop management vi), training in papaya growing and vii) marketing.

In order to determine the sample size, the snowball non-probability sampling method was considered (Briones, 1996). Its objective was to understand cultural or personal realities (Quintana-Peña, 2006). The choice criterion was being a papaya producer with a farming area established in any chose municipality and with availability to take part in the research. The final sample was of 114 producers located in the 45 towns in seven municipalities.

The information obtained was recorded in Excel 2007®. A data exploratory analysis was made to obtain frequencies, central trend measures and charts in Excel 2007®, together with measures and correlation in Statistica® version 7 (Spiegel & Stephens, 2002).

RESULTS AND DISCUSSION

Identification and use of financing sources by papaya producers

The following formal financing agencies are located in the area of influence for the seven municipalities of study in central Veracruz: Rural Financing (FR), an institution with branch offices in the cities of Veracruz and Xalapa. Only 10 producers (8.8%), in three municipalities knew that FR is a potential financing source for the activity that they develop; two more (1.8%) mentioned FIRA.

85 producers (74.6%) stated that they did not know about any formal financing sources in support to their activity, albeit they stated that they did know Bancos Asociados a Cadenas Comerciales (BACC), who represent a semi-formal source. The experience of these banks integrated to commercial chains, which rose in order to address sectors not covered by traditional banks is based on the marketing of their products through credit schemes (SHCP, 2012) and are not banks specialized in agricultural credit. Producers also consider agrochemical stores, the producer organization they are affiliated to and a micro-financing company located in the region as a potential financing source. As these businesses have grown, they represent a real resource source option and, according to the classification of Carranza (2007), they are internal production chain agents.

In four of seven municipalities, 26 producers (22.8%) used some sort of financing or loan for addressing papaya crops. Six of these cases indicated obtaining financing from formal sources; out of these, three were granted by FR and two from commercial banking; in three of the four remaining cases, credits were granted by the BACC, which is a semi-formal source, and one chose to obtain cash through a credit card, with interest rates that are from 15.8 to 71.2%, according to the banking institution (CONDUSEF, 2012).

Agrochemical stores and other inputs are other financing options used by six papaya producers (5.2%) that fall within the internal production chain agents according to Carranza (2007). The input granted as a credit was provided by one of the companies located in the zones of influence and municipalities of study, practically in the beginning of the harvest, with the commitment of selling products and short installments that go from one week to one month. The term derives from fruit cut frequency (8 to 10 days), during the harvest performance period. Preference for granting financing is not limited to papaya or small producers. BANXICO (2012) states that commercial banking and input suppliers have been the main financing sources; *i.e.*, suppliers provided 81.9% of financing in the last four-month period of year 2012.

77% of interviewed producers stated that their own resources are those supplied to finance the establishment and maintenance of papaya growth. One of them states that *"agriculture is uncertain; therefore, one cannot mortgage one's property"*. This common opinion among producers matches that of Landini (2011), who states that the trend in farmer objectives and preferences lies toward risk reduction, before profit maximization.

General Aspects of Producers

Out of the interviewed producers, 100% are male. They have an average schooling of 5.7 years; i.e. they have an incomplete primary education; in contrast the maximum degree of one producer is a post-graduate degree. The average age is of 48 years, within an age range of 21 to 74 years. This age interval is similar than the one identified in peach producers (33 to 75 years) in the State of Mexico (Larqué-Saavedra *et al.*, 2009). INEGI (2009) states that the average age of independent producers in the agricultural sector is 51 years (Cabello, 2012). Un municipalities that comprise this research, 9.5% of interviewed producers are older than 65 years of age.

A diversity of papaya-grown surface in the central Veracruz zone of 0.75 to 20 ha was identified, with a greater frequency in intervals lower than 3 ha, which represent 69% of the sample. These results match the sown area classification for papaya by Cerdas & Sáenz (1993), where the greater percentage is located among "small producers" that grow more than one crop and have less than 4 ha.

The average time in the papaya growing activity is 17.7 years, within an age range of 21 to 52 years. Interviewed producers stated differences in crop handling, attributed to physical and financial resource availability enjoyed by each producer, as native varieties were predominant in the region until 20 years ago. "Yellow" or "coconut" varieties stand out. These did not require an intensive use of inputs and labor and were not that vulnerable to pests and diseases; although their disadvantage was their short shell life (Villanueva *et al*., 2007).

It is likely that producers have experience in handling native papaya varieties that did not require a strict handling and control. This may be one of the main reasons why the growth of the Maradol variety does not apply a smooth agronomic handling, as they adapt to the surface to be grown in each productive cycle and handling practices depending on financial resources available. This happened despite the fact that 28.1% of producers (32) stated having received training on plantations, production, health and packaging. "Yellow" papaya handling evidences were documented by the Papaya Interdisciplinary Group (GIP, 1995). Also, the application of integrated papaya handling suggested by GIP, was assessed in the Maradol variety by Hernández-Castro *et al*., (2004).

Production costs

Production costs per papaya hectare by producers integrating the sample show a high variation between municipalities of study and even between towns of the same municipalities. Interviewed producers mentioned values from MX$7500 in the municipality of Cotaxtla to MX$130,000 in Soledad de Doblado, with a general mean of MX$68,292 for the seven municipalities. Producers stated that activities demanding greater papaya crop investment are pests control and diseases (33.3%), fertilization (25.4%), cultural work (14.9%) and land preparation (13.2%).

For the 24 producers classified in the production cost interval from $86 to $130 thousand pesos, the average investment was of $103,958 pesos that approach the $110 mil pesos reported by Sistema Producto Papaya del estado de Veracruz, A.C. (2011) in the technology package for the 2011-2012 productive cycle. Although 90 producers (78.9%) reported costs under those considered for this civil partnership.

Crop Yield

According to information from interviewed producers, the average papaya yield estimated for the 2011-2012 period was of 79.5 t ha^{-1}. The average yield per municipality varied from 41.8 t ha^{-1} in the municipality of Tlalixcoyan to 115 t ha^{-1} in the municipality of Puente Nacional. However, at an individual level, the interval is wider, as some producers stated obtaining yields of 10 t ha^{-1}, in contrast with others who reported up to 160 t ha^{-1}. This wide variation in yield may be explained due to differences in crop handling, which may also be associated to the availability of financial resources destined to growing, and the lack of technical knowledge or trust in technology that may be related to the high percentage of senior producers and, in other cases, limits for information access on financing sources or new crop handling technologies. This situation does not match the report for the southeast region of Mexico, where producers face several impediments that limit the papaya production growth. Financial, technology, infrastructure, training and organization problems cause a negative impact in the development of the agroalimentary chain for this fruit (Guzmán *et al*., 2008).

Papaya Crop Profitability

Even when the crop handling was varied, associated to production and physical and financial resource options available for the producers, econometric indicators report that the papaya crop is profitable (Table 1), as profits above 100% of investment costs per hectare are observed in all municipalities. This matches the statement of Guzmán *et al*. (2008) who concluded that, even when the technology level differed among producers in the financial assessment for papaya production, results show profitability.

Table 1. Profitability indicators of papaya production for the 2011-2012 cycle, in the central region of Veracruz state, Mexico..

Municipality	Production cost ha^{-1}	Yield t ha^{-1}	Whole sale price kg^{-1}	Whole sale price t^{-1}	Production cost t^{-1}	Profits ha^{-1}	Utility ha^{-1}	Profitability indicator
	a	b	c	d=c*1000	e=a/b	f=b*d	g=f−a	h=g/a
Cotaxtla	61,196.0	68.37	2.81	2,810.0	895.07	192,119.70	130,923.70	2.14
Actopan	46,250.0	53.20	4.20	4,200.0	869.36	223,440.00	177,190.00	3.83

In an interview for La Jornada del Campo (2009), the director of FIRA mentioned that outside assessment made for FIRA by Universidad Autónoma Chapingo (UACh) and Grupo de Economistas y Asociados (GEA) showed that the credit itself increased producer risk in 24%, technical assistance in 28% and 42% when going together. This statement must refer to those producers who obtained a FIRA credit and those who were provided with technical assistance. This situation was not observed in papaya producers in the central region of the state of Veracruz.

CONCLUSIONS

Something remarkable is that every four producers do not know the formal financing sources for those that may support their activity, reason why the use of the agricultural credit come from formal sources is very low among papaya producers in the central region of the state of Veracruz; the main financing source is their own financial resources. Other semi-formal and informal financing sources are input suppliers, friends, family and BACC.

There is a wide variety in production costs per hectare in the growth of papaya, which is associated to the technology level with handling practices that demand greater investment and is finally reflected in the understanding of the crop. Even with low access to financing, the papaya crop is profitable.

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AP AGRO PRODUCTIVIDAD

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Cerium (Ce) Affects the Phenological Cycle and the Quality of Tulip (*Tulipa gesneriana* L.)

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ABSTRACT

Objective: To study the effect of cerium (Ce) applied in a nutrient solution during the productive cycle, on the duration of the phases of the phenological cycle of tulip (*Tulipa gesneriana* L.) cv. Jan van Nes.

Design/Methodology/Approach: Commercial bulbs (caliber 12+) were planted under shade cloth conditions during the autumn-winter period. The levels of Ce used were 5, 15 and 15 μM from $CeCl_3$ $7H_2O$; Ce was applied in the nutrient solution from the first day of the sowing, apart from the control without its application.

Results: The different concentrations of Ce stimulated bulb sprouting. The low concentration of Ce (5 μM) promoted the early formation of floral buds and their coloration. Hence, the application of 5 μM Ce induces flowering of the tulip without exhibiting changes in the period of time to reach senescence. When 25 μM Ce were applied, the opposite effects were observed. The duration of the flower was not significantly affected by the treatments.

Study Limitations/Implications: This study was made only in one cultivar of tulip.

Findings/Conclusions: The application of 5 μM of Ce had a positive effect in the tulip cycle, by stimulating bulb sprouting, the formation of the floral bud, the coloration, and the induction of the flowering cycle.

Keywords: biostimulation, rare earth elements, hormesis, ornamentals.

INTRODUCTION

Rare earth elements (REE) are a family of 17 chemical elements formed by group III of the periodic table (scandium and yttrium) and the series of lanthanides (from lanthanum and lutetium) which exhibit chemical similarities as a group, while they express individually distinctive and varied electronic properties (Voncken, 2016; Cheisson and Schelter, 2019).

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For this study, cerium (Ce) is of particular importance, for which both positive and negative effects are reported in plants, with these being dependent on the dose, time of exposure, method of application, plant species, growth conditions, pH, as well as nutrient interaction, development stage, among other factors (Zhang *et al*., 2013; Ramos *et al*., 2016, Xu *et al*., 2016; García-Jiménez *et al*., 2017).

On the other hand, tulip is the main ornamental bulb plant produced worldwide. The Netherlands has 60% of global production. In recent years, the studies performed in tulip have centered on increasing stem enlongation, bulb quality, and stimulating early flowering (Kurtar and Ayan, 2005). In this study we aimed to evaluate the effect of Ce supplied during the productive cycle in nutrient solution, on the duration of the phenological cycle stages of tulip cv. Jan van Nes.

MATERIALS AND METHODS

Plant Material and Experiment Conditions

The experiment was developed in a greenhouse under 50% black monofilament shadecloth. The average temperature that was found during the cultivation cycle was 14 °C, 52% of relative humidity, and light intensity of 125 lumen m^{-2}.

Commercial cultivar Jan van Nes (caliber 12+) tulip bulbs were used. This cultivar produces intense yellow flowers. Planting was done in 7-inch pots, and a mixture of red *tezontle*, perlite (Agrolita^{MR}) and peat (Promix® FLX) in a proportion of 70:20:10 (v:v:v) was used as substrate. Before planting, the bulbs were previously disinfected.

Steiner's nutrient solution (Steiner, 1984) at 50% was used for the fertilization, which contained in g L^{-1}: 0.5313 $Ca(NO_3)_2\ 4H_2O$, 0.2464 $MgSO_4\ 7H_2O$, 0.0680 KH_2PO_4, 0.1516 KNO_3 and 0.1306 K_2SO_4; it was complemented with a commercial mixture of micronutrients, TradeCorp® AZ, added at 0.0665 g L^{-1} of the nutrient solution. The pH of the nutrient solution was adjusted to 5.3, using concentrated H_2SO_4. The nutrient solution was supplied in the localized drip irrigation system using ½ HP pumps.

Treatment and Experiment Design

Different concentrations of Ce added to the nutrient solution were evaluated. The levels of Ce used were 5, 15 and 25 μM from $CeCl_3\ 7H_2O$; in addition to a control, without application of Ce.

The experiment was established in a completely randomized design (CRD), and the experimental unit consisted of one plant per pot and each treatment had eight repetitions. The application of the treatments started from the first day of planting the bulbs.

Evaluated Variables

The influence of Ce on bulb emergence, formation of flower bud, coloration of buds, anthesis and senescence; these variables were evaluated at different days after planting (dap).

Emergence of bulbs was characterized with the appearance of the apical meristem. The coloration was defined when the flower bud presented changes in its coloration (green tepals with green border). Anthesis was defined as the days in full flowering, the flower was completely open, and the gyneceum showed the three lobes of the stigma and all the completely formed stamens. The plant was considered senescent when the flower presented withering and tepal fall.

The duration of the flower was estimated by counting the days from anthesis until senescence.

Statistical Analysis

With the data obtained, an analysis of variance was performed and the means were compared using Tukey's test with a significance of α=0.05. The statistical analysis system version 9.4 (SAS Institute, 2013) was used.

RESULTS AND DISCUSSION

The cultivation cycle of the tulip plants was prolonged on average 4.28 days with the addition of 25 μM Ce in the nutrition solution, compared with the control plants that completed their cycle in 57.14 days, whereas the other concentrations had a similar duration to the control (data not shown).

Bulb emergence was stimulated with the addition of different concentrations of Ce in the nutrition solution, which happened on average at 6 dap, while the emergence of the apical meristem took place 2 days later (8 dap) in control plants without addition of Ce (Figure 1).

In a similar way as in bulb emergence, the formation of the flower bud was ahead in 1.85 and 3.25 days in treated plants with 5 and 15 μM Ce, respectively, compared to the control where this event happened at

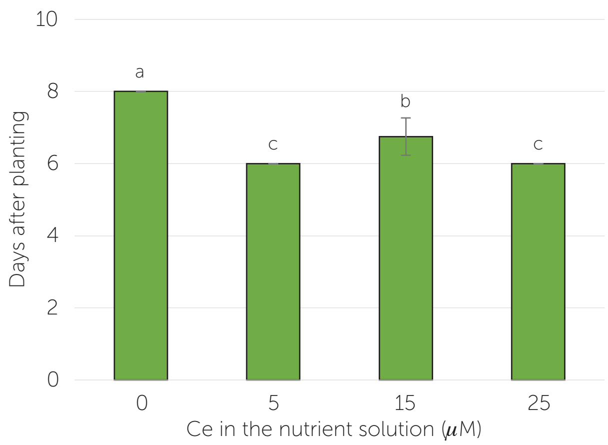

Figure 1. Sprouting of tulip bulbs treated with different concentrations of Ce in the nutrient solution during the productive cycle. Means ± SD with different letters indicate significant differences (Tukey, p≤0.05). n=8.

38.62 dap. In contrast, the dose of 25 μM Ce delayed the formation of the flower bud by 0.5 days, also compared to the control (Figure 2a). Plants treated with 5 μM Ce presented coloring of the bud in a shorter time (44.75 dap) compared to the control (46.25 dap) as observed in Figure 2b; as consequence, the period of anthesis was 1.14 days before than in the control plants (50.71 dap; Figure 2c). Meanwhile, in the plants that were exposed to 25 μM Ce, coloring of the flower bud (2.75 days; Figure 2b) and anthesis (3.29 days; Figure 2c) were delayed compared to the control plants.

In plants treated with Ce, the period of time to reach senescence was not different from the control, except in the plants treated with 25 μM Ce, where the period to reach senescence was prolonged on average in 4.28 days compared to control plants (57.14 dap) (Figure 3).

The duration of the flower was estimated by counting the days from the period of anthesis until senescence of the flower, that is, when the withering and fall of tepals happened. The doses of Ce of 5 and 25 μM prolonged the life of the flower in 1.15 and 1.05 days, respectively, compared to the control where the life of the flower was 6.42 days, although these increases were not significant (Figure 4).

DISCUSSION

In this study, the application of the different doses of Ce in the nutrition solution stimulated the emergence of the bulbs, advancing this process 2 days compared with the control (8 dap); however, only the low dose of Ce (5 μM) affected positively the formation of the flower bud, and therefore promoted the early coloration and flowering in tulip, although the period of time to reach senescence was equal to the that of the control plants. Contrasting results were obtained in plants treated with 25 μM of Ce, where all the phases evaluated were delayed compared to the control and the period to reach senescence was longer. The reason why the low dose of Ce stimulates the emergence of the bulbs and advances the flowering period is probably that Ce

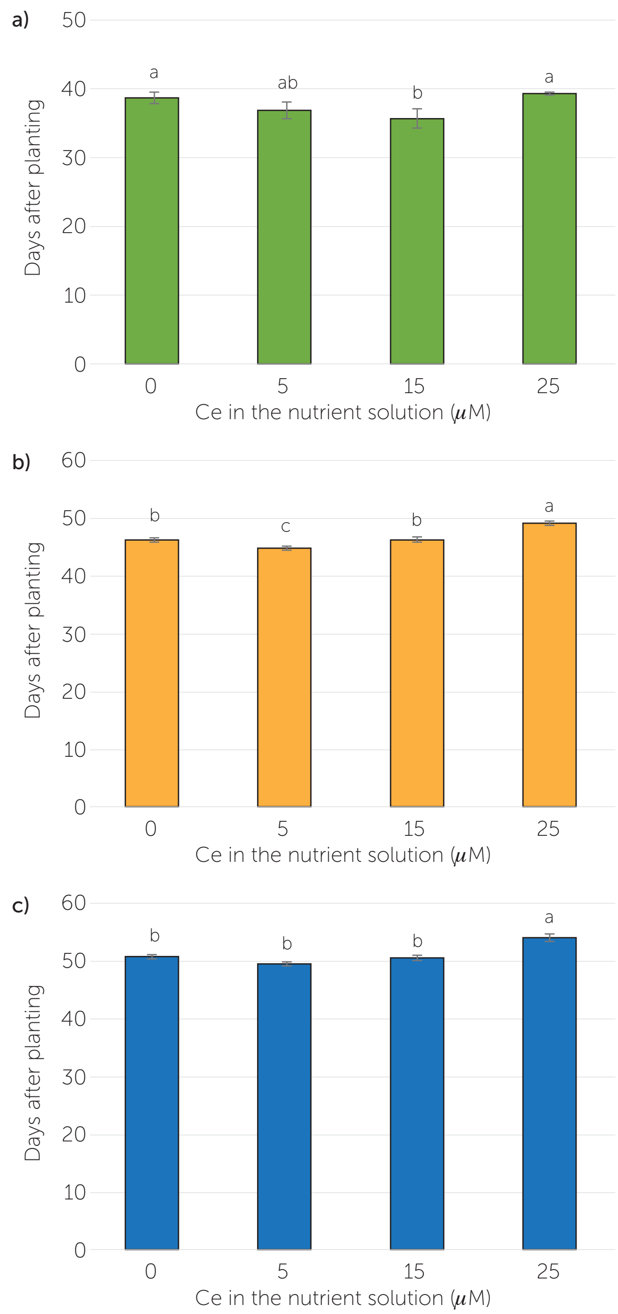

Figure 2. Flower bud formation (a), bud coloration (b) and anthesis (c) in tulip plants treated with different concentrations of Ce in the nutrient solution during the productive cycle. Means ± SD with different letters in each subfigure indicate significant differences (Tukey, p≤0.05). n=8.

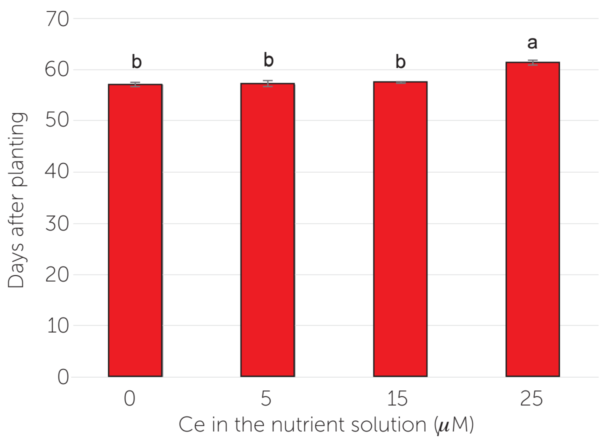

Figure 3. Senescence of tulip plants treated with different concentrations of Ce in the nutrient solution during the productive cycle. Means ± SD with different letters indicate significant differences (Tukey, p≤0.05). n=8.

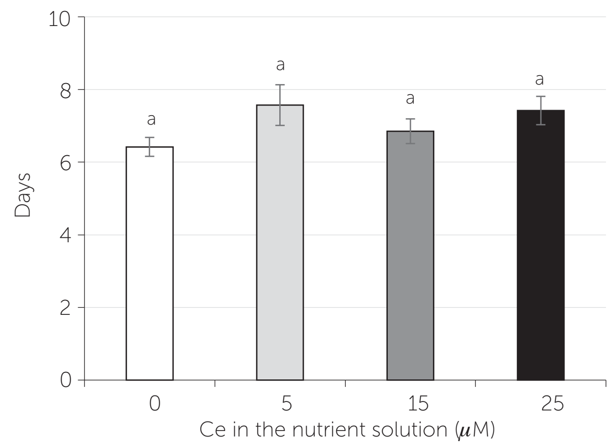

Figure 4. Duration of the flower in tulip plants treated with different concentrations of Ce in the nutrient solution during the productive cycle. Means ± SD with different letters indicate significant differences (Tukey, p≤0.05). n=8.

is related to some plant hormone that favors these processes.

The moment of transition of plant growth to flowering is important in agriculture. Flowering is regulated by a complex network of genes that integrate multiple environmental signs and endogenous signs for flowering to take place in the adequate moment; hormonal regulation, signaling and homeostasis are very important in this process (Galvão and Schmid, 2014; Campos-Rivero *et al*., 2017). In tulip, endogenous plant hormones that are related directly with bulb emergence and flowering are gibberellins (Cocozza-Talia and Stellacci, 1979). In various studies it has been found that the production of plant hormones can be affected by the presence of REE; in some cases, REE can act synergically with some plant hormones that can stimulate germination and flowering (He and Loh, 2002; Wang *et al*., 2014; Wang *et al*., 2015; Ramos *et al*., 2016). Despite this, it is not completely clear whether REE are directly involved with the signaling of plant hormones; likewise, the responses of stimulus or inhibition of plant hormones are variable between species and different REE (Wang *et al*., 2015). In *Arabidopsis* plants, La interacts with the signal from abscisic acid (ABA) on root growth, in addition to a concentration of 10 μmol La^{+3} L^{-1} which increases the rate of seed germination when these are inhibited by ABA (Wang *et al*., 2014). In *Dendrobium densiflorum* plant, the application of 5 μmol Nd^{+3} L^{-1} significantly increased the level of endogenous indole-3-acetic acid (IAA) and the rate of IAA and cytokinins during the formation process of the root primordium, which favored the rooting of cuttings (Luo *et al*., 2008). In *Arabidopsis thaliana*, low concentrations of Ce (0.5-10.0 μM) significantly stimulated flowering and the number of flowers per plant, which is why it was considered that Ce and other rare earth elements can have a potential to develop as non-hormonal flowering promoting agents for certain kinds of crops (He and Loh, 2000). He and Loh (2002) pointed out that these responses were related with a higher production of endogenous cytokinins in the plant, which is why they suggested that REE have a synergic effect with this plant hormone.

On the other hand, the duration of the potted flower was prolonged 1.15 and 1.05 days with a dose of Ce of 5 and 25 μM, respectively, in comparison to the control (6.42 days), although these increases were not statistically significant.

CONCLUSION

It is concluded that the application of 5 μM Ce has a positive effect on the growth, development and reproductive parameters of tulip, when stimulating the emergence of the bulb, formation of the flower bud, coloration, and advancing the flowering period.

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The melliferous flora of Veracruz, Mexico

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ABSTRACT

Objective: To contribute to the knowledge of the situation of the melliferous flora in Veracruz for pollinators and to communicate it for the benefit of beekeepers and stingless beekeepers, as well as to develop comprehensive strategies with these activities.

Design/Methodology/Approach: The information was obtained through a bibliographic review in reference databases such as Scopus, Web of Science Group, Academic Google, Elsevier and Springer Link, using the following keywords: flora, bees, pollinators, honey, pollen.

Results: 63 families were recorded, with 176 genera and 216 species of melliferous flora, finding that the largest number of species are found in the Fabaceae family (20%) and Asteraceae (16.55%). There were also 44 crops with 22 families.

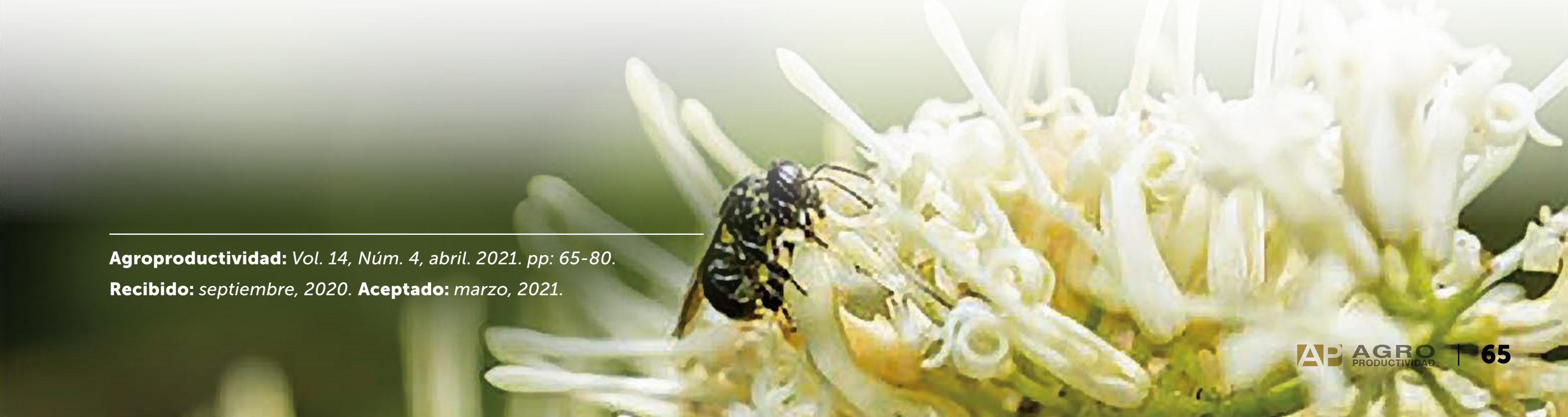
Study Limitations/Implications: There were no limitations in conducting this study.

Findings/Conclusions: The greatest diversity of melliferous flora species is related to wild plants, and strategies need to be implemented for their protection and multiplication. For these actions, various actors must be involved at different levels of government, educational and private institutions, civil society, farmers, beekeepers, and stingless beekeeping. Conservation actions include the use of melliferous plants in gardens and their protection in crops, sites surrounding crops and on edges. It is necessary to preserve natural landscapes and restore damaged ones, as well as to lead favorable practices in pollinator-dependent crops.

Keywords: flora, bees, pollinators, honey, pollen.

INTRODUCTION

Bees maintain a close relationship with melliferous flora, since they depend on them for their food, when consuming nectar and pollen obteined from the flowers. Likewise, they also collect resinous material that they use for the construction of their nest and for the elaboration of propolis, which serve as protection against pathogens and predators (Bonet and Vergara, 2016).



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Melliferous flora or honey flora is made up of plants that produce resins or whose flowers produce nectar and/or pollen; it is classified into polliniferous, nectariferous or pollen-nectariferous (Montoya-Bonilla *et al*., 2017). In exchange for food or resins that the bees receive from wild and cultivated plants, they pollinize their flowers thus favoring the formation of fruits that serve as food for human beings and other animals, contributing with this to food security and ecological equilibrium of ecosystems (Alquisira-Ramírez, 2019).

The availability of flower resources for the development and reproduction of bee colonies is required during the whole year. This is achieved through short flowering periods that most agricultural crops have, as well as native plants of the Asteraceae and Fabaceae families, which are important to feed the populations of bees and other pollinators because they are the most visited (González-Suárez *et al*., 2020).

The conservation and multiplication of melliferous flora is of huge interest for beekeepers and meliponiculture producers, because they ensure the production and quality of honey from their bee colonies (Araujo-Mondragón and Redonda-Martínez, 2019). In order to achieve this, the following strategies have been applied: use of melliferous plants in agroecologic gardens, or else interspersed in the crops or on the edges of the paths (Kremen and M'Gonigle, 2015; Landaverde-González *et al*., 2017).

The implementation of conservation strategies for both melliferous flora and pollinators is vital, since the absence or decline of the populations of any of them can impact their survival, in addition to reducing the production of fruits and seeds, which will have an environmental, social and economic impact globally (Hipólito *et al*., 2016; Wilson *et al*., 2017).

Therefore, the objective of this study was to understand the situation of the melliferous flora of the state of Veracruz, Mexico, through a bibliographic review with the aim of broadening knowledge about the available flower resources for pollinators, in addition to contributing with this information to beekeepers and meliponiculture producers to develop integral strategies in these activities.

MATERIALS AND METHODS

The information of melliferous flora of the state of Veracruz, Mexico, was obtained through the bibliographic review of the reference databases Scopus, Web of Science Group, Academic Google, Elsevier and Springer Link, using the following keywords: flora, bees, pollinators, honey, pollen. The information was systematized assigning categories of use, phenology, taxonomy and biology, in the following way: family, scientific name, resource that bees are supplied with —nectar or pollen—, flowering period, status —whether native, exotic or naturalized—, and life form; in the case of crops pollinated by bees, the common name was added.

RESULTS AND DISCUSSION

Flora in Mexico

In Mexico there is a record of 23,314 species of vascular plants, among which 2,854 genera, 297 families and 73 orders were included; in this flora there are 149 gymnosperms and 22,126 angiosperms (Ulloa *et al*., 2017; Villaseñor, 2016). The state of Veracruz occupies the third place in floristic richness of the country (Martínez-Adriano *et al*., 2016), divided into 271 families, 1,956 genera and 8,497 species (Villaseñor, 2016).

Despite the great floristic richness of Veracruz, it is primarily threatened by deforestation, as shown in a study carried out by Von *et al*. (2021), in three regions of the state of Veracruz from 2003 to 2013, in the region of the Tuxtlas, with a loss of natural plant coverage of 4.6% (3,516 ha), the old Antigua with 2% (1,634 ha) and Sierra de Otontepec with 1.4% (618 ha). This deforestation also causes fragmentation of habitats, loss of soil fertility, loss of biodiversity, and reduction of environmental services (Ramírez-Bravo and Hernández-Santin, 2016).

Additionally, erosion and genetic loss were caused by the loss of biodiversity, since angiosperms present reduced germination and progeny of lower quality (Aguilar *et al*., 2019), because of the loss of biological corridors for their pollinators (Gómez-Pompa *et al*., 2010), which has the consequence of smaller, scarce and isolated populations at the local scale, landscape and regional, with which their probability of extinction increases (Auffret *et al*., 2017).

Bee-Plant Ecological Interactions

Bees have evolved with plants and present a complex network of inter-specific interactions where sight, smell, moisture detection, contact and weak electrostatic field between a flower and a bee are involved; through these interactions flowers use bees as vehicles for the transport of pollen for fertilization (Thakur and Nanda, 2020), and the bees benefit from nectar and pollen as sources of food that plants provide, thus establishing an ecological relationship between them known as mutualism. Therefore, bees are attracted by the nectar which is an aqueous substance, rich in sugars, which contributes carbohydrates as main source of energy for the bees. During nectar collection, bees transport pollen from the anthers to the stigma of the plants, thus benefiting a large number of species of angiosperms (Castellanos-Potenciano *et al*., 2012).

Bees, in addition to nectar, use the pollen that they find in the anthers (apical part) of the stamens, both in angiosperms and in gymnosperms; during their visits, foraging bees attract these grains of pollen through the generation of a weak electrostatic field generated between the flower (with negative charge) and the bee's body (positive charge) (Clarke *et al*., 2017).

The way in which the bees harvest pollen from the flowers is by scraping or licking the anther and then sticking it on the carbuncle (cavity that is found in the tibia of the third pair of legs), using nectar to stick the pollen and thus transport it, accumulating it in form of granules; then, they take it to their nest and, generally, they deposit it around the breeding area where the larvae are developing, since it is the protein source for larvae and adults, containing between 10 and 40% of protein (Leonhardt *et al*., 2007; Vossler, 2015).

Pollen is an indicator that allows understanding the botanical and geographic characteristics of beekeeping products such as honey (Stephen, 2014; Thakur and Nanda, 2020). In addition, bees collect resins from some plants for the production of propolis, which they use as building material and defensive substance (Bankova *et al*., 2018).

The interactions that happen between plant and pollinator play an important role in the structure of communities, in addition to determining the diversity, wealth and persistence of species in a specific locality (Martínez-Adriano *et al*., 2018). Entomopalynology studies pollen found in the body or in the intestine of insects and provides information about the migration routes and their feeding, in addition to defining the pollination mechanisms and the foraging resources. Another important research area is Melissopalynology, which studies the botanical and geographic origin of honey, through the analysis of pollen in honey (Stephen, 2014). In palynological studies, there are records that bees, particularly *Apis mellifera*, visit approximately 2,000 plant species (Cadena *et al*., 2019).

Melliferous Plant Species in Veracruz, Mexico

Based on the information gathered through scientific search engines, an inventory of 63 families were obtained, with 176 genera and 216 species of melliferous flora in the state of Veracruz, Mexico. The families that present the highest number of genera are Fabaceae with 20%, and Asteraceae with 16.55%, the same as the highest number of species (Fabaceae 22.58% and Asteraceae 15.59%) (Table 1, Annex 1), as mentioned by González-Suárez *et al*. (2020).

Most of the species of melliferous flora reported for the state of Veracruz are native (85.65%), exotic species contribute 10.19% and naturalized 4.17%. Concerning their life form, 37.04% are trees, 33.80% are herbaceous, 24.07% shrubs, 2.31% arborescent, 2.31% vines, and 0.46% liana. Most of the species of melliferous flora are nectar-producing (37.96%), followed by pollen-producing (32.87%) and, in lower numbers, there are pollen-nectariferous (29.17%) (Figure 1).

The Asteraceae family is one of the most diverse plant families in Mexico, with around 392 genera and approximately 3,005 species; several of its species are of interest to beekeepers (Cadena *et al*., 2019), so they are considered as a nectar-polliniferous family. The

Table 1. The most representative melliferous flora families of Veracruz, Mexico.

Family	Genus	%	Species	%
Asteraceae	24	16.55	29	15.59
Combretaceae	4	2.76	4	2.15
Commelinaceae	4	2.76	4	2.15
Convolvulaceae	3	2.07	6	3.23
Euphorbiaceae	6	4.14	7	3.76
Fabaceae	29	20	42	22.58
Lamiaceae	6	4.14	9	4.84
Malvaceae	8	5.52	10	5.38
Myrtaceae	4	2.76	5	2.69
Poaceae	4	2.76	5	2.69
Rubiaceae	4	2.76	4	2.15
Sapindaceae	7	4.83	8	4.30
Verbenaceae	4	2.76	4	2.15

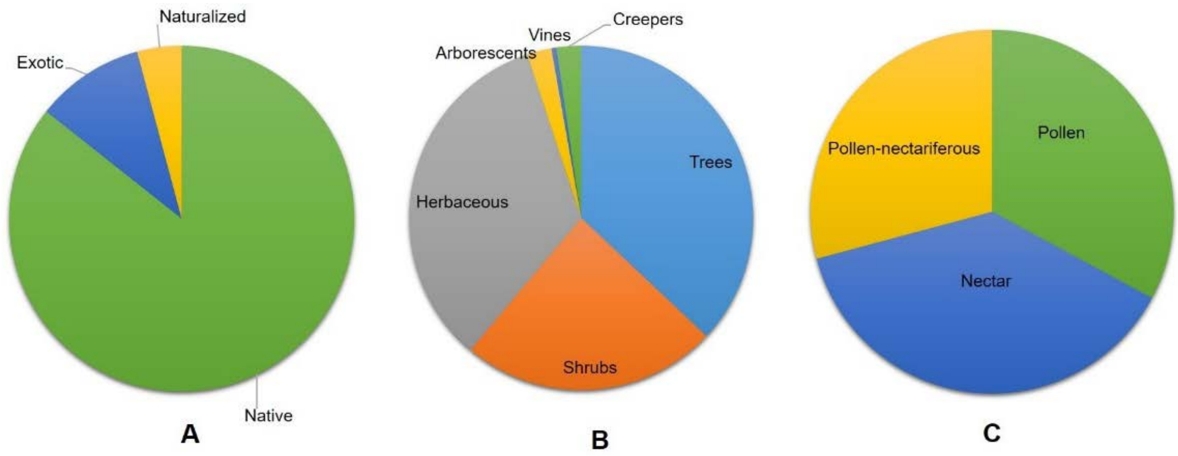

Figure 1. Main characteristics of melliferous flora: A) Status, B) Life form and C) Resource offered to pollinators.

Fabaceae family is also one of the most important in Mexico, since it presents 139 genera and 1,850 species (Ramírez-Arriaga *et al*., 2016).

On the other hand, there is a record of 44 plant species that are cultivated and visited by bees to obtain their food; these crops belong to 23 botanical families, of which 43.18% are nectariferous and the same percentage are also pollen-nectariferous, and only 9.09% are polliniferous (Annex 2, Figure 2).

The crops that depend on pollination are soybean, coffee, tomato and orange; the importance of pollinators in agricultural crops is that they improve the yield and quality of the seeds and fruits, so this service presents a social and economic impact (Giannini *et al*., 2020); however, some of the crops only provide food to pollinators during a few weeks, that is, during a short period, and then they must survive a long scarcity, and although some may migrate, social pollinators require accessible floral resources throughout the year for survival of the colony. For that, wild melliferous flora can provide food and nesting sites, so changes must be made in agricultural practices to foster biodiversity and restore, at least to a certain degree, the complexity of the ecosystem, as well as its functionality and sustainability (Kevan and Silva, 2020).

On the other hand, regional and local crops could depend on more

Figure 2. Crops pollinated by bees: A) *Persea americana* Mill., B) *Citrus limon* (L.) Osbeck, C) *Macadamia integrifolia* Maiden & Betche D) *Byrsonima crassifolia* (L.) Kunth, E) *Capsicum annuum* L. y F) *Zea mays* L. Photographs: Diana Caballero Alvarado.

specialized pollinators, although more research in this regard is required, particularly in small-scale agriculture, since this benefits the local and regional economy, in addition to this knowledge being important in local communities (Giannini *et al*., 2020).

Beekeeping and meliponiculture are important activities thanks to the pollination service that they provide, in addition to the products that bees provide to human beings, such as honey, pollen, wax and propolis, which arise directly or indirectly from the melliferous flora from which working bees feed (Kevan and Silva, 2020).

CONCLUSIONS

In Veracruz there is a great richness of melliferous flora represented by 215 wild plant species, the vast majority of species belong to Fabaceae (20%) and Asteraceae (16.55%). There were also 44 crops detected that provide pollen and nectar to the bees.

The bibliographic references analyzed in this study report that melliferous flora is represented essentially by wild plants, which tend to be eliminated because they are considered weeds. Due to the importance of this type of plants in the life of bees, it is necessary to implement strategies for their protection and reproduction. These actions involve various actors at different levels of government, educational and private institutions, as well as in civil society, although especially farmers, beekeepers and meliponiculture producers. Among the actions for conservation of melliferous flora, the use of melliferous plants in garden design stands out, both in urban and in rural zones in places next to the crops or edges, whether of crops, paths, forests, etc. It is necessary to conserve natural landscapes and restore those damaged by agriculture and livestock activities, as well as using favorable practices for bees in agriculture, primarily for the crops on which these pollinators depend.

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Appendix 1. Melliferous flora in Veracruz state, Mexico

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Acanthaceae	*Avicennia germinans* (L.) L.	X	X	April-July	Native	Tree	Castellanos-Potenciano *et al.* (2012);Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Bravaisia integerrima (Spreng.) Standl.		X	January-April	Native	Tree	Villegas *et al.* (2000)
Altingiaceae	*Liquidambar* sp.	X		January-March	Native	Tree	Niembro-Rocas *et al.* (2015); Ramírez-Arriaga *et al.* (2018)
Amaranthaceae	*Chamissoa altissima* (Jacq.) Kunth		X	February-April	Native	Shrub	Villegas *et al.* (2000)
	Dysphania ambrosioides (L.) Mosyakin & Clemants	X		April-December	Native	Herbaceous	Contreras-Oliva *et al.* (2018)
	Iresine diffusa Humb. & Bonpl. ex Willd.	X			Native	Herb	Bonet y Vergara (2016)
Anacardiaceae	*Spondias mombin* L.	X		April-May	Native	Tree	Castellanos-Potenciano *et al.* (2012); Contreras-Oliva *et al.* (2018); Niembro-Rocas *et al.* (2010)
Apocynaceae	*Asclepias curassavica* L.		X	May-August	Native	Herbaceous	Villegas *et al.* (2000)
	Plumeria rubra L.	X	X	March-September	Native	Tree	Villegas *et al.* (2000)
	Tabernaemontana citrifolia L.		X	February-April	Native	Shrub	Villegas *et al.* (2000)
Araliaceae	*Dendropanax arboreus* (L.) Decne. & Planch.	X	X	December-August	Native	Tree	Contreras-Oliva *et al.* (2018); Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Oreopanax sp.	X		September-December	Native	Tree	Ramírez-Arriaga *et al.* (2018)
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.		X	March-September	Native	Arborescent	Villegas *et al.* (2000)
	Attalea butyracea (Mutis ex L. f.) Wess. Boer		X	January-May	Native	Arborescent	Villegas *et al.* (2000)
	Sabal mexicana Mart.	X	X	December-April	Native	Arborescent	Villegas *et al.* (2000)
Asparagaceae	*Echeandia albiflora* (Schltdl. & Cham.) M. Martens & Galeotti	X		March-June	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari y Espejo (1995)
	Nolina parviflora (Kunth) Hemsl.		X	January-March	Native	Arborescent	Villegas *et al.* (2000)
	Yucca gigantea Lem.		X	January-April	Native	Arborescent	Villegas *et al.* (2000)
Asteraceae	*Achillea millefolium* L.	X		May-November	Native	Herbaceous	Villegas *et al.* (2000)
	Ageratum houstonianum Mill.	X		All year	Native	Herbaceous	Villegas *et al.* (2000)
	Ambrosia peruviana Willd.	X	X	May-July	Native	Herbaceous	Villegas *et al.* (2000)
	Baccharis conferta Kunth		X	January-March	Native	Shrub	Villegas *et al.* (2000)
	Baccharis trinervis (Cham.) Pers.	X	X	January-March	Native	Shrub	Villegas *et al.* (2000)
	Baltimora recta L.	X	X	July-September	Native	Herbaceous	Villegas *et al.* (2000)
	Barkleyanthus salicifolius (Kunth) H. Rob & Brettell	X	X	January-March	Native	Shrub	Villegas *et al.* (2000)
	Bidens pilosa L.	X	X	September-January	Native	Herbaceous	Contreras-Oliva *et al.* (2018); Parra-Tabla *et al.* (2019); Villegas *et al.* (2000)
	Bidens reptans (L.) G. Don		X	All year	Native	Herbaceous	Villegas *et al.* (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Asteraceae	*Bidens triplinervia* Kunth	X	X	December-March	Native	Herbaceous	Villegas *et al.* (2000)
	Chromolaena odorata (L.) R.M. King & H. Rob.		X	September-December	Native	Shrub	Villegas *et al.* (2000)
	Elephantopus mollis Kunth	X			Native	Herbaceous	Bonet y Vergara (2016)
	Helianthus sp.	X			Native	Herbaceous	Contreras-Oliva *et al.* (2018)
	Heliopsis buphthalmoides (Jacq.) Dunal	X			Native	Herbaceous	Bonet y Vergara (2016)
	Melampodium divaricatum (Rich.) DC.	X	X	August-December	Native	Herbaceous	Villegas *et al.* (2000)
	Montanoa grandiflora Alamán ex DC.	X	X	January-March	Native	Shrub	Villegas *et al.* (2000)
	Parthenium fruticosum Less.	X			Native	Shrub	Contreras-Oliva *et al.* (2018)
	Pluchea odorata (L.) Cass		X	September-December	Native	Shrub	Villegas *et al.* (2000)
	Sanvitalia procumbens Lam.	X		August- January	Native	Herbaceous	Villegas *et al.* (2000)
	Simsia amplexicaulis (Cav.) Pers.	X	X	September-December	Native	Herbaceous	Hernández-Villa *et al.* (2020) Villegas *et al.* (2000)
	Simsia eurylepis S. F. Blake	X	X	October-December	Native	Herbaceous	Villegas *et al.* (2000)
	Smallanthus maculatus (Cav.) H. Rob.	X		August-October	Native	Herbaceous	Bonet y Vergara (2016)
	Tithonia tubiformis (Jacq.) Cass.	X	X	December-March	Native	Herbaceous	Hernández-Villa *et al.* (2020) Villegas *et al.* (2000)
	Tridax procumbens L.	X	X	December-March	Native	Herbaceous	Villegas *et al.* (2000)
	Verbesina sp.	X			Native	Shrub	Contreras-Oliva *et al.* (2018)
	Vernonia sp.	X			Native	Herbaceous	Contreras-Oliva *et al.* (2018)
	Vernonanthura patens (Kunth) H. Rob.		X	January-April	Native	Shrub	Villegas *et al.* (2000)
	Viguiera dentata (Cav.) Spreng.	X	X	August-December	Native	Herbaceous	Gónzalez(2014) Villegas *et al.* (2000)
	Viguiera grammatoglossa D. C.		X	August-February	Native	Shrub	Villegas *et al.* (2000)
Balsaminaceae	*Impatiens walleriana* Hook. f.	X		January-June	Naturalized	Herbaceous	Bonet y Vergara(2016)
Berberidaceae	*Berberis trifolia* Schult. & Schult. f.		X	January-March	Native	Shrub	Villegas *et al.* (2000)
Bignoniaceae	*Handroanthus chrysanthus* (Jacq.) S. O. Grose	X	X	January-March	Native	Tree	Villegas *et al.* (2000)
	Tabebuia rosea (Bertol.) DC.	X	X	February-April	Native	Tree	Niembro-Rocas *et al.* (2010; Villegas *et al.* (2000)
	Tecoma stans (L.) Juss. ex Kunth		X	All year	Native	Shrub	Canto *et al.* (2017) Villegas *et al.* (2000)
Bixaceae	*Cochlospermum vitifolium* (Willd.) Spreng.		X	December-May	Native	Tree	Niembro-Rocas *et al.*, (2010; Villegas *et al.* (2000)
Boraginaceae	*Cordia alliodora* (Ruiz & Pav.) Oken	X	X	August-April	Native	Tree	Contreras-Oliva *et al.* (2018); Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Cordia dentata Poir.		X	All year	Native	Tree	Villegas *et al.* (2000)
	Cordia megalantha S.F. Blake	X		February-May	Native	Tree	Villegas *et al.* (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Brassicaceae	*Brassica rapa* L.	X	X	May-December	Naturalized	Herbaceous	Villegas *et al.* (2000)
	Brassica nigra (L.) W.D.J. Koch	X		December-February	Naturalized	Herbaceous	Villegas *et al.* (2000)
	Raphanus raphanistrum L.	X	X	September-May	Exotic	Herbaceous	Villegas *et al.* (2000)
Burseraceae	*Bursera simaruba* (L.) Sarg.	X	X	February-August	Native	Tree	Contreras-Oliva *et al.* (2018); Herrera-López *et al.* (2019); Villegas *et al.* (2000)
Cactaceae	*Cilindropuntia imbricata* (Haw.) F.M. Knuth	X	X	January-April	Native	Shrub	Villegas *et al.* (2000)
	Opuntia huajuapensis Bravo	X	X	February-May	Native	Shrub	Villegas *et al.* (2000)
	Opuntia stricta (Haw.) Haw.	X	X	February-April	Native	Shrub	Villegas *et al.* (2000)
Campanulaceae	*Lobelia xalapensis* Kunth	X		January-April	Native	Herbaceous	Bonet y Vergara (2016)
Cannabaceae	*Trema micrantha* (L.) Blume		X	February-April	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
Chloranthaceae	*Hedyosmum mexicanum* C. Cordem.	X			Native	Shrub	Ramírez-Arriaga *et al.* (2018)
Combretaceae	*Combretum farinosum* Kunth		X	December-March	Native	Vine	Villegas *et al.* (2000)
	Conocarpus erectus L.	X	X	April-June	Native	Tree	Parra-Tabla *et al.* (2019) Villegas *et al.* (2000)
	Laguncularia racemosa (L.) C.F. Gaertn.		X	February-May	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Terminalia catappa L.		X	February-March	Naturalized	Tree	Villegas *et al.* (2000)
Commelinaceae	*Commelina diffusa* Burm. f.	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari *et al.* (2014)
	Gibasis pellucida (M. Martens & Galeotti) D.R. Hunt	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari *et al.* (2014)
	Tinantia erecta (Jacq.) Schltdl.	X		August-November	Native	Herbaceous	Bonet y Vergara, 2016; Hernández-Villa *et al.*, 2020
	Tripogandra serrulata (Vahl) Handlos	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari *et al.* (2014)
Convolvulaceae	*Convolvulus nodiflorus* Desv.	X	X	May-December	Native	Herbaceous	Villegas *et al.* (2000)
	Ipomoea arborescens (Humb. & Bonpl. ex Willd.) G. Don		X	December-March	Native	Tree	Villegas *et al.* (2000)
	Ipomoea carnea subsp. fistulosa (Mart. ex Choisy) D.F. Austin		X	November-May	Native	Shrub	Villegas *et al.* (2000)
	Ipomoea indica (Burm.) Merr.	X		All year	Native	Vine	Bonet y Vergara (2016)
	Ipomoea triloba L.		X	October-February	Native	Herbaceous	Canto *et al.* (2017) Villegas *et al.* (2000)
	Merremia dissecta (Jacq.) Hallier f.	X	X	All year	Native	Vine	Canto *et al.* 2017) Villegas *et al.* (2000)
Crassulaceae	*Sedum praealtum* A. DC.		X	January-February	Native	Herbaceous	Villegas *et al.* (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Cucurbitaceae	*Luffa aegyptiaca* Mill.		X	All year	Exotic	Vine	Villegas *et al.* (2000)
	Momordica charantia L.	X	X	All year	Exotic	Vine	Villegas *et al.* (2000)
	Sicyos microphyllus Kunth		X	September-December	Native	Herbaceous	Villegas *et al.* (2000)
Cyperaceae	*Rhynchospora radicans* (Schltdl. & Cham.) H. Pfeiff.	X			Native	Herbaceous	Bonet y Vergara (2016)
Ehretiaceae	*Ehretia anacua* (Terán & Berland.) I.M. Johnst.		X	April-December	Native	Tree	Villegas *et al.* (2000)
	Ehretia tinifolia M. Martens & Galeotti		X	February-July	Native	Tree	Villegas *et al.* (2000)
Euphorbiaceae	*Alchornea latifolia* Sw.	X		December-April	Native	Tree	Niembro-Rocas *et al.* (2010); Ramírez-Arriaga *et al.* (2018)
	Cnidoscolus multilobus (Pax) I.M. Johnst.	X	X	December-March	Native	Shrub	Villegas *et al.* (2000)
	Croton draco Schltdl. & Cham.		X	October-February	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Croton reflexifolius Kunth		X	February-April	Native	Shrub	Villegas *et al.* (2000)
	Euphorbia heterophylla L.	X			Native	Herbaceous	Bonet y Vergara (2016)
	Euphorbia schlechtendalii Boiss.		X	March-June	Native	Tree	Villegas *et al.* (2000)
	Ricinus communis L.	X	X	All year	Exotic	Shrub	Villegas *et al.* (2000)
Fabaceae	*Acacia* sp.	X			Native	Shrub	Ramírez-Arriaga *et al.* (2018)
	Vachellia cornigera (L.) Seigler & Ebinger	X	X	February-April	Native	Shrub	Villegas *et al.* (2000)
	Vachellia farnesiana (L.) Wight & Arn.	X	X	December-May	Native	Shrub	Villegas *et al.* (2000)
	Vachellia pennatula (Schltdl. & Cham.) Seigler & Ebinger	X	X	April-June	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Bauhinia divaricata L.	X	X	All year	Native	Shrub	Villegas *et al.* (2000)
	Caesalpinia cacalaco Bonpl.	X	X	November-February	Native	Tree	Villegas *et al.* (2000)
	Cajanus cajan (L.) Huth	X		September-February	Exotic	Shrub	Villegas *et al.* (2000)
	Cassia fistula L.	X		February-April	Exotic	Tree	Villegas *et al.* (2000)
	Cassia grandis L. f.	X		February-May	Native	Tree	Villegas *et al.* (2000)
	Chamaecrista sp.	X			Exotic	Shrub	Contreras-Oliva *et al.* (2018)
	Cojoba arborea (L.) Britton & Rose		X	January-March	Native	Tree	Villegas *et al.* (2000)
	Dalbergia brownei (Jacq.) Schinz		X	February-April	Native	Shrub	Villegas *et al.* (2000)
	Dalea botterii (Rydb.) Barneby		X	September-December	Native	Herbaceous	Villegas *et al.* (2000)
	Delonix regia (Bojer ex Hook.) Raf.		X	April-July	Naturalized	Tree	Villegas *et al.* (2000)
	Desmodium adscendens (Sw.) DC.	X			Native	Herbaceous	Contreras-Oliva *et al.* (2018)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Fabaceae	*Desmodium canescens* (L.) DC.	X		April-July	Exotic	Herbaceous	Bonet y Vergara (2016)
	Desmodium tortuosum (Sw.) DC.	X			Native	Herbaceous	Contreras-Oliva *et al.* (2018)
	Enterolobium cyclocarpum (Jacq.) Griseb.	X	X	March-May	Native	Tree	Niembro-Rocas *et al.*, (2010); Villegas *et al.* (2000)
	Eysenhardtia polystachya (Ortega) Sarg.	X	X	September-October	Native	Tree	Villegas *et al.* (2000)
	Gliricidia sepium (Jacq.) Kunth ex Walp.	X	X	December-April	Native	Tree	Niembro-Rocas *et al.* 2010: Villegas *et al.* (2000)
	Haematoxylum brasiletto H. Karst.	X	X	February-March	Native	Tree	Villegas *et al.* (2000)
	Haematoxylum campechianum L.	X	X	September-April	Native	Tree	Gónzalez, (2014) Villegas *et al.* (2000)
	Inga inicuil Schltdl. & Cham. ex G. Don	X	X	February-April	Native	Tree	Niembro-Rocas *et al.*(2010); Villegas *et al.* (2000)
	Inga vera Willd.	X	X	April-May	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Leucaena diversifolia (Schltdl.) Benth.	X		August-December	Native	Tree	Villegas *et al.* (2000)
	Leucaena lanceolata S. Watson	X			Native	Shrub	Villegas *et al.* (2000)
	Leucaena sp.	X			Native	Tree	Ramírez-Arriaga *et al.* (2018)
	Lonchocarpus guatemalensis Benth.		X	February-May	Native	Tree	Villegas *et al.* (2000)
	Lonchocarpus sp.	X			Native	Tree	Ramírez-Arriaga *et al.* 2018)
	Lysiloma acapulcense (Kunth) Benth.	X	X	March-May	Native	Tree	Villegas *et al.* (2000)
	Mimosa albida Humb. & Bonpl. ex Willd.	X		August-November	Native	Shrub	Villegas *et al.* (2000)
	Mimosa pigra L.		X	March-July	Native	Shrub	Villegas *et al.* (2000)
	Mimosa pudica L.	X		September-November	Native	Herbaceous	Bonet y Vergara (2016)
	Mimosa scabrella Benth.	X		December-January	Exotic	Shrub	Villegas *et al.* (2000)
	Piscidia piscipula (L.) Sarg.	X	X	May-July	Native	Tree	Niembro-Rocas *et al.* (2010); Canto *et al.* (2017); Villegas *et al.* (2000)
	Pithecellobium dulce (Roxb.) Benth.	X	X	November-May	Native	Shrub	Niembro-Rocas *et al.* (2010); Contreras-Oliva *et al.* (2018); Villegas *et al.* (2000)
	Pithecellobium insigne Micheli ex Donn. Sm.	X	X	January-March	Native	Tree	Villegas *et al.* (2000)
	Prosopis juliflora (Sw.) DC.	X	X	January-April	Native	Tree	Villegas *et al.* (2000)
	Trifolium repens L.	X	X	All year	Naturalized	Herbaceous	Villegas *et al.* (2000)
	Vachellia pringlei (Rose) Seigler & Ebinger	X	X	February-may	Native	Tree	Villegas *et al.* (2000)
	Verbesina turbacensis Kunth	X	X	November-January	Native	Shrub	Villegas *et al.* (2000)
	Vicia sativa L.		X	January-March	Native	Herbaceous	Villegas *et al.* (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Fagaceae	*Quercus* sp.	X		June	Native	Tree	Ramírez-Arriaga *et al.* (2018)
Hypoxidaceae	*Hypoxis decumbens* L.	X			Native	Herbaceous	Bonet y Vergara(2016)
Juglandaceae	*Juglans pyriformis* Liebm.	X		February-March	Native	Tree	Villegas *et al.* (2000)
Lamiaceae	*Hyptis mutabilis* (Rich.) Briq.		X	August-December	Exotic	Herbaceous	Villegas *et al.* (2000)
	Hyptis suaveolens (L.) Poit.		X	August-October	Native	Herbaceous	Villegas *et al.* (2000)
	Marrubium vulgare L.		X	February-May	Naturalized	Herbaceous	Villegas *et al.* (2000)
	Marsypianthes chamaedrys (Vahl) Kuntze	X			Native	Herbaceous	Bonet y Vergara (2016)
	Mentha × *piperita* L.		X	June-October	Exotic	Herbaceous	Villegas *et al.* (2000)
	Ocimum sp.	X			Native	Herbaceous	Ramírez-Arriaga *et al.* (2018)
	Salvia albiflora M. Martens & Galeotti	X			Native	Herbaceous	Bonet y Vergara (2016)
	Salvia purpurea Cav.		X	September-January	Native	Herbaceous	Villegas *et al.* (2000)
	Salvia rubiginosa Benth.		X	September-January	Native	Shrub	Villegas *et al.* (2000)
Lauraceae	*Nectandra ambigens* (S.F. Blake) C.K. Allen		X	February-May	Native	Tree	Villegas *et al.* (2000)
Lythraceae	*Ginoria nudiflora* (Hemsl.) Koehne	X	X	November-May	Native	Tree	Villegas *et al.* (2000)
Malvaceae	*Ceiba aesculifolia* (Kunth) Britten & Baker f.		X	November-May	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Dombeya wallichii (Lindl.) Baill.		X	November-February	Exotic	Tree	Villegas *et al.* (2000)
	Hampea nutricia Fryxell		X	September-November	Native	Shrub	Villegas *et al.* (2000)
	Heliocarpus pallidus Rose	X		October-February	Native	Tree	Contreras-Oliva *et al.* (2018); Villegas *et al.* (2000)
	Heliocarpus appendiculatus Turcz.	X		December-March	Native	Tree	Ramírez-Arriaga *et al.* (2018)
	Malvaviscus arboreus Cav.	X	X	All year	Native	Shrub	Canto *et al.* (2017); Parra-Tabla *et al.* (2019) Villegas *et al.* (2000)
	Pachira aquatica Aubl.		X	All year	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Pseudobombax ellipticum (Kunth) Dugand	X	X	January-June	Native	Tree	Villegas *et al.* (2000)
	Sida acuta Burm. f.	X			Exotic	Shrub	Bonet y Vergara (2016)
	Sida rhombifolia L.	X		All year	Native	Herbaceous	Bonet y Vergara (2016)
Meliaceae	*Trichilia havanensis* Jacq.		X	December-April	Native	Tree	Niembro-Rocas *et al.*(2010); Villegas *et al.* (2000)
	Trichilia hirta L.		X		Native	Tree	Villegas *et al.* (2000)
Melastomataceae	*Miconia* sp.	X			Native	Herbaceous	Ramírez-Arriaga *et al.* (2018)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Muntingiaceae	*Muntingia calabura* L.		X	All year	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
Myrtaceae	*Callistemon citrinus* (Curtis) Skeels		X	December-April	Exotic	Shrub	Villegas *et al.* (2000)
	Eucalyptus globulus Labill.		X	May-July	Exotic	Tree	Villegas *et al.* (2000)
	Eugenia capuli (Schltdl. & Cham.) Hook. & Arn.	X			Native	Shrub	Contreras-Oliva *et al.* (2018)
	Eugenia mexicana Steud.	X	X	May-August	Native	Shrub	Villegas *et al.* (2000)
	Syzygium jambos (L.) Alston		X	February-July	Naturalized	Tree	Villegas *et al.* (2000)
Nyctaginaceae	*Pisonia aculeata* L.		X	January-April	Exotic	Shrub	Villegas *et al.* (2000))
Oleaceae	*Ligustrum lucidum* W. T. Aiton	X	X	March-June	Exotic	Tree	Villegas *et al.* (2000)
Onagraceae	*Lopezia hirsuta* Jacq.		X	November-January	Native	Herbaceous	Villegas *et al.* (2000)
Papaveraceae	*Argemone mexicana* L.	X	X	January-April	Native	Herbaceous	Villegas *et al.* (2000)
	Argemone platyceras Link & Otto	X	X	All year	Native	Herbaceous	Villegas *et al.* (2000)
Piperaceae	*Piper* sp.	X			Native	Shrub	Ramírez-Arriaga *et al.* (2018)
Platanaceae	*Platanus mexicana* Moric.	X		January-May	Native	Tree	Ramírez-Arriaga *et al.* (2018)
Poaceae	*Brachiaria plantaginea* (Link) Hitchc.	X		May-November	Native	Herbaceous	Bonet y Vergara (2016)
	Panicum sp.	X			Native	Herbaceous	Bonet y Vergara (2016)
	Paspalum conjugatum P.J. Bergius	X		All year	Native	Herbaceous	Bonet y Vergara (2016)
	Paspalum virgatum L.	X			Native	Herbaceous	Bonet y Vergara (2016)
	Pseudechinolaena polystachya (Kunth) Stapf	X			Native	Herbaceous	Bonet y Vergara (2016)
Polygonaceae	*Antigonon leptopus* Hook. & Arn		X	August-December	Native	Vine	Villegas *et al.* (2000)
	Coccoloba uvifera (L.) L.	X	X	February-April	Native	Shrub	Contreras-Oliva *et al.* (2018); Villegas *et al.* (2000)
Pontederiaceae	*Pontederia sagittata* C. Presl		X	January-March	Native	Herbaceous	Villegas *et al.* (2000)
Proteaceae	*Grevillea robusta* A. Cunn. ex R. Br.	X	X	March-April	Exotic	Tree	Villegas *et al.* (2000)
Resedaceae	*Reseda odorata* L.		X	September-December	Exotic	Herbaceous	Villegas *et al.* (2000)
Rhamnaceae	*Gouania lupuloides* (L.) Urb.		X	September-November	Native	Shrub	Villegas *et al.* (2000)
	Ziziphus sp.	X		June	Native	Shrub	Ramírez-Arriaga *et al.* (2018)
Rhizophoraceae	*Rhizophora mangle* L.		X	All year	Native	Tree	Villegas *et al.* (2000)
Rosaceae	*Prunus serotina* Ehrh.		X	January-March	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
Rubiaceae	*Calycophyllum candidissimum* (Vahl) DC.		X	October- January	Native	Tree	Villegas *et al.* (2000)
	Ixora coccinea L.		X	November-January	Exotic	Shrub	Villegas *et al.* (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Rubiaceae	*Murraya paniculata* (L.) Jack		X	April-June	Exotic	Tree	Villegas *et al.* (2000)
	Spermacoce confusa Rendle		X	September-December	Native	Herbaceous	Villegas *et al.* (2000)
Sapindaceae	*Acer negundo* L.	X		February-March	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Cupania sp.	X		August	Native	Tree	Ramírez-Arriaga *et al.* (2018)
	Sapindus saponaria L.		X	August-March	Native	Tree	Villegas *et al.* (2000)
	Serjania sp.	X			Native	Shrub	Contreras-Oliva *et al.* (2018)
	Serjania racemosa Schumach.		X	November-January	Native	Shrub	Villegas *et al.* (2000)
	Talisia oliviformis (Kunth) Radlk.		X	February-May	Native	Tree	Villegas *et al.* (2000)
	Thouinia paucidentata Radlk.	X			Native	Tree	Ramírez-Arriaga *et al.* (2018)
	Thouinidium decandrum (Bonpl.) Radlk.		X	February-April	Native	Tree	Villegas *et al.*, (2000)
Sapotaceae	*Manilkara zapota* (L.) P. Royen		X	June-October	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
	Pouteria sp.	X		May	Native	Tree	Contreras-Oliva *et al.* (2018); Niembro-Rocas *et al.* (2010)
Scrophulariaceae	*Buddleja cordata* Kunth	X	X	March-October	Native	Tree	Niembro-Rocas *et al.* (2010); Villegas *et al.* (2000)
Solanaceae	*Solanum rostratum* Dunal		X	May-September	Native	Herbaceous	Villegas *et al.* (2000)
	Solanum sp.	X			Native	Herbaceous	Contreras-Oliva *et al.* (2018)
Malvaceae	*Waltheria indica* L.		X	January-March	Native	Herbaceous	Villegas *et al.* (2000)
Urticaceae	*Cecropia peltata* L.		X	All year	Native	Tree	Villegas *et al.* (2000)
	Cecropia obtusifolia Bertol.	X		All year	Native	Tree	Ramírez-Arriaga *et al.* (2018)
Verbenaceae	*Aloysia virgata* (Ruiz & Pav.) Pers.		X	All year	Exotic	Shrub	Villegas *et al.* (2000)
	Lantana camara L.		X	All year	Native	Shrub	Villegas *et al.* (2000)
	Lippia myriocephala Schltdl. & Cham.		X	September-January	Native	Tree	Villegas *et al.* (2000)
	Phyla fruticosa (Mill.) K. Kenn. ex Wunderlin & B.F. Hansen		X	All year	Native	Herbaceous	Villegas *et al.* (2000)
Zygophyllaceae	*Tribulus cistoides* L.	X	X	September-March	Native	Herbaceous	Parra-Tabla *et al.* (2019) Villegas *et al.* (2000)
	Tribulus terrestris L.		X	January-April	Naturalized	Herbaceous	Villegas *et al.* (2000)

Appendix 2. Crops pollinated by bees in Mexico.

Family	Crop	Common name	Pollen	Nectar	Flowering	Status	Reference
Anacardiaceae	*Mangifera indica* L.	"mango"	X	X	November-March	Naturalized	Meléndez *et al.* (2018); Villegas *et al.* (2000)
	Spondias mombin L.	"jobo"		X	March-May	Native	Villegas *et al.* (2000)
	Spondias purpurea L.	"ciruelo"	X	X	December-March	Native	Villegas *et al.* (2000)
Arecaceae	*Cocos nucifera* L.	"cocotero"	X	X	All year	Naturalized	Castellanos-Potenciano *et al.* (2012); Meléndez *et al.* (2018); Ramírez-Arriaga *et al.* (2018); Villegas *et al.* (2000)
Asteraceae	*Helianthus annuus* L.	"girasol"	X	X	March-July	Native	Villegas *et al.* (2000)
Brassicaceae	*Brassica napus* L.	"canola"	X	X	September-December	Exotic	Villegas *et al.* (2000)
Caricaceae	*Carica papaya* L.	"papaya"	X	X	All year	Native	Badillo-Montaño *et al.* (2019) Villegas *et al.* (2000)
Convolvulaceae	*Ipomoea batatas* (L.) Lam.	"camote"	X	X	July-April	Native	Villegas *et al.* (2000)
Cucurbitaceae	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	"sandía"		X	All year	Exotic	Villegas *et al.* (2000)
	Cucurbita ficifolia Bouché	"calabaza"		X	May-August	Native	Villegas *et al.* (2000)
	Cucurbita maxima Duchesne	"calabaza"	X	X	May-August	Exotic	Villegas *et al.* (2000)
	Cucumis melo L.	"melón"		X	January-June	Exotic	Villegas *et al.* (2000)
	Cucurbita moschata Duchesne	"calabaza"	X			Native	(eléndez *et al.* (2018)
	Cucumis sativus L.	"pepino"	X	X	January-June	Exotic	Villegas *et al.* (2000)
	Sechium edule (Jacq.) Sw.	"chayote"		X	All year	Native	Villegas *et al.* (2000)
Ebenaceae	*Diospyros digyna* Jacq.	"zapote negro"		X	March-June	Naturalized	Villegas *et al.* (2000)
Euphorbiaceae	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.	"hule"		X	February-April	Exotic	Villegas *et al.* (2000)
Fabaceae	*Medicago sativa* L.	"alfalfa"		X	All year	Exotic	Villegas *et al.* (2000)
	Phaseolus coccineus L.	"ayocote" "frijol colorado"		X	September-October	Native	Villegas *et al.* (2000)
	Tamarindus indica L.	"tamarindo"		X	May-November	Naturalized	Villegas *et al.* (2000)
Lauraceae	*Persea americana* Mill.	"aguacate"		X	February-May	Native	Meléndez *et al.* (2018); Villegas *et al.* (2000)
Malpighiaceae	*Byrsonima crassifolia* (L.) Kunth	"nanche"	X	X	March-June	Native	Villegas *et al.* (2000)
Malvaceae	*Gossypium hirsutum* L.	"algodón"	X	X	August, February, May	Native	Canto *et al.* (2017)
Musaceae	*Musa paradisiaca* L.	"plátano"	X	X	All year	Naturalized	Villegas *et al.* (2000)
Myrtaceae	*Psidium guajava* L.	"guayaba"	X	X	April-June	Native	Villegas *et al.* (2000)
Poaceae	*Zea mays* L.	"maíz"	X	X	February-March, July-August	Native	Villegas *et al.* (2000)
Proteaceae	*Macadamia integrifolia* Maiden & Betche	"macadamia"		X	January-March	Exotic	Villegas *et al.* (2000)

Family	Crop	Common name	Pollen	Nectar	Flowering	Status	Reference
Rosaceae	*Crataegus mexicana* DC.	"tejocote"	X	X	March-May	Native	Villegas *et al.* (2000)
	Eriobotrya japonica (Thunb.) Lindl.	"níspero"		X	December-February	Naturalized	Villegas *et al.* (2000)
	Malus pumila Mill.	"manzana"	X	X	February-March	Exotic	Villegas *et al.* (2000)
	Prunus domestica L.	"ciruelo"	X	X	February-April	Exotic	Villegas *et al.* (2000)
	Prunus persica (L.) Batsch	"durazno"		X	February-April	Exotic	Villegas *et al.* (2000)
	Pyrus communis L.	"pera"		X	February-March	Exotic	Villegas *et al.* (2000)
	Rubus eriocarpus Liebm.	"zarzamora", "mora"		X	January-March	Native	Villegas *et al.* (2000)
Rubiaceae	*Coffea arabica* L.	"café"		X	April-June	Exotic	Ramírez-Arriaga *et al.* (2018); Villegas *et al.* (2000)
Rutaceae	*Casimiroa edulis* La Llave	"zapote blanco"		X	January-February	Native	Villegas *et al.* (2000)
	Citrus × *aurantiifolia* (Christm.) Swingle	"limón agrio"	X	X	All year	Exotic	Villegas *et al.* (2000)
	Citrus maxima (Burm.) Merr.	"toronja"	X	X	December-February	Exotic	Villegas *et al.* (2000)
	Citrus reticulata Blanco	"mandarina"		X	June-February	Exotic	Villegas *et al.* (2000)
	Citrus × *sinensis* (L.) Osbeck	"naranja"		X	June-February	Exotic	Villegas *et al.* (2000)
Sapindaceae	*Litchi chinensis* Sonn.	"lichi"	X	X	January-March	Exotic	Villegas *et al.* (2000)
	Nephelium lappaceum L.	"rambután"	X			Exotic	Meléndez *et al.* (2018)
Solanaceae	*Capsicum annuum* L.	"chile"	X		All year	Native	Meléndez *et al.* (2018); Villegas *et al.* (2000)
	Solanum lycopersicum L.	"jitomate"	X			Native	Meléndez *et al.* (2018)

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Evaluation of Surgical Castration *vs* Immunocastration in Fattening Pigs

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ABSTRACT

Objective: To determine the effect of surgical castration and immunocastration on productive parameters, carcass quality, as well as the physicochemical characteristics of the meat of fattening pigs.

Design/Metodology/Aproach: Ten male pigs of the York/Pietrain/Landrace breed with a body weight of 25±5 kg were used per treatment. They were housed in individual pens and fed diets according to their physiological state. The variables evaluated were analyzed with a student's t-test for independent samples.

Results: Results do not show differences (p>0.05) in the productive variables, quality of the carcass or physicochemical characteristics.

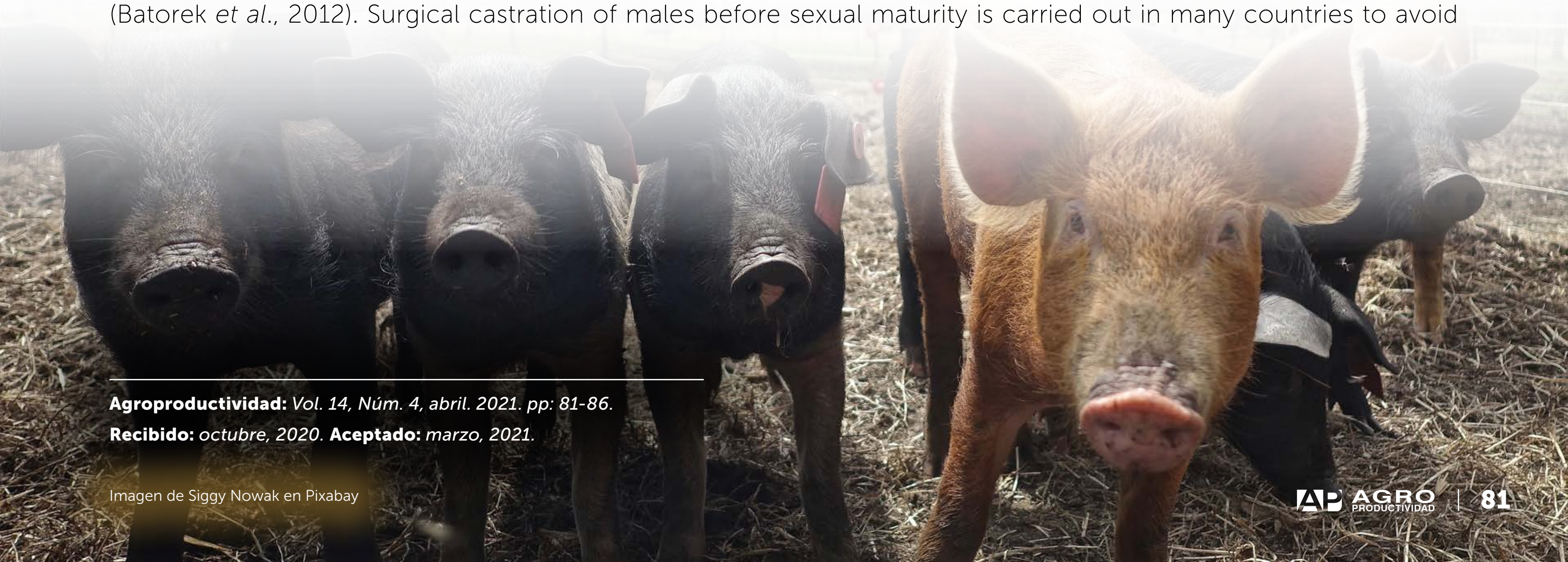
Study Limitations/Implications: The study did not consider qualitative variables such as flavor and smell of the treatments.

Findings/Conclusions: Immunocastration is an alternative to surgical castration since the quality of the carcass, the productive variables and the physicochemical characteristics of the meat are not affected, and it favors animal welfare.

Keywords: surgical castration, immunocastration, carcass quality, physicochemical characteristics.

INTRODUCTION

The odor and taste of pork meat is caused primarily by the accumulation of androstenone and skatole in the fatty tissue, which is a significant quality problem of the carcass of complete males (Clarke *et al*., 2008). There are two castration alternatives to raise fattening pigs and thus avoid meat contamination, which are surgical castration and immunocastration (Batorek *et al*., 2012). Surgical castration of males before sexual maturity is carried out in many countries to avoid



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bad odor and bad flavor, increase the content of dorsal fat, and prevent stress in the farmyard. However, the preoccupation over animal welfare has increased and it necessary to resort to other castration practices (Fàbrega *et al*., 2010). The surgical castration of young pigs is associated to a higher mortality from complications such as infections and hernias; in addition, this practice is criticized since it is generally practiced without anesthesia, causing pain and a significant increase in the concentration of serum cortisol that indicates stress (McGlone *et al*., 1993; Clarke *et al*., 2008). However, immunocastration allows improving animal welfare in pork production, avoiding them suffering pain, in addition to increasing the profitability from growth to the finalization period, which is why this technique provides good meat quality (Dunshea *et al*., 2013). The objective of immunocastration is to deactivate testicular function through the neutralization of the hormone from the hypothalamus-pituitary-gonadal axis (GnRH) (Oonk *et al*., 1998). For the effectiveness of the GnRH vaccine, two applications are necessary: the first dose prepares the pig's immune system without altering the size or the function of the testicles, and the second dose stimulates the immunoprotection response that inhibits the function of the testicles (Font-i-Fornols *et al*., 2012). Because of this, the objective of this study was to determine the effect of surgical castration and immunocastration on productive parameters (average daily gain, daily feed intake and feed conversion ratio), carcass quality (backfat thickness, Longissimus dorsi mulcle área, percentage of lean meat), as well as the physicochemical characteristics of meat (water holding capacity, pH and color) in fattening pigs.

MATERIALS AND METHODS

The study was performed in a pig farm located in the municipality of Tulancingo de Bravo, Hidalgo, Mexico (20° 05' N, 98° 22' W and 2160 m of altitude). The climate is semi-dry temperate, with mean annual temperature of 14 °C, and mean annual precipitation of 553 mm (INEGI, 2003).

The treatments were the following: T1 (surgically castrated males, SCM) and T2 (immunicastrated males, ICM); the study was divided into three experimental stages: 25-50, 50-75 and 75-100 kg of body weight (BW). The experimental units were 20 hybrid males (York×Pietrain ×Landrace) with average initial body weight (IBW) of 25±5 kg, with ten pigs per treatment. The pigs were housed in individual pens (1.8× 1.8 m) equipped with hopper type troughs and nipple drinking troughs. Food and water were offered as free access. The evaluation period lasted twelve weeks. The diets were formulated with the Solver command (Microsoft Excel, 2007), according to the requirements of the NRC (2012) for the three experimental stages (Table 1).

The technique of surgical castration was executed at 7 days of age: the piglet was restrained and the scrotum was washed with drinking water, then iodine was applied, and in the lower part of the scrotum an incision was made with a scalpel and at the same time the testicle was pressured to be extracted, and the other testicle was removed in the same way. Later, an antibiotic was applied via intramuscular and a cicatrizant on the wound, the latter during three days.

Table 1. Composition of diets.

Ingredients (%)	25 – 50 kg BW	50 – 75 kg BW	75 – 100 kg BW
Sorghum	75.06	77.80	84.53
Soybean meal	19.70	17.13	11.90
Soybean oil	2.20	2.25	0.92
Lysine[A]	0.57	0.46	0.62
DL- Methionine	0.14	0.15	0.20
L-Threonine	0.26	0.15	0.20
Vitamins and minerals [B y C]	0.30	0.30	0.30
Salt	0.20	0.25	0.30
Calcium carbonate	1.31	0.92	0.55
Calcium orthophosphate	0.56	0.89	0.75
Total	100.00	10.00	100.00
Nutritional Contribution (%)			
Metabolic energy (Mcal kg^{-1})	3.30	3.30	3.30
Crude Protein	16.10	14.5	13.50
Ca	0.66	0.59	0.64
P	0.46	0.27	0.45

[A]Supplied 50% lysine. [B]Supplied per kg of feed: vitamin A, 15,000 UI; vitamin D3, 2,500 UI; vitamin E, 37.5 UI; vitamin K, 2.5 mg; thiamine, 2.25 mg; riboflavin, 6.25 ámg; niacin, 50 mg; pyridoxine, 2.5 mg; cyanocobalamin, 0.0375 mg; biotin, 0.13 mg; choline chloride, 563 mg; pantothenic acid, 20 mg; folic acid, 1.25 mg. [C]Provided per kg of feed: Fe, 150 mg; Zn, 150 mg; Mn, 150 mg; Cu, 10 mg; Se, 0.15 mg; I, 0.9 mg; Cr, 0.2 mg. T=Treatment.

For immunocastration, two doses of the Improvac® vaccine by Zoetis of 2 mL were applied via subcutaneous at the neck's base, immediately behind the right ear. This contains analogous protein conjugate from the gonadotropin liberation factor, the first at ten weeks of age and the second four weeks after the first dose.

Productive Variables: The variables evaluated in each stage were: daily weight gain (DWG); average daily feed intake (ADFI); feed conversión ratio (FCR). These variables were measured weekly.

Characteristics of the carcass: Backfat thickness (BT) and *Longissimus dorsi* muscle area (LMA) were measured at the beginning of the experiment and later at 50, 75 and 100 kg of BW. Ultrasound equipment was used in real time (Landwind CU30VET, Shenzhen, China), performing the measurement on the loin at the height of the tenth rib. Lean meat percentage (%LM) was calculated with these data and those of Initial body weight (IBW) and final body weight (FBW), using the equation from the National Pork Producers Council (1991).

Physicochemical characteristics of the meat: These characteristics were evaluated at the end of the third experimental stage. When the pigs reached 100 kg of BW, five animals were slaughtered per treatment and samples were taken from the pigs' lumbar area to determine: pH, color, and the water holding capacity (WHC). The slaughter was performed in the farm complying with the Official Mexican Norm NOM-033-SAG/ZOO-2014 (SEGOB, 2015).

The pH and the color were measured in the loin muscle 24 h *post mortem*. The pH was measured with a potentiometer (model pH1100), according to the measurement of pH in meat homogenates (Braña *et al.*, 2011). The color measurements were performed with the help of a colorimeter (Hunter Lab, Chroma meter CR-410, Konica Milolta Sesning, Inc., Japan) following the scale of the International Commission on Illumination (CIE) L*a*b*, where (L*) = luminosity, (a*) = red-green index, and (b*) = yellow-blue.

The WHC was determined in the samples according to the method proposed by Guerrero *et al.* (2002) at 24 h *post mortem*: 5 g of finely chopped meat were used, which were placed in tubes for centrifuge with 8 mL of 0.6 M sodium chloride solution. Later, they were placed in ice during 30 min, stirred in a vortex during 1 min, and centrifuged for 15 min at 10,000 rpm. The supernatant was collected by decanting and measured in a test tube. The retained water volume is reported as the amount of water retained in 100 g of meat.

Statistical analysis: The variables evaluated were analyzed with a student's t- test for independent samples, which compares the means of two populations, with two treatments of 10 repetitions each, a degree of confidence of 95%, and 0.05 degree of error, using the Statistical Analysis System software (SAS, 2010).

RESULTS AND DISCUSSION

Productive Variables and Carcass Quality

The productive variables DWG, ADFI and FCR in pigs of both treatments in the three stages evaluated were similar (Tables 2, 3 and 4) since they do not present differences ($P>0.05$). These results differ from those of other studies, which reported that the best productive parameters (DWG and FCR) were for the ICM in comparison to those of SCM in animals of 71-115 kg BW (Fábrega *et al.*, 2010; Fernandes *et al.*, 2017; Grela *et al.*, 2020).

Poulsen Nautrup *et al.* (2018) performed a meta-analysis of 78 studies where different parameters of SCM and ICM were compared and they found that the ICM had an increase in DWG (32.54 g day^{-1}) compared to the SCM; the FCR was lower during the entire period in the ICM, which resulted in 0.23 kg of ADFI less than kg of livestock weight; it was also found that the BW was approximately 2 kg higher in the MCI compared to the SCM.

However, in this study despite not showing differences ($p>0.05$), the ICM had a lower DWG and higher index of FCR in the first period of evaluation (Table 2) and a better response in the productive characteristics compared with the SCM, in the stages of 50-75 kg and 75-100 kg (Table 3 and 4). The variation in the results from the different studies can be because of the age at which castration is done, since it can affect the growth rhythm of the animals and the higher growth of the muscular tissue as it approaches puberty (Quiles, 2005).

On the contrary, Morales *et al.* (2013) found that the ICM had a lower DWG compared to the SCM, and at the same time the ICM had a lower CAL ($P<0.001$) than the SCM with 2.33 and 2.77 kg day^{-1}, respectively. Fàbrega *et al.* (2010) mention that this could be justified due to the stress that pigs suffer when being injected, and to an increase in body temperature.

Table 2. Productive characteristics and carcass quality in male pigs with different castration techniques in the stage of 25 - 50 kg BW.

Variable	Surgical castration		Immunocastration		p Value
	MNS	SD	MNS	SD	
DWG (kg d^{-1})	0.81	0.41	0.73	0.32	0.50
DFI (kg d^{-1})	1.66	0.65	1.62	0.57	0.84
FC (kg/kg)	2.22	0.62	2.26	0.60	0.84
BT (mm)	4.66	1.29	2.56	0.91	0.16
LMA (cm^2)	27.58	3.57	28.26	2.35	0.73
LM (%)	45.68	1.05	47.51	2.28	0.14

Pr>|t|: values <0.05 are statistically different. MNS: mean; SD: standard deviation. DWG: daily weight gain; DFI: daily feed intake; FCR: feed conversion ratio; BT: backfat thickness; LMA: *Longissimus dorsi* muscle area; LM: lean meat.

Table 3. Productive characteristics and carcass quality in male pigs with different castration techniques in the stage of 50 - 75 kg BW.

Variable	Surgical castration		Immunocastration		p Value
	MNS	SD	MNS	SD	
DWG (kg d^{-1})	0.74	0.46	0.80	0.15	0.68
DFI (kg d^{-1})	2.86	0.79	2.77	0.24	0.79
FC (kg/kg)	4.08	1.17	3.73	0.43	0.51
BT (mm)	6.24	1.51	6.18	0.26	0.94
LMA (cm^2)	32.38	2.58	32.52	0.67	0.92
LM (%)	42.18	1.24	42.10	0.18	0.89

Pr>|t|: values <0.05 are statistically different. MNS: mean; SD: standard deviation. DWG: daily weight gain; DFI: daily feed intake; FCR: feed conversion ratio; BT: backfat thickness; LMA: *Longissimus dorsi* muscle area; LM: lean meat.

Table 4. Productive characteristics and carcass quality in male pigs with different castration techniques in the stage of 75 - 100 kg BW.

Variable	Surgical castration		Immunocastration		p Value
	MNS	SD	MNS	SD	
DWG (kg d^{-1})	0.92	0.46	1.01	0.47	0.52
DFI (kg d^{-1})	3.52	0.98	3.44	0.70	0.81
FC (kg/kg)	4.69	2.68	3.97	1.78	0.43
BT (mm)	8.28	2.67	7.24	1.55	0.47
LMA (cm^2)	43.72	8.61	44.64	7.41	0.86
LM (%)	41.92	2.85	42.32	2.68	0.82

Pr>|t|: values <0.05 are statistically different. MNS: mean; SD: standard deviation. DWG: daily weight gain; DFI: daily feed intake; FCR: feed conversion ratio; BT: backfat thickness; LMA: *Longissimus dorsi* muscle area; LM: lean meat.

Dalla Costa *et al*. (2020), found that immunocastration improved DWG, FLW and FC (P<0.008), which also improved the reduction of DF (P<0.0001) and increased %LM (P<0.0001) in the ICM carcasses, because the androgenic hormones produced by the testicles in the second dose promote a redistribution of nutrients to favor the synthesis of muscular and bone tissue, and consequently the adipose tissue is reduced compared to surgically castrated pigs (Boler *et al*., 2011).

On the contrary, Daza *et al*. (2016) did not observe differences in BT and LMA due to the type of castration, results that are similar to this study since differences were not obtained (p>0.05) between BT, LMA and %LM treatments. However, although there were no differences in the present study, in the treatment of ICM the values of LMA were higher and the BT lower in the three stages compared to SCM (Table 2, 3 and 4); in the first stage (25-50 kg BW) there was a higher %LM in ICM, from the second application of the vaccine and the behavior of this variable is very similar to those of the SCM. These results are similar to those by Fábrega *et al*. (2010), who observed that the ICM presented higher LMA compared to the SCM.

Physicochemical Variables of the Meat

Table 5 shows that the values obtained in pH, WHC and color did not show differences (P>0.05) between treatments, which is similar to that reported by Fernandes *et al*. (2017). Zamaratskaia and Krøyer (2015) point out that the parameters of meat quality and of meat in general differ between ICM and SCM, similar results to those obtained in this study.

Braña *et al*. (2011) describe that the WHC is influenced by the muscle's pH. The further away the pH is from the isoelectric point (5.0-5.5) of meat proteins, the more water they retain. Considering this affirmation, the fact that there is not difference in the WHC between the treatments can be because the pH is also similar between both treatments.

In addition to the pH, there are other factors that affect WHC, among them the race, the type of fiber, the oxidative stability of their membranes, the maturation process, and if the case may be, the system used to freeze and thaw the meats (Braña *et al*., 2011).

Table 5. Physico-chemical characteristics of loin meat in male pigs with different castration techniques.

Variable	Surgical castration		Immunocastration		p Value
	MNS	SD	MNS	SD	
pH	5.28	0.30	5.15	0.27	0.19
WHC (ml)	14.0	8.55	11.40	4.72	0.24
Color:					
L*	45.97	3.91	43.96	2.41	0.05
a*	6.12	2.18	6.11	1.61	0.99
b*	6.59	1.71	6.05	1.41	0.27

Pr>|t|: valores <0.05 existe diferencia significativa, MNS: mean; SD: standard deviation, WHC: water holding capacity, Color: CIEL*a*b*, L* scale: brightness a*: red-green index b*: yellow-blue index.

CONCLUSIONS

Immunocastration does not affect the productive parameters, carcass quality, or physicochemical characteristics of the pork meat compared with surgical castration, which is why the first is an alternative to surgical castration, since this technique produces less stress in the pig and is more in accordance to animal welfare, in addition to immunocastration demanding less time invested.

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Pre-Weaning Growth of Criollo Tropical Milking Calves fed with Milk from Silvopastoral Systems

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ABSTRACT

Objective: Tropical Milking Calf (LT) growth and milk consumption and chemical composition were analyzed in two shepherding systems.

Methodology: 26 LT cows were used in rotational shepherding in monoculture (PRM) and intensive silvopastoral system (SSPi). Cows were milked by hand once per day in the morning with the presence of the calf, which consumed milk from one nipple. Live weight (PV), daily weight gain (GDP), milk consumption (CL) by the calf and the chemical composition of the milk were studied.

Results: PV was greater at 198 days in SSPi ($p \leq 0.05$) with 142.6±3.31 kg, and one GDP that outweighed the PRM ($p \leq 0.05$) in 80 g per day^{-1}. There were no differences in CL ($p > 0.05$). Non-fatty solids, protein, lactose and total solids were greater ($p \leq 0.05$) for SSPi with 8.1±0.07, 3.0±0.02, 4.5±0.04 and 12.1±0.21 %, respectively; although fat was similar (3.7 and 3.3 %, $p > 0.05$) in both systems.

Implication: The chemical composition of milk should be assessed from the nutritional perspective for the calf and the more appropriate techniques for its measurement should be implemented.

Conclusions: PV and GDP were greater in SSPi than in PRM due to the chemical composition and not the amount of ingested milk. The chemical composition of milk affected the pre-weaning growth of calves. The tropical milking race and SSPi are an alternative for tropical livestock raising in warm weathers.

Keywords: warm weathers, livestock raising, river tamarind, gene resources, agroecology systems.

INTRODUCTION

Milk production systems in Mexican warm weather intertropical zones supply 25% of domestic production (Orantes-Zebadúa *et al*., 2014) while boosting local economy; their products are marketed locally and represent income for families. Nevertheless, the seasonality of the rain period, the use of technology, managerial abilities and local traditions affect their productivity

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and may have an adverse incidence in the preservation of natural resources (Murgueitio *et al*., 2015). Tropical milk production is characterized by the flexibility of its zootechnical function (Martínez *et al*., 2012), due to the fact that feeding the calves before the milking is used to stimulate the descent of milk and both milk is produced and calves are weaned. Calf growth from birth to weaning is determined by the amount and chemical composition of the consumed milk, which in turn depends on the feeding by the mother (Martínez *et al*., 2012; Díaz *et al*., 2014; Orantes-Zebadúa *et al*., 2014). The calf is allowed to consume residual milk after the milking, which is regulated by the depth of the milking and number of milked nipples, which influences the daily weight gain that may be lower than 365 g per day^{-1} (Salamanca *et al*., 2011). Although supplements may be used to contribute to feeding calves and destining more milk for sale and obtainment of greater income, both supplements and the financial resource for their acquisition should be available for the producer (Guarneros *et al*., 2017).

The criollo Tropical Milking (LT) race is adapted to shepherding systems, requires little inputs, its productive capacity is 1174±11.4 kg of milk per breastfeeding, reason why it is a gene alternative for tropical milking (Rosendo-Ponce & Becerril-Pérez, 2015). Intensive silvopastoral systems (SSPi) meet agroecology productive and environmental functions upon combining herbaceous strata with local and improved grass, as well as shrub strata such as river tamarind (*Leucaena leucocephala* [Lam.] de Wit); SSPis are an alternative for improving animal productivity and mitigating climate change effects. SSPis and the LT race may be an alternative for sustainable milk production in the warm weather intertropical region. Upon shepherding in a SSPi, LT cows may increase their production and milk quality, which would in turn power the growth and daily weight gain of calves due to the fact that, during the first 90 days of life, their feeding depends mainly on milk (Heras-Torres *et al*., 2008). Therefore, the objective hereof was to compare growth and consumption of criollo Tropical Milking calves and determining the chemical composition of milk in rotational shepherding systems in monoculture and intensive silvopastoral system.

MATERIALS AND METHODS

The study was performed from June to December 2018 in the "El Huilango" land lot, Cotaxtla, Veracruz, Mexico (18° 53′ N, 96° 15′ O), a 30 altitude. It has a subhumid warm weather Aw_0(w)(i')g, with rains in summer (García, 1988), with mean annual temperature and rains of 25.4 °C and 1042 mm.

26 first-birth LT cows and 40.45±0.67 months of age. At 24 h after birth they entered a paddock with pará grass (*Brachiaria mutica* [Forssk.] Stapf), where they stayed while they produced colostrum and then they were transferred to the paddock according to the corresponding shepherding system. Calf identification and weight measurement upon birth were performed on the first 24 hours of life, they consumed colostrum and milk once per day until reaching 10 days of life. Then, they were transferred to giant star grass (*Cynodon plectostachyus* [K.Schum.] Pilg.) and native vegetation paddock, where they remained apart from their mother during the entire study. Cows were milked by hand once per day with the presence of the calf, and calves consumed milk from one nipple (Figure 1). As of 90 days after birth, calves were supplemented with ground corn offered individually in 760 g per day^{-1}.

Figure 1. Criollo Tropical Milking cow hand milking with the presence of the calf in the "El Huilango" land lot, Cotaxtla, Veracruz, Mexico.

Thirteen cows were randomly allocated to each rotational shepherding system in monoculture (PRM) in SSPi and were given *ad libitum* water and minerals. Each system had four 1-ha paddocks, with an electric fence and distributed randomly in the area of study. The PRM had *Megathyrsus maximus* grass only (Jacq.) B.K. Simon & S.W.L. Jacobs cv. Mombasa (Figure 2a); the SSPi had *M. maximus* grass in the herbaceous stratum and an arrangement or rows at a distance of 1.6 m with *Leucaena leucocephala* (Lam.) de Wit, with a density of 8400±184 plants ha^{-1} (Figure 2b). The occupation and paddock resting period was of 4 and 28 days during the

Figure 2. Tropical Criollo Milking cows in rotational shepherding systems in a) grass monoculture and b) intensive silvopastoral system in the "El Huilango" land lot, Cotaxtla, Veracruz, Mexico.

humid warm season (June - October) and 5 and 35 days during the dry cold season (November – December). No fertilization nor ancillary irrigation were applied in both systems.

The live weight of calves (PV, kg) was measured with a digital scale (EziWeigh5i, Tru-Test®, NZ) before the milking every 28 days. The weight was adjusted through the equation described by Salamanca *et al*. (2011). The daily weight gain (GDP, g per day^{-1}) were calculated every 28 days with the equation:

$$GDP = [(PRP - PRPA)/(DEP)]$$

where: *PRP*=Current live weight (kg), *PRPA*=Previous live weight (kg) y *DEP*=Days between weighing. Milk consumption per calf (CL, kg d^{-1}) was estimated at 90 and 180 days, through the difference in calf weight and before sucking for two consecutive days, and one milk sample was taken per thoroughly milked cow. Milk was refrigerated at 5 °C and transferred to the laboratory, where fat (G), protein (P), lactose (L), non-fatty solid (SNG) and total solid (ST) content was determined with a Lactoscan MCC ultrasonic milk analyzer (MIlktronic, Bul).

In order to analyze GDP, CL, G, P, L, SNG and ST, a model that included the stationary effects of the calf shepherding system and sex was used; PV was analyzed with a mixed model with repeated measurements with covariance structure in an integrated autoregressive mobile average model. Data were processed with GLM and MIXED procedures of SAS® 9.3 (SAS Institute, 2010). Treatment measure comparison was made with Tukey's test (α=0.05).

RESULTS AND DISCUSSION

Birth weight of LT calves was of 25.68±1.03 kg in females and 29.07±1.05 kg in males. These birth weights were lower than cross-bred genotypes of European races with cebuine breeds of 31.1±4.7 females and 31.66±0.23 kg in males (Madrid-Bury *et al*., 2007; Arce *et al*., 2017). The smallest size of native races may be an adaptative feature of natural selection at adverse warm tropical conditions. The live weight of LT calves in both shepherding systems appears in Table 1. During the first 60 days, calves almost doubled their birth weight. Heras-Torres *et al*. (2008) describe a primary slow-growth stage, attributed to a non-ruminant to ruminant transition and a more developed immune system; in this study, the slow growth period occurred from day 60 to 120; as of 120 days, calves fed with milk from both shepherding systems showed an accelerated growth. Nevertheless at 170 and 198 days, calves fed with SSPi had a PV greater than in PRM ($p \leq 0.05$, Table 1).

PV at 98 days for calves fed with SSPi milk was greater than 121.4±32.5 kg at 224 days of age for domestic cow *vs* zebu (Osorio-Arce and Segura-Correa, 2008), fed with one nipple and supplemented with commercial feed. Saddy *et al*. (2015) reported weights of 105.7±14.22 and 109.7±13.65 kg at 190 days, supplemented with 0.869 and 0.980 kg of commercial concentrate of 10 and 20% raw protein (PC) for cF1 Holstein×Brahman cross breeds, which suggests that it feasible to obtain a better pre-weaning growth for LT calves in SSPi.

GDP in SSPi was greater than 99 g per day^{-1} than the one obtained in the PRM system, which meant 18.11 kg more of PV upon weaning (Table 2). Romosinuano

Table 1. Live weight (kg) in Tropical Milking calves fed with milk from two shepherding systems.

Day	Rotational shepherding in monoculture	Intensive silvopastoral system	Standard error	p value
0	27.8	27.4	3.22	0.943
22	42.2	41.2	3.22	0.832
60	49.1	52.1	3.22	0.510
88	52.7	58.7	3.22	0.189
116	63.7	69.1	3.22	0.233
142	76.1	83.7	3.26	0.105
170	90.4a	103.9b	3.29	0.004
198	123.6a	142.6b	3.31	0.001

[a,b] Different letters on the same row indicate differences ($p \leq 0.05$).

calves cross-bred with Jersey calves during the restricted 5-hour breastfeeding had a GDP of 299 g per day^{-1} and a weaning weight adjusted to 106.15 kg at 270 days (Salamanca *et al*., 2011), lower than LT calves; genotype, technology and environment affect calf response.

There were no differences ($p>0.05$) in GDP for females and males, similar to zebu cross-bred calves (Cárdenas *et al*., 2015); nevertheless, other studies state differences in GDP and weaning weight between sexes (Heras-Torres *et al*., 2008; Salamanca *et al*., 2011). CL in LT calves was similar in both shepherding systems ($p>0.05$, Table 2) and at 3±0.2 kg per day^{-1} for cross-bred calves fed with one nipple for the first 100 days of life (Chirinos *et al*., 2011);nevertheless, their GDP was of 287±20 g per day d^{-1}, supplemented with 300 g of concentrated feed (20% PC), lower than the GDP of LT calves. The difference in GDP obtained in PRM and SSPi systems in relation to other studies, evidence that the chemical composition of milk is a determining factor for calf growth (Table 3) (Chirinos *et al*., 2011; Salamanca *et al*., 2011).

The chemical composition of milk in both shepherding systems was not different in fat ($p>0.05$); results match those of 3.7 and 3.6±0.05 for milk produced in a PRM and an SSPi system with cross-bred cows supplemented with concentrate (Mohammed *et al*., 2016). Prieto-Manrique *et al*. (2016) obtained 2.88 and 4.41% in similar shepherding conditions, while Hernández and Ponce (2004) obtained 4.07±0.16 and 4.2±0.22% fat for PGM and SSPi, respectively. The proportion of volatile acetic and propionic fatty acids in rumen determined the milk fat content (Ramos *et al*., 1998); the difference in fat content with respect to other studies may be attributed to the forage-concentrate ratio and the amount of fiber in diet, due to the fact that the proportion of acetic and propionic acid in rumen is sensitive to these factors; in this sense, legumes affect the quality of milk as their degradability in rumen is more similar than that of grain, as it shows lower neutral effective detergent fiber compared with grass (Silva *et al*., 2016).

SNGs were greater in the SSPi at 90 and 180 days ($p \leq 0.05$), due to the fact that their main components, protein and lactose, were also found in greater amounts

Table 2. Daily weight gain and milk consumption by Tropical Milking calves fed with milk from two shepherding systems.

Characteristic	Intensive rotational shepherding	Standard error	Intensive silvopastoral system	Standard error	p value
Daily weight gain (g d^{-1})	488.7a	0.12	587.7b	0.14	0.01
Milk consumption in 90 days (kg d^{-1})	2.7a	0.21	3.2a	0.21	0.10
Milk consumption in 180 days (kg d^{-1})	2.6a	0.23	2.8a	0.21	0.54

[a,b] different letters on the same row indicate differences ($p \leq 0.05$).

Table 3. Chemical composition of milk consumed by Tropical Milking calf in two shepherding systems during their pre-weaning stage at 90 and 180 days.

	Fat		Non-fatty solids		Protein		Lactose		Total solids	
	90	180	90	180	90	180	90	180	90	180
Intensive rotational shepherding	3.5^{a}	3.7^{a}	7.9^{b}	8.0^{b}	2.9^{b}	2.9^{b}	4.3^{b}	4.4^{b}	11.4^{b}	11.7^{a}
Intensive silvopastoral system	3.9^{a}	3.3^{a}	8.1^{a}	8.5^{a}	3.0^{a}	3.1^{a}	4.5^{a}	4.7^{a}	12.1^{a}	11.8^{a}
Standard error	0.2	0.3	0.1	0.1	0.02	0.04	0.04	0.07	0.21	0.25

[a,b] different letters on the same column indicate a significant amount ($p \leq 0.05$).

($p \leq 0.05$). Cows fed in SSPi have access to a diet with greater protein content (Murgueitio *et al*., 2015), which may be related to the difference in protein and lactose content in milk between shepherding systems; the mammary gland synthetizes milk protein from the availability of aminoacids and greater propionic acid levels increase lactose synthesis (Ramos *et al*., 1998); SNG, protein and lactose contents were similar in PRM and SSPi with 8.1, 2.9 and 4.3% and 8.2, 3.0 and 4.5% (Mohammed *et al*., 2016).

ST were greater in SSPi milk at 90 days; this difference in milk chemical composition influenced the productive behavior of calves, as they depend on the consumed milk; albeit there were no differences between shepherding systems at 180 days ($p > 0.05$). Protein and lactose amounts were greater for SSPi related to greater GDP of calves. Rumen begins to become functional at 60 days of life in calves, reason why the daily ingestion of milk is considered to be a diet supplement, capable of favoring greater growth rates (Cárdenas *et al*., 2015). Martínez *et al*. (2010) found a significant correlation between weight at 210 days and protein present in milk. Estimated STs were similar than those obtained by Mohammed *et al*. (2016), although lower than 1% for PRM and 0.5% for SSPi (Hernández & Ponce, 2004), the difference is attributable to a different supplementation.

CONCLUSIONS

In an intensive silvopastoral system with legume availability, criollo Tropical Milking calves had a greater weight at 180 days and a greater daily weight gain, although milk consumption per day was similar than that of calves within a grass monoculture shepherding systems. The chemical composition of milk for cows in the intensive silvopastoral system had greater content of components, except for fat. Also, the difference in the chemical composition of milk had differential effects in the productive behavior of calves.

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AP AGRO PRODUCTIVIDAD

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Hybridization of Castor Bean (*Ricinus communis* L.) in Morelos, México

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ABSTRACT

Objective: To determine the stigma receptivity and the pollen viability in order to make manual crosses and obtain viable progeny in castor bean (*Ricinus communis* L.).

Design/Methodology/Approach: Pollen viability tests were made on breeding materials by staining with acetocarmine solution. In elite materials, the receptivity of the stigma was evaluated with hydrogen peroxide. From the inflorescences, the male ones were removed and the female ones were preserved, which were covered with a glassine bag. After six days, they were checked and when they were considered receptive, manual pollinations were carried out between viable pollen materials and receptive stigma. The pollen of the male parent was impregnated in the stigmas and the inflorescence was covered again.

Results: The breeding materials exhibited viable pollen since they were stained red. Whereas, the application of hydrogen peroxide to the stigmas of the elite materials showed bubbling, indicative that they were receptive. In 2014, 400 inflorescences were pollinated with 8 flowers on average and a fruit pollinated percentage of 61.21. In 2015, 245 inflorescences with 12 flowers on average and 61.24% of fruit were pollinated.

Study Limitations/Implications: Temperature and relative humidity were fundamental factors for the success of castor bean fertilization.

Findings/Conclusions: The elite castor bean materials presented receptive stigmas and the improved viable pollen materials. Manual crosses produced fruits and seeds. The fruits pollinated were 61%.

Keywords: Pollen viability, stigma receptivity, fruits pollinated, hybridization, genetic improvement.

INTRODUCTION

The irreversible exhaustion of oil reserves globally led to the search for alternative sources of renewable energies such as bioenergy. Biofuels in their solid, liquid and gas forms are currently of great importance, and therefore their study, production and use have intensified in the last 15 years (Guo *et al*., 2015). The search for new bioenergetics sources have centered on the production of ethanol and biodiesel from biomass of sugarcane

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(*Saccharum* spp. hybrids), maize (*Zea mays* L.) and grain sorghum (*Sorghum bicolor* L.). Advances have also been made in the research and technological development of other crops such as castor bean (*Ricinus communis* L.). Castor bean belongs to the Euphorbiaceae family, with chromosome number 2n=2x=20. Their area of distribution is extensive worldwide, from tropical and subtropical regions to temperate zones (Lu *et al*., 2019). In Mexico, it is possible to find it throughout the country, and it is common for it to grow on the edges of paths and disturbed vegetation areas.

At the commercial scale, castor bean is cultivated in 1.5 million hectares in the world, where India, China, Brazil, Russia and Thailand stand out as main producers (Rukhsar *et al*., 2018). The oil from the seeds has chemical and physical properties that are unique and exceptional for industrial use (Lu *et al*., 2019; Rodrigues *et al*., 2019). In Brazil its cultivation is considered for family subsistence, interspersed with maize and bean, using local varieties with long cycles whose seed maturation is heterogeneous (Milani and Nóbrega, 2013).

In Mexico there are native populations of castor bean with wide morphological, productive, genetic and adaptive variability (Barrios-Gómez *et al*., 2018; García-Herrera *et al*., 2019). However, the productive potential is limited because they are normally tall plants with abundant aerial biomass, lax bunches (sparse) of small size, sometimes indehiscent, with few fruits per bunch and seeds per fruit, and lower grain yield.

The commercial cultivation of castor bean in Mexico uses landrace and imported breeding materials. The landrace varieties are tall with low yield potential, but with tolerance to adverse factors, a useful trait to generate hybrid or improved varieties. These two groups of materials, together with the germplasm from native populations from Mexico, represent a valuable opportunity for genetic improvement of the species. Generating breeding materials that are adapted to particular production zones in Mexico require strategies that include the selection, mutagenesis, use of molecular markers and hybridization.

The success of hybridization in any plant species is sustained on understanding the moment when the stigmas are receptive and the time lapse when pollen grains are liberated during the day. In genetic improvement of cultivated species it is difficult to find two parents that originate a progeny with the highest amount of desirable traits (Ferreira *et al*., 2015). However, it should be considered that the quantitative traits of greatest economic importance are controlled by many pairs of genes.

The inflorescence of castor bean is a monoecious bunch with female flowers in the higher part and male in the lower part (Merkouropoulos *et al*., 2016). It is considered to be a crossed-pollination species (Ramesh *et al*., 2017) where wind is the main pollinating agent (Anjani *et al*., 2018). The liberation period of the pollen grains lasts 1 to 2 days, with optimal temperature conditions between 26 and 29 °C and relative humidity of 60%. Meanwhile, the stigma is completely receptive for a period of 5 to 10 days depending on environmental conditions (Milani and Nóbrega, 2013). With the aim of establishing the bases of hybridization in castor bean in Mexico this study had the objectives of determining the receptivity of the stigma and viability of pollen, and making manual crosses to obtain viable progeny.

MATERIALS AND METHODS

This study was carried out in the Zacatepec Experimental Field of the National Institute for Forest, Agricultural and Livestock Research (Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, INIFAP), located in the Zacatepec-Galeana Highway km 0.5, on coordinates 18° 39′ 16′′ LN, 99° 11′ 54.7′′ LW and an altitude of 911.8 m. The zone presents warm sub-humid climate with summer rains (Aw0), where average annual precipitation is 800 mm and average annual temperature 24 °C (Ornelas *et al*., 1997).

The genetic material used consisted of six elite materials of castor bean collected in many states of the country, which were selected for having greater size, weight and seed yield (Barrios *et al*., 2013), and three commercial varieties liberated by foreign seed companies. Receptivity tests were made on the stigma of elite materials, and pollen viability tests were applied on the breeding materials.

In 2014, pollen viability tests were made with the method proposed by Dempsey (1993), which consists in staining with acetocarmine (Meyer® coloring solution) and observing the change of color in the stereoscopic microscope. The stigma receptivity tests were applied following the method proposed by Osborn *et al*. (1988), which consists in placing a drop of hydrogen peroxide at 3% on the stigmas; if bubbles are produced in the reaction then they are considered as receptive.

The genetic materials that resulted with viable pollen and receptive stigmas were used as parents to make manual crosses in November 2014 and October 2015. From the inflorescences, 10 female flowers were chosen that were in the same phenological state and the male flowers were eliminated (Figure 1a); then the inflorescence was covered with a glassine bag. The state of development of the stigmas was checked six days later and, when they were considered receptive, manual pollination impregnating the male parent's pollen on the stigmas was done; then the inflorescence was covered again (Figure 1b). Pollination was carried out from 9:20 a.m. to 11:30 a.m. in 2014 and from 10:00 a.m. to 1:30 p.m. in 2015. In the Zacatepec Experimental Field, in Morelos, the values of mean maximum, mean minimum, and mean daytime temperatures were 30.8, 15.9 and 27.4 °C in October and 30.8, 12.1 and 26.7 °C in November, respectively. The monthly average precipitation was 67.2 mm in October and 10.4 mm in November. These means come from records that cover from 1961 to 2003 (Díaz *et al*., 2008). For each cross the variables that were found were the number of pollinized flowers, number of harvested fruits, and percentage of fruit pollinated.

RESULTS AND DISCUSSION

In the pollen viability tests in breeding materials, pollen grains stained with red color were observed, which indicated that they were viable so they could be used as male parents. Likewise, the application of hydrogen peroxide to the stigmas of the elite materials showed bubbling, indicative that they are receptive (Figure 1c). The results of pollen viability and stigma receptivity indicated that the environmental conditions in the zone were optimal to carry out the pollination and later fertilization. Studies about the determination of pollen viability and stigma receptivity are essential activities to carry out genetic recombination. These tests have been useful in hybridization processes in species of the *Echeveria* genus (Rodríguez-Rojas *et al*., 2015) and in poinsettia (*Euphorbia pulcherrima* Willd. ex Klotszch) (Canul-Ku *et al*., 2015; Rodríguez *et al*., 2017).

In the year 2014, 400 inflorescences were pollinized, with 8 flowers on average each and fruit pollinated was 61.21%. In 2015, 245 inflorescences were pollinized, with 12 flowers on average and fruit pollinated of 61.24% (Figure 1d).

Figure 1. Hybridization process in castor. a) Emasculated inflorescence. b) Manual pollination. c) Receptive stigma. d) Fruit development.

In the evaluation of the behavior of fruit pollinated in function of the time of pollination in 2014, it was observed that the highest percentage was obtained from pollinized flowers at 9:20 in the morning and the lowest at 10:30 (Figure 2). These results show that the minimal differences of time to do the manual pollinations are dependent on climate conditions.

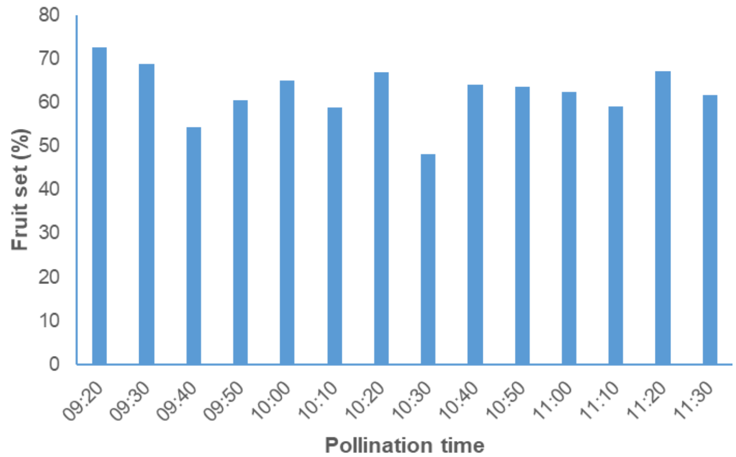

Figure 2. Percentage of fruit set as a function of pollination time. Zacatepec Experimental Field. 2014.

In the year 2015 the pollinations performed at 10:20 in the morning presented the lowest percentage of fruit pollinated with 33% and at 12:30 the highest with 77%. In that year, the lowest fruit pollinated was during the period of 10:20 to 10:50 (Figure 3).

The best behavior of fruit pollination was obtained in 2014 (Figure 2). The next year increases and decreases were observed during the pollination period (Figure 3). This response is probably due to the environmental conditions that were present. Historical data show that the mean daytime temperature in the Zacatepec Experimental Field is 26.7 to 27.4 °C (Díaz *et al*., 2008) during the time period when the pollinations were performed. If it considered that pollen grains from castor bean are liberated in optimal conditions of temperature between 26 and 29 °C for 1 to 2 days and the stigma is completely receptive 5 to 10 days (Milani and Nóbrega, 2013), it is deduced that the environmental conditions of the zone favored fertilization.

In the pollination of five species from the *Echeveria* genus, 100% of fruit pollinated was obtained, although the viable seeds only formed in intra and interspecific crossed pollination (Rodríguez-Rojas *et al*., 2015). In poinsettia it was reported that fruit pollinated is 68% with the technique of modified emasculation and it is crucial for hybrid generation. The process consists in cutting two thirds of the bract from the apex to the base of the inflorescence, eliminating male flowers, leaving between three and five non-receptive female flowers with the same phenological state covered with a waxed bag (Canul-Ku *et al*., 2015).

The knowledge generated about pollen viability, stigma receptivity and fruit pollinated in these castor bean materials establish the bases that will allow generating genetic variants. With this information it would be possible to undertake the genetic improvement of castor bean and to obtain varieties and hybrids for specific environmental conditions in Mexico. The main goal of this genetic improvement will be to reduce the varietal dependency on imported breeding material.

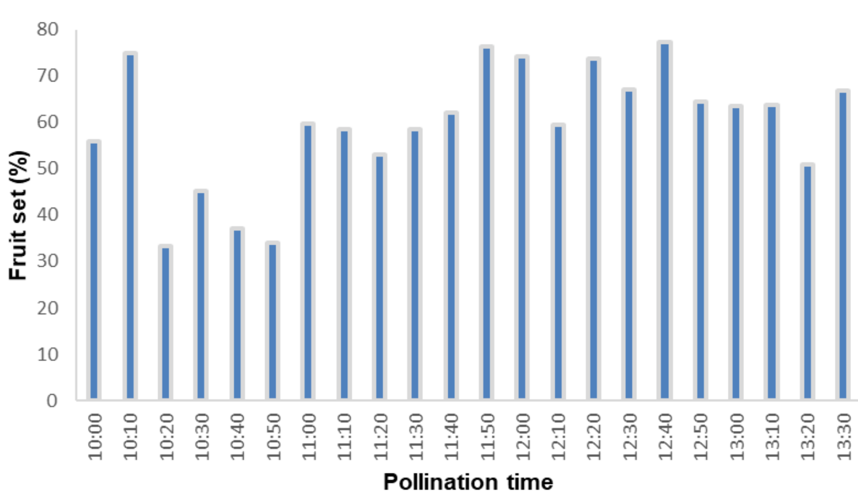

Figure 3. Percentage of fruit set as a function of pollination time. Zacatepec Experimental Field. 2015.

CONCLUSIONS

The elite materials of castor bean presented receptive stigmas and the breeding materials viable pollen. Manual crosses produced fruits and seeds. Fruit pollination was 61%. This indicates that there is genetic potential to generate new combinations through hybridization in castor bean.

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Livestock resources and their conservation facing climate change

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ABSTRACT

Objective: To analyze the importance of local livestock resources facing climate change.

Methodology: A review of studies referenced in scientific databases disclosed in the livestock sector and animal genetic resources was made within the context of climate change.

Results: Livestock breeding is an economic activity that contributes to the food security of the country; in view of its importance, technologies and necessary changes to perform this according to the accelerated changes that occur in the environment, brought by human activity, should be implemented.

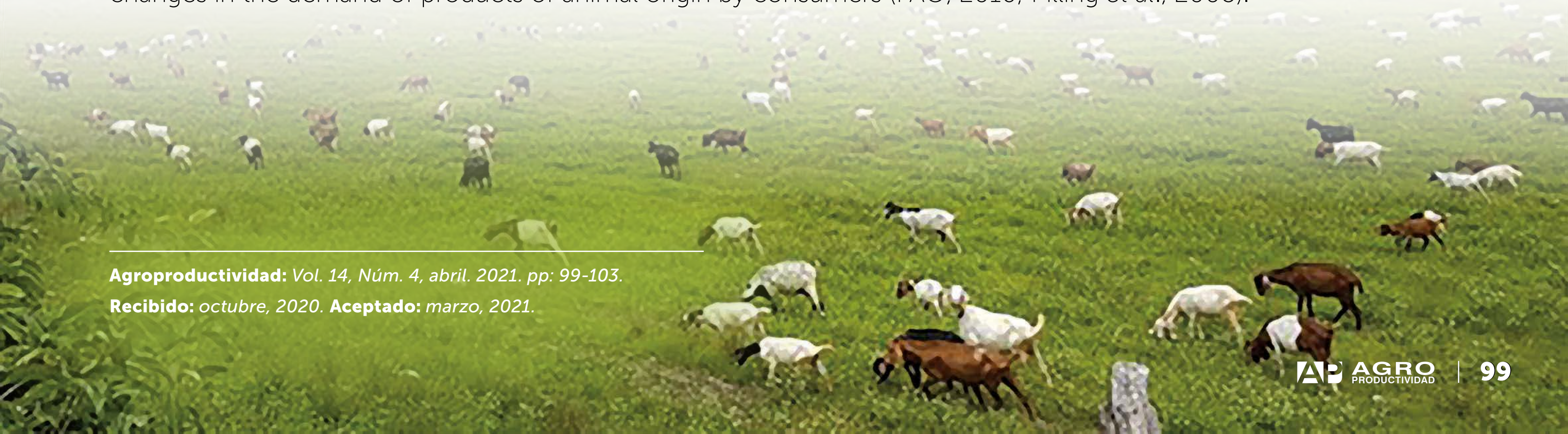
Implications: Using highly productive races that depend on external inputs and are not adapted to face the effects of climate change, make it a priority to appraise the use of local races that contribute to production under adverse conditions that prevail in warm weathers in the inter-tropical zone.

Conclusions: Adapted local race breeders should preserve local animal genetic resources so that they perform as a climate change adaptation alternative that will have repercussions on livestock production systems.

Keywords: Environmental change, local races, biodiversity.

INTRODUCTION

The preservation and improvement of local animal genetic resources is essential so that those who breed these resources may satisfy the production needs of foodstuffs, both now and in the future, that derive from environmental changes. There are many challenges facing the animal breeding and production sector for food supply, such as an increase in demand, poverty, climate change, threats to support forms based on animal breeding, new animal health issues, environmental degradation, as well as the loss of species and races adapted at a local level. This is why efforts should be aimed at responding to changes in the demand of products of animal origin by consumers (FAO, 2016; Pilling *et al.*, 2008).



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Resilience, understood as a system's capacity to recover from a negative event parallel to keeping its basic setup, is a relevant property of agroecosystems in relation to changes in the environment. Biodiversity keeps the resilience of the livestock breeding system, as it provides environmental goods and services that contribute to the profitability and sustainability of such system (Oyhantcabal *et al*., 2010; Morales *et al*., 2016).

One likely scenario accepted by several researchers (Oyhantcabal *et al*., 2010), assumes exceeding the resilience of several ecosystems with the unprecedented combination of climate disturbances (floods, droughts, fires, insects) added to other global changes, such as changes in land use, pollution, and over-exploitation of natural resources. Increases in mean temperatures may exceed 1.5 to 2.5 °C, and include changes of great magnitude in the structure and function of ecosystems and species present, which implies predominantly negative consequences for biodiversity and goods and services, such as food production and water supply.

Currently, the effects of climate change on the production of food makes that the need of fulfilling the development objectives, as well as generating awareness toward the adoption of measures improving the management of animal genetic resources for nourishment become urgent (Pilling *et al*., 2008). Therefore, this work analyzes the references that underlines the importance of local animal husbandry resources and the preservation thereof facing the effects of climate change.

Biodiversity preservation

Reduction in biodiversity compromises ecosystem functions and its capacity to generate essential services for society and the environment. Therefore, biodiversity preservation has gained relevance as a key factor for life sustainability in the planet. Hence the importance of considering the inextricable link of the biodiversity-ecosystem (functions)-agroecosystem trilogue (Velásquez, 2010).

Biodiversity represents the degree of variation of lifeforms. This is the total sum of genes, species, and ecosystems of a region. The suppression of a single species may affect the performance of local and even global ecosystems. Due to their importance as animal genetic resources, global efforts have been made in order to raise awareness on the reduction of biodiversity in animal livestock breeding agroecosystems as well as promoting actions for the preservation thereof (Mara *et al*., 2013; Sharma & Sharma, 2013).

The main objectives of animal genetic resource preservation are a) to keep genetic variation as gene combinations in a reversible manner, and b) to keep specific genes of interest (Figure 1) (Mara *et al*., 2013). The Nagoya protocol sets forth that, upon using gene resources, the performance of research and development activities on the genetic and/or biochemical composition of these resources is allowed; such activities include the application of biotechnology, which is understood as all technology that uses biological systems and live organisms or the by-products thereof for the creation or modification of products or processes for specific uses (FAO, 2011).

PRESERVATION METHODS

In order to preserve animal genetic resources, methods have been used on site, i.e. In the natural or semi-natural habitat or in some specially designed environment. Therefore, the preservation of different animal autochthonous or local species has been performed through the formation of breeding populations (Figure 2); nevertheless, also off-site preservation is available (Miceikiene *et al*., 2003; Sawicka *et al*., 2011; Sharma & Sharma, 2013). Specifically, on-site preservation means preserving live animals in a livestock production system in its surroundings and, if feasible, improving the production characteristics thereof. On the other hand, off-site preservation means two manners of preserving the race

Figure 1. Romosinuano breed cow and Hairless Tropical breed pigs, two local species in development and production in the same environment, the Capilla, Cotaxtla, Veracruz, Mexico.

outside the natural habitat: off-site *in vivo* refers to safekeeping live animals in zoos, natural parks, experimental farms or other specialized centers; off-site *in vitro* is cryopreservation of gene material in haploid form (semen and oocytes), diploids (embryos) or DNA sequences (Lascuráin *et al.*, 2009; Mara *et al.*, 2013).

Figure 2. The creole hen is a local genetic resource of greater importance in feeding rural families. Flock of chickens in the selection process as breeders at the Huilango farm, Cotaxtla, Veracruz, Mexico.

In recent years, off-site *in vitro* preservation programs of livestock gene resources have centered their interest on the cryopreservation of gametes, embryos and somatic cells, as well as testicles and ovary tissues in a cryogenic bank. A cryogenic bank is a place where biological samples are frozen or cryopreserved to keep their integrity for a variety of foreseen and unforeseen uses; it offers unique opportunities to advance basic knowledge on biological systems and the evolution thereof. Also, it represents a useful form for re-directing selection or limiting the loss of gene diversity of a selected race and it is a vital component of efforts to recover gene variability of endangered races or restore races that have extinguished as a consequence of disuse, an epidemic or the destruction of their natural habitat (Lermen *et al.*, 2009; Leroy *et al.*, 2011; Sawicka *et al.*, 2011; Mara *et al.*, 2013). The above actions do not apply as an exclusion; they may be incorporated into a preservation program that integrates, organizes, and coordinates different preservation alternatives with congruency, efficiency and reasoning (Delgado, 2012).

Livestock breeding and climate change

Animal production systems, climate change and animal health are related among themselves through complex mechanisms. Animal production influences climate change upon emitting greenhouse effect gases (GEI) such as methane and nitrous oxide. This situation allows animal production to present significant opportunities for reducing emissions, as well as increasing greenhouse effect gas capture (Oyhantcabal *et al.*, 2010).

On the other hand, the effect that climate change exerts on livestock breeding may be analyzed from several viewpoints:

a) Nutritional - the bovine will consume more lignified pastures, resulting from the increase in temperature, more frequent extreme events, and a decrease in rain.
b) Health - animal health may be affected both by extreme events (*e.g.*, temperature) and the emergence and re-emergence of infectious diseases, some transmitted by vectors, highly dependent on weather conditions, as the climate effect also affects plague insect populations, as they move through thermal floors.
c) Social - there are changes in plant comfort zones and, together with this, cultivation zones in order to improve production, as well as the increase in the incidence of frosts, droughts and floods; and
d) Environmental - heat detrimental effects reduce reproduction rates and livestock productions. Livestock breeding produces greenhouse effect gases (methane and nitrous oxide), the enteric fermentation in ruminants and manure are the main contributing factors for gas emissions in animal production. On the other hand, livestock breeding is one of the few economic sectors that have the possibility to decrease the emission of these gases and extract CO_2 from the atmosphere through mitigation practices as the great potential of pastoralism to increase the efficiency of productive processes, reduce deforestation and sequestrate carbon in soils under grasslands (Figure 3) (FAO, 2016; Garzón, 2011; Oyhantcabal *et al.*, 2010).

Local livestock resources and climate change

It is likely that livestock breeding is one of the activities that suffer more with climate change due to the modification of the agroecosystem that it inhabits. Therefore it is necessary to analyze the part of local races, traditional production systems and, above all,

Figure 3. Herd of goats in grazing system in dry tropical environment in Copalillo, northern zone of the state of Guerrero, Mexico.

grazing, as this activity searches balance between greenhouse effect gas emission and production upon correctly dimensioning the number of animals per sustainable territory unit (Delgado, 2011). For many, it is easy to distinguish between animal production with good environmental sustainability practices and criteria (either traditional or extensive) that generate multiple benefits and animal production that pollutes water, degrades soil, generates deforestation, and erodes biodiversity. Nevertheless, today both types of livestock breeding search the implementation of a greater number of technologies and handling practices that allow improving production processes and reducing GEI emissions (Morales *et al*., 2016).

The advance toward a sustainable livestock breeding that optimizes systems would be a more intelligent response than reducing meat production and consumption (Oyhantcabal *et al*., 2010). Local races and their gene biodiversity make it possible to produce in the most diverse conditions and territories; they support the spread of production in great areas and offer the capacity for soil to sequestrate carbon and perform other mechanisms, such as balancing the emission of GEI with its capacity of fixation thereof, which contributes to the ecology balance of agroecosystems. Therefore, the preservation of animal genetic resources becomes even more necessary before global warming (Delgado, 2011; Delgado, 2012).

Both traditional livestock breeding and that of high technology based on local races, grazing and the balance of livestock loads is related to the preservation of biodiversity and cultural diversity and takes part in the correct management of GEI, especially in the sequestration of carbon (Rodríguez *et al*., 2011; Delgado, 2011).

CONCLUSIONS

The preservation of local animal genetic resources consists in preserving gene variability and genes of economic interest in animal populations used in production. Upon fostering practices that favor diversification and the interaction of local races within the livestock agroecosystem, the use of local livestock resources is fostered, and these constitute a development alternative in the intertropical warm weather zone of the Mexican territory. Livestock breeding production systems that use local races represent a competitive economic reconversion alternative that reduces the environmental impact before climate change.

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Generation of socio-environmental indicators in the territorial structure of San Luis Huexotla, Texcoco, México

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ABSTRACT

Objective: This article aims to show the statistical density of the population per block, to know its effect as a critical spatial result and its relationship with some socio-environmental indicators, this analysis-process incorporates statistical data and geographic information systems as a model for territorial spatial analysis, which shows the relationship between demand and generation of services.

Design/Methodology/Approach: The Urban Basic Geostatistical Units data of INEGI (the Spanish acronym of the National Geostatistical Information Institute in Mexico) was used on block-level as: number of inhabitants and number of dwellings. It was associated with variables identified by exploring those key stakeholders at the locality (Delegates, and the Council for Citizenship Participation (in Spanish, COPACI), as well as the Huexotla Ejido Commissariat, their clergy representative and some other key informants. In addition, GIS were used to digitize vector information and to integrate a relational database for the geospatial analysis of the variables, data and indicators in order to obtain zoning maps.

Results: This study presents a proposal for the generation of socio-environmental indicators that can be used in territorial analysis with urban and rural applications using Geographic Information Systems as a tool.

Study limitations: Transition processes converge in geographic transformation and, consequently have effects on landscape changes; demand for public services; and solid waste generation.

Findings/Conclusions: The size of the scale used for the locality analysis contributes to determine the territorial planning of a geographical space. Thus, results obtained deliver information for planning in the decision-making processes at localities in rural to urban transitional zones.

Keywords: Geographic Information Systems, socio-environmental indicators, territorial structure.

INTRODUCCIÓN

In general, a socio-environmental indicator refers to simplify, quantify, and analyze various phenomena that occur in a social or territorial environment. However, in their classification, there are specific environmental indicators as well as social or economic indicators, etc., that explicitly measure their own objective. Because of that, depending on their origin, merging two indicators seeks to integrate physical and technological aspects in order to consider sustainability, and the economic and social systems at different scales and levels (Dixon and Fallon, 1991).

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Globally, environmental indicators are used to statistically measure the impacts on phenomena such as climate, soil, and species, air quality, etc. that society has generated on environment in a particular territorial space. Some organizations like OECD (Organization for Economic Co-operation and Development) define a set of indicators as base information for periodic assessments of the environmental care performance in different countries of the organization (OECD, 1993). In Mexico, SEMARNAT, through Dirección General de Estadística e Información Ambiental (one of its Directorate Departments), is responsible for the development and updating of the National Environmental Indicator System (SNIA, the acronym in Spanish). This system has interrelation with the National System of Environmental and Natural Resources (in Spanish, SNIARN), which responsibility is to collect, organize and communicate environmental and natural resources information in Mexico. Both systems integrate statistical, geographical and documentary databases that are updated with the information generated by different entities of the Federal, state and municipality levels of government; in order to provide reliable and opportune information for decision-making (SEMARNAT, 2018).

The aim of this article is to explain how to use environmental indicators as an important tool for territorial planning and decision-making processes affecting actions within a geographical area. Such indicators specify how the variable is behaving over the territorial structure; so, they become keys to evaluate and predict trends expressed in reality.

Therefore, indicators are a necessary tool to measure or classify a phenomenon. In this study-case some indicators are considered to acknowledge some important aspects in a territorial space. This study-case includes indicators, based on the areas from a locality, that monitor the problems classified as important by the surveyed stakeholders.

Population dynamics is a function of a territorial pattern, which explains population growth by various factors depending one on each other; as it is the case of variables such as birth, mortality, migration, and immigration. These can have transitions that affect mobility such as environmental or spatial factors that characterize a certain location (Molero, 2007). However, it is essential to observe historical growth rates to get a projection based on growth indexes and to perform demographic calculations on the series of population censuses that occur in Mexico every 10 years. The relationship between the number of people per unit of area in a territorial space is called population density (INEGI, 2010).

The state of Mexico has suffered changes in its surface, due to overcrowding and territorial density. According to statistical data, the state of Mexico has an area of 22, 487.85 km^2; the population density was 582 inhabitants per km^2 in 2000, but in 2010 population density grew to 675 inhabitants per km^2 and in 2015, it was 720 inhabitants per km^2. This means an observed increase in the total population figure from 13 096 686 (2000) to 16 187 608 inhabitants in 2015 (INEGI, 2015).

Regarding the municipality of Texcoco, it has a surface of 422.53 km^2; the population density was 483 inhabitants per km^2 in 2000, and it reached 570 inhabitants per km^2 in 2015. Total population increased from 204 102 (2000) to 240 749 in 2015 (H. Ayuntamiento of Texcoco, 2016). The studied locality (San Luis Huexotla) has an area of 9.52 km^2 and a total of 12 269 inhabitants in 2010; this means a population density of 1288 inhabitants per km^2 in that year.

MATERIALS AND METHODS

a) Statistical information

Statistical information was collected from the results of the 2010 INEGI census with information at block-level of statistical data such as number of inhabitants and number of dwellings.

The considerations of the official census and yearbook data of the study area for the case of San Luis Huexotla, a locality belonging to the Municipality of Texcoco, were taken independently due to its structural conception by INEGI.

Throughout history, San Luis Huexotla has modified its territory due to various circumstances and because there is no definition of limits by any governmental authority, its delimitation is based on considerations of the local authorities who administer and regulate the actions of the locality; its population is also territorially recognized by their uses and customs.

To carry out this study, it was considered to take as a reference the territorial delimitation made by the INEGI from the year 1990, a geographical modification that was

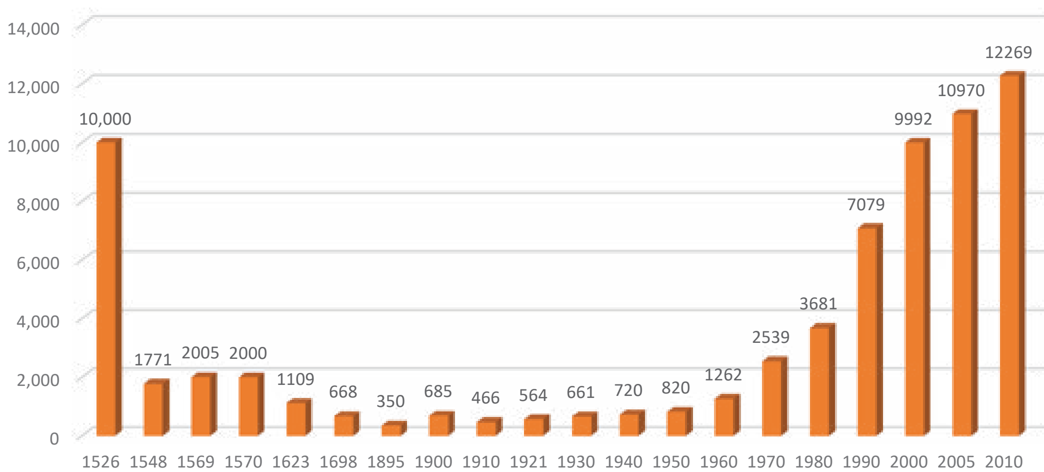

Figure 1. Historical population growth at San Luis Huexotla (Espinosa, 2017).

implemented by that Institute, in order to guarantee the national geographic coverage of the General Census of Population and Housing No. XI. It is stated as well, that in cases such as Huexotla which had some modifications, this data had a code number and statistical information registered. However, such coded data were discarded in 1980, and Huexotla was integrated as a conurbation into the Municipality of Texcoco de Mora, México (Figure 1).

Due to the merging and subsequent integration as a metropolitan area, Huexotla lost its code and name in the National Geostatistical Framework (Marco Geoestadístico Nacional) and became a part of the urban Texcoco, thus sharing features of a population greater than 2500 inhabitants. The division of geostatistical areas includes three levels of desegregation: state (AGEE), municipal (AGEM) and basic (AGEB), the latter divided into rural and urban (INEGI, 2010b). Huexotla is territorially integrated by 5 urban AGEBs (basic geostatistical units), and rural/Ejidal zones, delimited as (Figure 2).

b) Interviews with local key informants

To obtain additional information in this research, we resorted looking for stakeholders within the locality (a.k.a., key informants), who have privileged information that will allow understanding some important elements of the locality. By applying 50 surveys taking a sample from a total of 181 ejidatarios. The key informants according to Martínez (1991) are those "people with special knowledge, status and good information capacity". In our selection, the informants considered pertinent to address the research topic were some auxiliary authorities (Delegates), the former commissariate of the ejido, historians at the locality, clergy representative, the commissioned anthropologist in the INAH zone. The information obtained with each of the key stakeholders helped to determine four indicators (population density, housing, water consumption, and solid waste production).

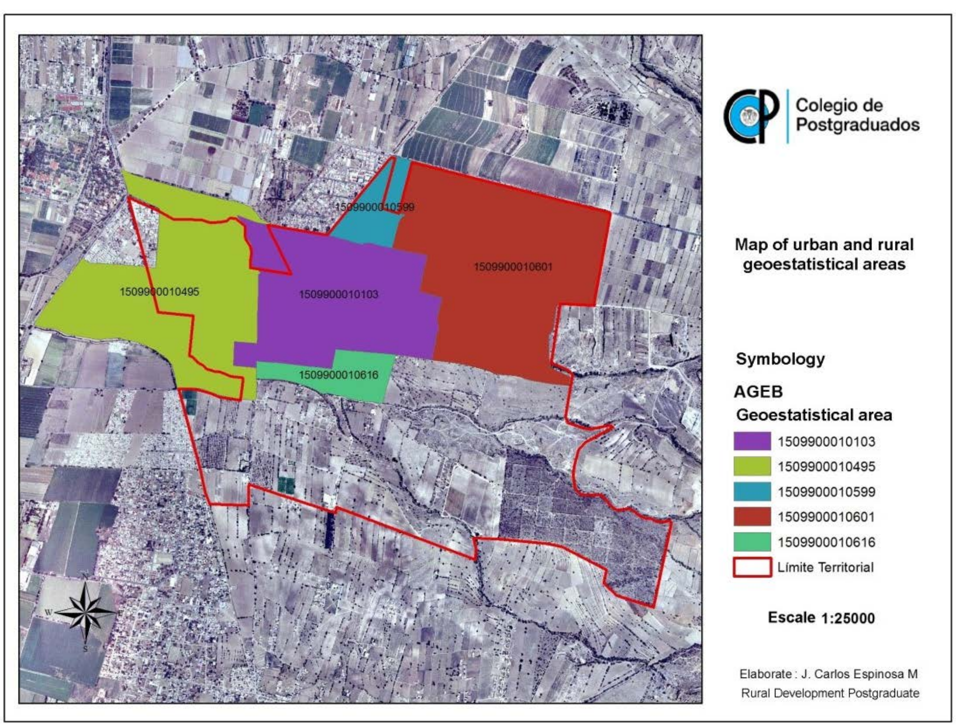

Figure 2. Map of urban and rural geostatistical areas of San Luis Huexotla.

c) Geographic Information Systems

SPOT 6 satellite image. Two images were obtained from the Federal Government remote station (ERMEX NG1) of satellite images from the SPOT 6 satellite. That image was authorized for this investigation (Internal application Num. 101251/0233-2016), with a resolution of 1.5 m in the panchromatic image, which was processed for geometric correction (Espinosa, 2017).

For the digitization of the locality, the INEGI ortho-corrected 1996 photo from SPOT 6, dated May 4, 2016 and the QGis 10.4 software were used. Using each segment, a table of attributes was filled in to identify polygons by color, identifier and name. When digitizing the segments, care was taken to close the units, especially in urban blocks and those buildings where intersections, closure of polygons or segments overlapping were not obtained (Bosque, 1997 and Ortega, 2016).

In the field verification, the following tools were used:

- Verification points were determined, and they were georeferenced by geographic coordinates.
- Data collection with GPS.
- Drone flight and collection of photographic images.
- Georeferencing of drone images, based on the 2007 Orthophoto.

RESULTS AND DISCUSSION

The socioeconomic indicators

a) Population density. The idea of measuring population density is to estimate the number of people living in a geographic space. According to statistical data, the state of Mexico has an area of 22 487.85 km^2 and the population density was 582 inhabitants per km^2 in 2000; 675 inhabitants per km^2 in 2010, and 720 inhabitants per km^2 in 2015. An increase in the population was observed, with a total of 13 096 686 inhabitants in 2000 to 16 187 608 in 2015 (H. Ayuntamiento de Texcoco, 2016). The municipality of Texcoco has an area of 422.53 km^2, and the population density increased from 483 inhabitants per km^2 in 2000 to 570 inhabitants per km^2 in 2015. Total population escalated from 204 102 (in 2000) to 240 749 in 2015 (H. Ayuntamiento de Texcoco, 2016). In the following map, based on statistical data at block-level from the INEGI 2010 Census of Population and Housing, population density was classified per square-block (Figure 3).

b) Housing density per square-block. In the state of Mexico, the number of dwellings is 3 432 480. Texcoco has 51 007 houses and Huexotla accounts for 6.9% of total housing in Texcoco, this is, 3514 dwellings according to the 2010 INEGI Population and Housing Census. In the following map we can see the population density per block at Huexotla.

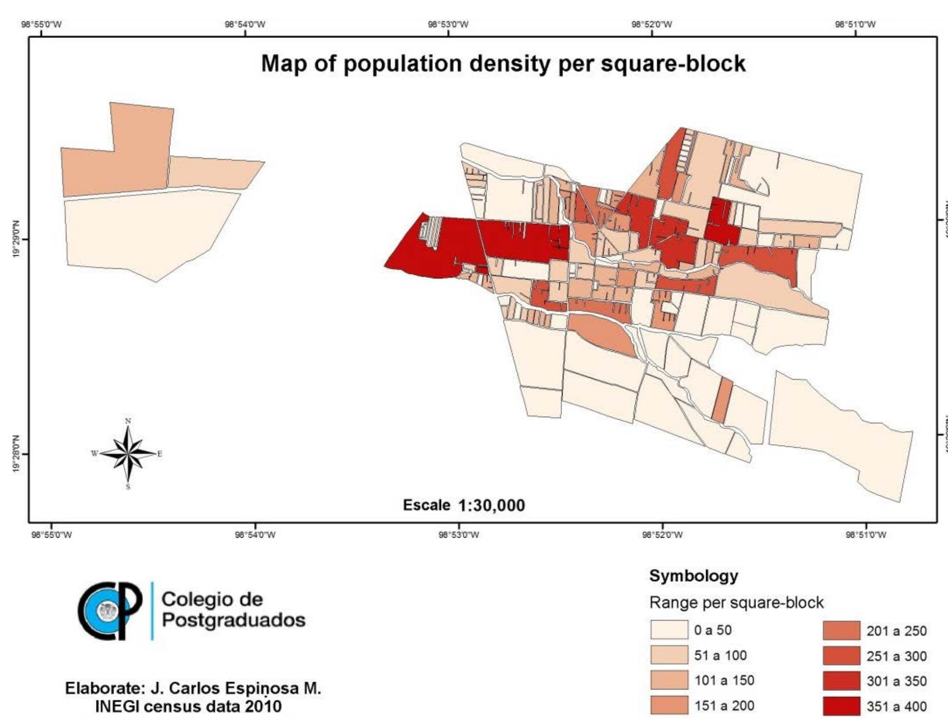

Figure 3. Map of population density per square-block.

The ranges defined in the projection of this map of housing density per block were divided into class intervals from 0-9 up to more-than-110 dwellings. The class that shows the highest density of dwellings is the one located in the western area of the town with 111 dwellings and a population of 338 people in an area of 23 ha (Figure 4).

Environmental indicators

a) Water consumption and demand

The characteristic land uses, as well as the conservation of natural resources are customary to the population of Huexotla. Natural resources

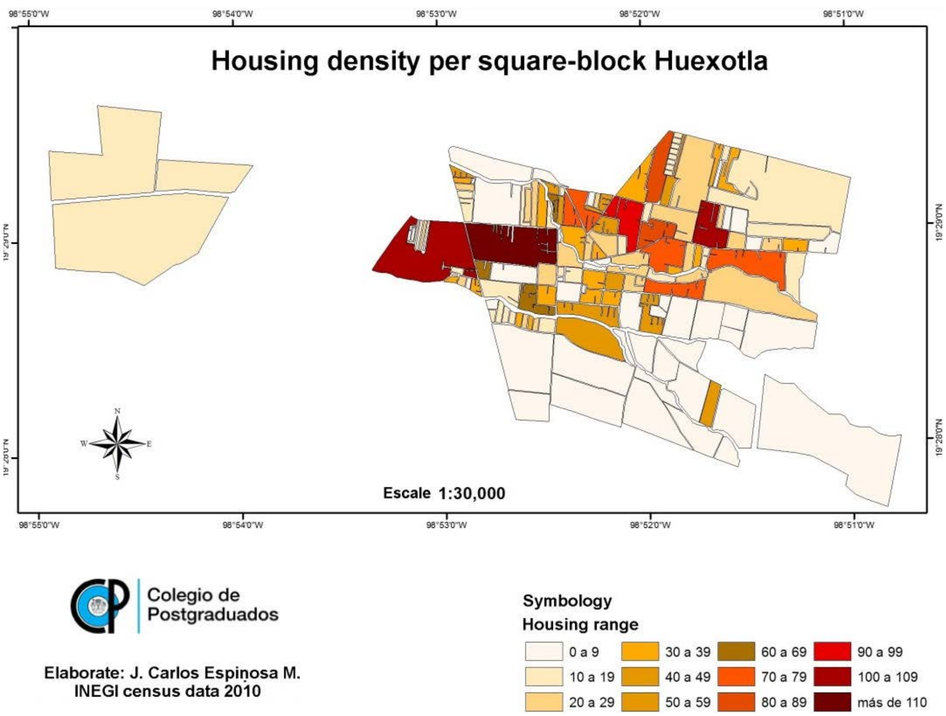

Figure 4. Map of housing density per square-block.

and their degradation rates can be decisive for their conservation, the levels of pollution of water and soils as well as the generation of solid waste are some of those factors resulting from the increase in urbanization. The Sistema Nacional de Indicadores Ambientales (SNIA) integrates 14 indicators that seek to evaluate the progress in the conservation and sustainable use of the environment and natural resources in the country (SEMARNAT, 2016). Some of them are biodiversity, solid waste, atmosphere, water, soil and forest. The importance of analyzing the condition of some indicators at Huexotla is a proof of the condition of its territorial space, the increase in demand for services and the conservation of them. This knowledge makes feasible to carry out resource analysis and decision making for conservation.

Water supply is used mainly by the population, but it is also a major input for agricultural activities and industry (Ki-moon, 2000). Water use should be moderate, since its excessive demand can cause problems as the overexploitation of aquifers, that would risk supply of the resource in the future (SEMARNAT, 2016). Huexotla has wells for the distribution and service of tap water, which are considered in the Table 1.

Table 1. Public water wells.

Location	Number of wells
San Luis Huexotla	2 2 Drinking water spring
San Mateo Huexotla	1
San Nicolás Huexotla	1
Sector Popular	1
Bellavista	1
Fraccionamiento Prywer	1

Because water is a primary resource for human beings, its consumption should be moderate since according to CONAGUA (2009) in Mexico around 320 liters are used per inhabitant per day. This estimation is pertaining only to domestic use by individual. In the following figure we observe the annual tap water demand by population size and per block. Annual water consumption is estimated to be 1433019.2 m^3 (Figure 5).

In Huexotla there are 3514 dwellings that are inhabited by 3 to 5 people apiece, according to the INEGI estimates in 2010. Of that housing total in the town, 3258 are in the urban area, and only 2614 get piped water as a public service; the 256 remaining dwellings are in rural areas and these figures are not considered in the AGEBs delimited for the study area. The following map shows the percentage of piped water supply respect to the number of dwellings, the data considered represents the territorial area of urban AGEBs of Texcoco (Figure 6).

b) Solid waste production

The inadequate management of solid waste can cause a lot of problems, especially on natural resources such as air quality, soil, ground water and surface water. Main effects on humans are diseases, and others indirect as, loss of fauna and landscape deterioration (SEMARTNAT, 2016). Within the waste produced by the inhabitants, several types of solid waste are considered (litter, paper and cardboard, plastics, glass, and metals, among others). Currently the production of solid waste in Mexico is 1.2 kg per person per day according to The World Bank (2012); this figure means for Huexotla a solid waste gross production of 14.7 tons / day in 2010 (Table 2).

The dwellings with drainage are 2818 out of 3514 (total dwellings).

CONCLUSIONS

Huexotla, considered a town with abundant and important agricultural spaces, and identified as a population with farming characteristics, has undergone a process of territorial transformation in terms of structure, modifying its social, economic and cultural activities.

As it was possible to observe in the results obtained from the maps of Population and Housing density, there is an important growth showing that the surface area used for housing is in the central part of the town, but its growing areas are classified as Rural Geostatistical basic units (in Spanish, AGEBs).

The environmental analysis also shows an increase in the demand for public services (water, electricity, drainage), and generation of waste or polluting residues. In 2010 there were 3 514 inhabited dwellings with 3 to 5 people each, which required 1 433 019.2 m^3 of water per year and generated 5373.8 tons of solid waste per year.

In the end, this study is considered pertinent to generate strategies for local authorities regarding the distribution of main services such as water; and to consider the amount of solid waste generated per number of inhabitants in the locality.

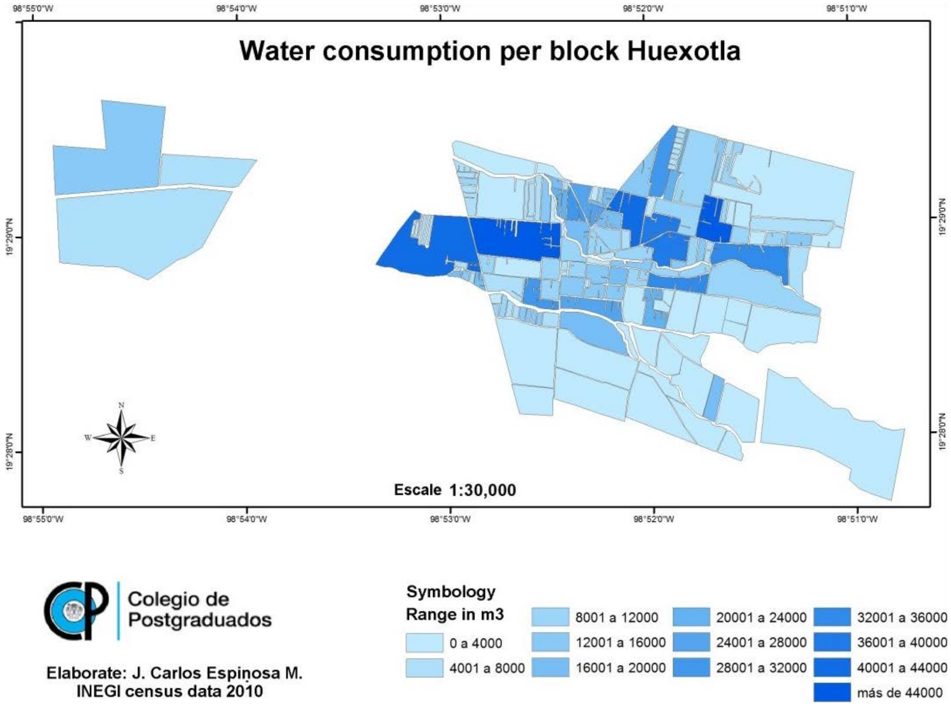

Figure 5. Map of water consumption per block.

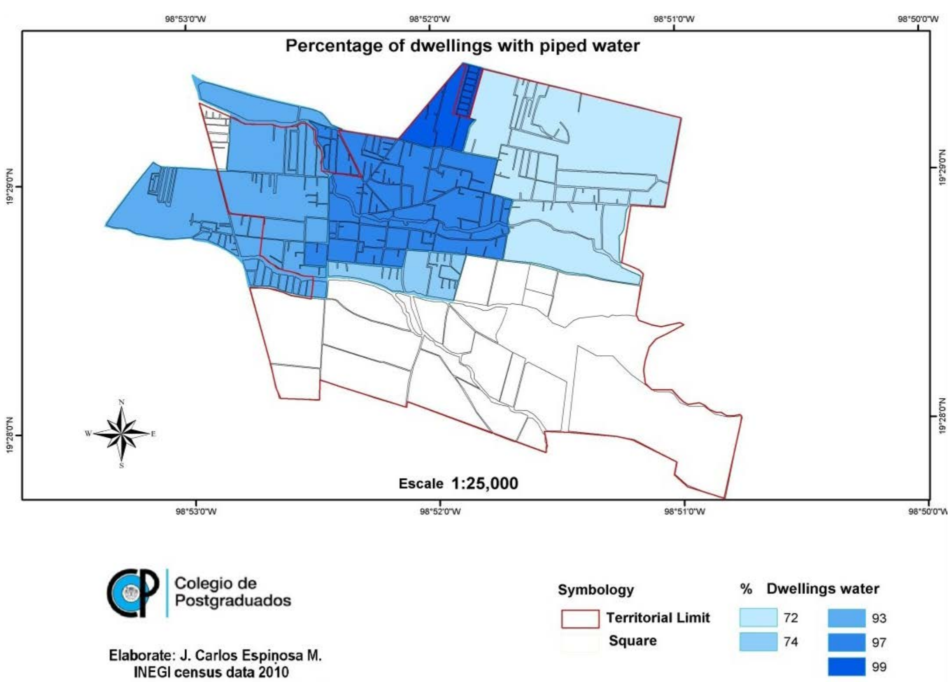

Figure 6. Percentage of dwellings with piped water per geostatistical basic unit (AGEB)

Table 2. Total solid waste per year.

Year	Population	Ton/day	Ton/Year
1980	3681	4.4	1612.3
1990	7079	8.4	3100.6
2000	9992	12.0	4376.5
2010	12269	14.7	5373.8
Total	33021	31.1	11362.6

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Analysis of the Tilapia (*Oreochromis* spp.) Value Chain in the State of Veracruz Rural Aquaculture for the Small Producer

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ABSTRACT

Objective: To analyze the importance of the aquaculture value chain links in the state of Veracruz, Mexico, especially those of production and marketing.

Methodology: The information was obtained in the six main tilapia (*Oreochromis* spp.) production regions in the state of Veracruz through poles based in a questionnaire that addresses key informants; variables related to each link and chain agent were considered; five juvenile producers, 41 tilapia producers and 12 marketers.

Results: A fish farming value chain map was generated with the description of distribution channels, production cost estimation and sales income, as well as the participation of producers in demand.

Implications: The implementation of integrative models is required in order to have a constant supply of inputs from suppliers in farms. Also, associative models that allow accessing markets in units where the high payment availability for the product should be developed.

Conclusions: Chain economic agents are related. Upon meeting the quality and performance required by marketers, there is potential to develop value aggregation strategies through associativity models, linked to service businesses such as restaurants.

Keywords: marketing, distribution, tilapia production

INTRODUCTION

Aquaculture is the technique that allows increasing the production of aquatic animals and plants for human consumption through certain control of organisms and their environment (FAO, 2014). Currently, this aquatic vegetation and animal species farming technique is one of the activities that demands more attention from cooperation organizations due to its capacity to reduce malnourishment and marginalization levels. Its growth has included small-scale units in the global value chain in Asia, where the activity's growth in recent

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years has been exponential. According to the National Geography and Statistics Institute (INEGI), in 2019 the state of Veracruz had 2321 fisheries and aquaculture units, which accounts to 9.5% with respect to the national total. Due to its production volume, tilapia (*Oreochromis* spp.) is positioned in the fifth position in Mexico and third in production value. The mean annual growth rate from 2009 to 2018 was of 9.08% (CONAPESCA, 2018). In 2017, 179 900 t of bream-tilapia were produced; out of these, 30 800 t account for sea bream captures and 149 100 t account for tilapia, of which 93 700 t are produced in aquaculture fisheries consisting in repopulating dams and inland water bodies; the rest is produced in controlled systems (Téllez, 2019). The four main tilapia producing states are Jalisco (20.51%), Chiapas (16.12%), Veracruz (11.25%) and Michoacán (9.45%) (CONAPESCA, 2018). The aquaculture gross domestic product for 2014 accounted for 3.3%, and it is the lowest economic activity in the country and does not represent significant growth (World Bank, 2015).

The value chain methodology applied to aquaculture has been useful in several regions of the world (Macfadyen *et al*., 2012). This model allows assessing problematic aspects of equal distribution and growth aspects that favors the poor, benchmarking assessment, costs and competitiveness, as well as critical points and action programs. Mayoux *et al*. (2007) propose a methodology guideline for the development of research with this approach. Among works of this kind, those of Veliu *et al*. (2009), Ndanga (2013), Engle & Stone (2013), Vivanco *et al*. (2010), El-Sayed *et al*. (2015) and Ponte *et al*., stand out (2014). As a baseline for the generation of market strategies that benefit tilapia value chain competitiveness in the state, the objective of analyzing the importance of aquaculture value chain links in the State of Veracruz with respect to production and marketing, through the value chain approach in the producing regions of the state of Veracruz is posed.

MATERIALS AND METHODS

The study was performed from September to October 2015 in six administrative regions of the state of Veracruz: Totonaca, Nautla, Capital, Sotavento, Papaloapan and Olmeca. 46 interviews were made to producers, biological input suppliers, tilapia feeders and marketers (Table 1) in the municipalities of Papantla, Atzalan, Martínez de la Torre, Tlapacoyan, Emiliano Zapata, Cotaxtla, Jamapa, La Antigua, Manlio Fabio Altamirano, Medellín de Bravo, Veracruz, Paso de Ovejas, Tlalixcoyan, Alvarado, Chacaltianguis and Minatitlán.

The methodological proposal was based on the input by Tallec & Bockel (2005) upon considering elements for a value chain analysis from a functional perspective, hence addressed through flow charts and a baseline economic analysis. Modernization proposals in economic agents foresee market strategies that correspond to market strategies posed by Sandhusen (2002).

Farms were classified based on Reta's typology (2009). The main aquaculture value chain links of *Oreochromis* spp. were identified and structured questionnaires were applied to key informants: producers, researchers, producer associations, technicians and biological input suppliers. Also, questionnaires structured with biological input supplier agents, feeding aquaculture farms and marketers were used to obtain detailed information of production volumes through different incurred

Table 1. Regions and municipalities where the types of interviewed producers live.

Region	Municipality	Questionnaires			
		Juvenile Producers	Tilapia Producers	Marketer	Total per Region
Totonaca	Papantla		1		1
Nautla	Atzalan		4		4
	Martínez de la Torre		4		4
	Tlapacoyan		1		1
Capital	Emiliano Zapata		2		2
Sotavento	Cotaxtla	1	1		2
	Jamapa		1		1
	La Antigua		3		3
	Manlio F. Altamirano		2		2
	Medellín de Bravo	1	11		12
	Veracruz		2	12	14
	Paso de Ovejas		1		1
	Tlalixcoyan	1	2		3
Papaloapan	Alvarado	2	4		6
	Chacaltianguis		1		1
Olmeca	Minatitlan		1		1
				Total	58

distribution channels, average sale price per kilogram and sales income.

Schematically, the research involved the following phases:

- Adjustment of research limits, as well as links and interviewed economic agents;
- Identification and description of activities performed by each economic agent, from the obtainment of raw materials up to the sale to the final consumer;
- Identification of aquaculture farms, depending on the proposed typology;
- Quantification of physical flows. Polls allowed estimating production volumes through different channels concurred by tilapia producers, as well as production costs and income from sales generated in each proposed typology for the study thereof.
- Estimation of local aquaculture participation in the demand of the fisheries market located in the municipality of Veracruz.
- Proposals of improvement for the aquaculture producer typology in Veracruz for the development of potential markets.

RESULTS AND DISCUSSION

Out of 58 questionnaires applied in 39 towns in 16 municipalities, 44 aquaculture farms were foreseen, two of which produce and feed juveniles and three prepare biological inputs (juveniles) only.

Chain Link Identification

Biological input suppliers: These are companies and producers that supply juveniles to tilapia feeders.

Tilapia feeder producer: There are three different levels. Industrial tilapia producer with productions above 41 000 kg per month. Entrepreneurial tilapia producer with production from 10 000 to 40 000 kg per month. Intermediate tilapia producer; those with a sales volume between 5000 and 10 000 kg per month. Small-scale tilapia producer with production from 1000 to 5000 kg per month. Starting tilapia producers are self-consumption producers who obtain from 1 to 1000 kg per month.

Wholesale Agent: They are marketers who have the capacity to purchase more than one tilapia ton per month by contract and supply retailers or mobile sales points, as well as restaurants.

Retailers: (Stationary tilapia sales point). Those retailers that condition an ideal environment to attain the survival of aquatic organisms (tilapia) purchased at feeding farms with the purpose of preserving them alive until the sale thereof.

Mobile tilapia sales point: They are merchants who purchase live products at feeding farms, which are placed in tanks with oxygen in order to transport them alive to rural communities, which generates a short-cycle process.

Integrated sales point: Stationary sales points installed as feeding aquaculture farm startup in order to distribute the products thereof.

Integrated restaurant: Venues part of feeding production units, where cooked products with added value are sold.

Restaurant: Businesses within rural communities that purchase products from feeding farms.

"Plaza del Mar" Seafood Market: The market where most of tilapia is distributed in the state. It is located in downtown Veracruz City.

Final farm gate consumer: Farm distribution channel that sells its products to its town's inhabitants as well as those from nearby zones.

Farm identification: 41 aquaculture farms were found; two produce juveniles and feed tilapia; three produce juveniles for local, state and national trade only. Table 2 shows the type and number of farms found in the state of Veracruz. Farms that produce juveniles are not included in the table.

Quantification of physical flows

The only production unit classified as industrial takes part with 64.5 % of the total live tilapia marketed by farms;

Figure 1. Tilapia value chain links identified in Veracruz.

Table 2. Classification and number of feeding aquaculture farms recorded in the research in the state of Veracruz.

Type of farm	Industrial	Entrepreneurial	Intermediary	Small-scale	Startup	Total
Number	1	14	8	3	12	38

that is, 66 666 kg per month. Entrepreneurial-type farms take part with 29.1% of the volume (30 118 kg per month); intermediate type participate with 3.6% (3700 kg per month); small-scale with 2.5% (2532 kg per month); self-consumption or startups barely participate with 0.3%.

Aquaculture farms generating biological inputs produce 3.3 million juveniles per month in the territory for the sale thereof here and in other states of the country. In tilapia feeding farms, industrial types destine 65.9% to wholesalers. That is, Plaza del Mar in Veracruz City. Entrepreneurial-type producers market 4.3% to the wholesale link and 4.0% to Plaza del Mar. The retailer link, which sales the product within the chain, accounts for 72.0%, comprising restaurants (6.1%), mobile sales points (36.9%); stationary sales points (7.2%); integrated sales points (9.3%) and restaurants integrated to production units (12.6%). Farm gate sale accounts for 23.6%.

Intermediate tilapia feeders supply 5.8% of the total production volume for wholesalers; these are represented by restaurants located in rural areas. Stationary tilapia sales points account for 10.8%, mobile sale points 6.5%, restaurants integrated to farms 14.1%, and farm gate sales 62.8%, and this distribution channel gets most of sales. Due to their low volume, small-scale producers are related to three distribution channels: in the retailer link, restaurants absorb 10.8%; in the retailer link, mobile sale points take 13.4%; finally, the final consumer farm gate sales account for 75.8% of sales. Startup or self-consumption producers consume their own tilapias.

Plaza del Mar sells 142.5 t of tilapia in the Veracruz-Boca del Río-Medellín metro area; aquaculture participation of the state in urban demand accounts for 40.8%; the only company of industrial type supplies 98.2% and entrepreneurial producers supply 1.8%. In Plaza del Mar, products supplied from outside the state come from Chiapas (43.1%), Nayarit (8.4%), Mexico City (La Viga Market, 2.3%), and other marketers (5.4%).

Production costs

According to the Veracruz State Tilapia Master Plan, the main costs are: Variable costs, attributed to labor, food, juveniles (breeding), electricity, water, gasoline, maintenance and telephone; fixed costs refer to professional salaries, office expenses, construction and machinery.

Analysis of variable costs

Entrepreneurial-type producers destine 65% of their variable costs to fish food, which is the main input for production; intermediate producers destine 56.0% while small-scale ones destine up to 97.2%. In that same order, electric power accounts for 28.8%, 21.3% and 2.20% of variable costs. Last, the cost of juveniles considers 5.3%, 22.7% and 0.6% of costs, respectively. Some farms, mostly those far away from distribution centers, choose to reproduce their own offspring; in some cases, small-scale farms feed juveniles found in feeding ponds.

Sales income

Entrepreneurial typology producers. Eight links are found with entrepreneurial producers that market their production (Table 4). They have both mobile sales points and marketers, and these represents the highest sales income (31.48%) and their income adds up to MX$527 682 per month.

Intermediate typology producers. As shown in Table 5, intermediate production units showed commercial relations among five distribution channels; based on sales, the most relevant one is the farm gate sale, followed by restaurants integrated to aquaculture farms and, in third place, stationary sales points.

Table 3. Unitary production costs per state tilapia producer typology.

	Entrepreneurial	Intermediate	Small-scale
Average variable cost (MX$)	33.40	36.60	50.71
Average fixed cost (MX$)	8.28	19.66	14.74
Unitary total cost (MX$)	41.68	56.26	65.44
Average sale price (MX$)	51.66	68.17	50.46
Gross margin (MX$)	9.98	11.91	−14.98

Small-scale typology producers

Small-scale producers market tilapia within three distribution channels. 8.52% for restaurants (MX$12 000). Mobile sales points account for 9.95% of their income (MX$14 000), and farm gate

Table 4. Monthly marketing in entrepreneurial typology producers.

Trade links	Average sale price (MX$)	Monthly sales (kg)	Income (%)	Sales income (MX$)
PVTVCP	43.00	100	0.25	4 300
Plaza del Mar	35.00	1200	2.50	42 000
Restaurant	38.60	1850	5.46	91 600
Mobile PVTV	47.00	11 100	31.48	527 682
Stationary PVTV	50.52	2175	6.71	112 525
Integrated PVTV	60.00	2800	10.24	168 000
Integrated restaurant	84.00	3796	20.30	340 261
Farm Gate	55.42	7097	23.24	389 525
Total	62.49	15 868	100.00	1 672 893

*PVTCP (Colegio de Postgraduados' Tilapia Sales Point), a rural innovation project with public financing implemented in certain towns of Veracruz to promote tilapia marketing and consumption. PVTV (Live Tilapia Sales Point).

Table 5. Monthly marketing in intermediate typology producers.

Trade links	Average sale price (MX$)	Sales volume (kg)	Income (%)	Sales income (MX$)
Restaurant	50.00	215	4.53	10 750
Mobile PVTV	50.52	240	6.07	18 000
Stationary PVTV	45.00	400	7.59	14 400
Integrated restaurant	84.00	520	28.52	67 600
Farm Gate	55.42	2325	53.26	126 225
Total	56.99	3700	100.00	236 975

Table 6. Monthly marketing in small-scale typology producers.

Trade links	Average sale price (MX$)	Sales volume (kg)	Income (%)	Sales income (MX$)
Restaurant	50.00	240	8.52	12 000
Mobile PVTV	47.00	300	9.95	14 000
Farm Gate	54.38	1692	81.52	114 691
Total	50.46	2232	100.00	140 691

sales account for the main income source (81.52 %). The total monthly sales amount to MX$140 691 for 2232 kg (Table 6).

DISCUSSION

The agent involved in the industrial typology tilapia value chain shows an orientation toward the wholesale market; the sale price that they get is the lowest one in all the above mentioned typologies and they access the Fisheries Market or Plaza del Mar in Veracruz City, which demand the highest production volumes in the state.

According to Trienekens (2011), market access sought by producers in developing countries depends mostly on technological capabilities, available infrastructures, negotiation capacity, as well as market knowledge and advice. The farm has a single-segment strategy, according to Stanton *et al*. (1980), which involves choosing the goal of a single open segment in the whole market, with a mixture of marketing in order to reach that single segment. Farms that manage to keep production through high investments decide to supply markets where the sale price is substantially lower (MX$20.00 cheaper) than the average pool gate price. In relation to the wholesale link, among entrepreneurial producers, on-farm sales account only to one fourth of sales. According to Asche *et al*. (2001), the market structure is important for the potential growth in aquaculture production, as the channels that demands lower tilapia volumes are those that offer a higher price for producers. Within the entrepreneurial typology, retail sales represent the most important link; mobile sale points contribute with 3/10 of the total income. These marketers have a rapid product capacity in rural areas and purchase live tilapia at aquaculture farms very frequently.

The sale price for final consumers in rural zones is higher than the one offered at the fisheries market. Tilapia sale points integrated to farms were identified. According to Sandhusen (2002) this is called an integrated growth strategy and occurs whenever the company increases its control on its distribution system. Also farms that provide added value to their products upon integrating restaurants to their production units were found. Intermediate typology tilapia producer sales are mostly made through the farm gate distribution channel. This represents half of the total income in the classification, as well as integrated restaurants that account for 3/10 of their income. This shows horizontal integration strategies in a group of tilapia feeders upon purchasing live tilapias among themselves at a preferential price in case their farm stock were depleted. Small-scale aquaculture farms foresee most of their income from farm gate sales: Finally, starting producers produce only for their family's consumption and sale to neighbors from their own communities.

CONCLUSIONS

Aquaculture farmers determine the number of distribution channels depending on their sales volume. Upon having a farm gate sale incapacity when having a high production level; that is, when the offer outweighs the local demand, the amount of distribution channels and physical flows to each of them increases. Market strategies identified among producers seek to keep constant sales beyond the obtainment of higher income through the addition of value to production. The implementation of integration models may supply constant inputs to farms from suppliers. Also, association models that allow accessing or developing markets with a greater availability of better payments for products should be developed.

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Strategy to strengthen the traditional milpa family production systems

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ABSTRACT

Objective: To characterize family production units (FPUs) to identify critical points for their activities and propose intervention strategies for them.

Design/methodology/approach: The research took place at Yaxcabá municipality, state of Yucatán, Mexico. It is descriptive and its information obtained through 1) a questionnaire in a mobile application compatible with the Android operating system, structured by modules: producer data, FPU characteristics, crops, infrastructure, machinery, equipment, and marketing. The sample size was randomized with replacement, under the maximum variance condition, 2) assessment visits to the farmer's plots and 3) participatory community diagnosis workshops.

Results: The traditional milpa system was oriented to the cultivation of corn, beans and squash of creole origin, for consumption by the FPUs with minimum technologies usage. Through apiculture, producers obtain an economic resource to finance other activities, including those of the milpa. It is, therefore, necessary to strengthen their productive capacities of this activity with a chain approach, for the diversification of their products and derivatives of their hives that allow their income to increase.

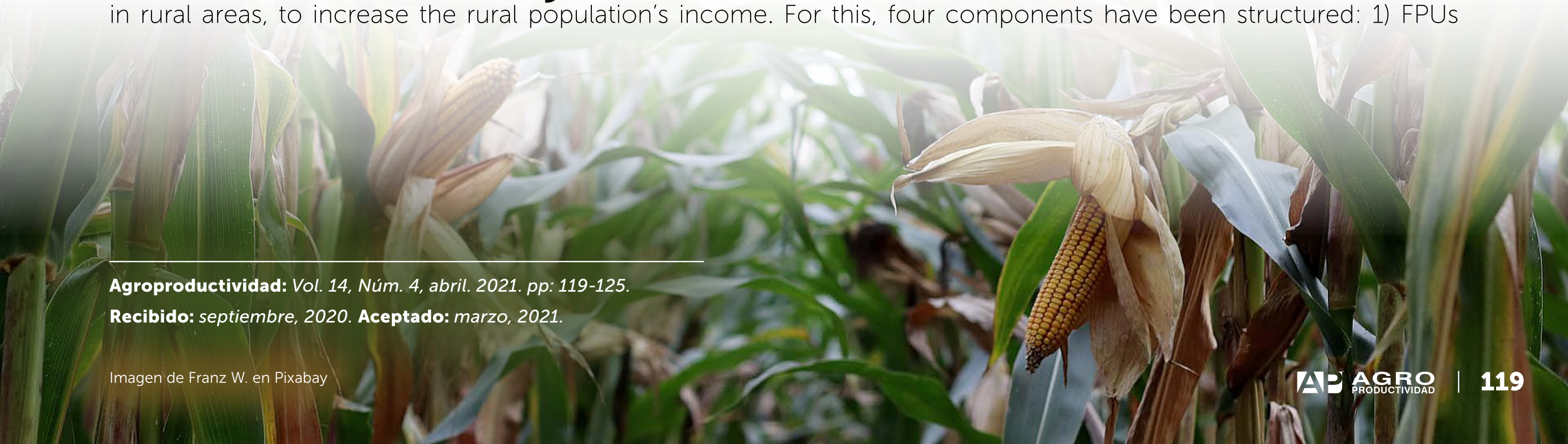
Limitations on study/implications: The proposals and intervention strategies may only be applied to the production system in the evaluated area.

Findings/conclusions: The strategies for the traditional milpa production should be oriented to food security, biodiversity preservation and the nutritional health of their related population. Apuculture strategies should aim to include producers in the value chain.

Keywords: PRODETER, UPF, milpa, rural development, apiculture.

INTRODUCTION

The main objective of the current rural development program in Mexico is to increase the productivity of family production units (FPUs) in rural areas, to increase the rural population's income. For this, four components have been structured: 1) FPUs



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strengthening, 2) Economic integration of the productive chains, 3) Capacity development, extension and rural advice, and 4) Research and technology transfer. The latter, where this research is framed, aims to articulate research with extensionism to promote the application of technological components, as well as address structural problems in rural environments or productive chains (SADER, 2019).

To achieve this, the Territorial Development Projects (PRODETER) were created. These, through investment, both in assets and knowledge, serve small producers in high and very high marginalization areas, applying gender equity and social inclusion criteria in the FPU (SADER, 2019).

The PRODETER projects are made up of three elements: 1) productive technical diagnosis for the FPU, 2) technology transfers, and 3) Technical support strategies. Taking the characteristics of FPUs as a reference, a PRODETER was established in the municipality of Yaxcabá, Yucatán, Mexico.

This municipality has high rates of marginalization, which limits the population's social opportunities and the ability to acquire or generate them. Likewise, they have deprivations and inaccessibility of fundamental goods and services for their well-being, the majority of this population (95.1%) are indigenous (SEDESOL, 2015).

Although the municipal poverty indicator decreased from 2010 to 2015 by 2.2%, 70.7% of the population are in poverty conditions; 50.4% report moderate poverty and 20.3% extreme poverty. The most frequent social deficiencies among the population were social security and basic housing services (CONEVAL, 2015).

Regard their agricultural production, corn cultivation continues to be of greater importance, due to the planted area and the value of the production. Even though in a smaller area, vegetables of high commercial value such as watermelons and habanero peppers also stand out (SIAP, 2018).

For these reasons, the objective of this research was to characterize the technological degree of the FPUs of a PRODETER in Yaxcabá, to generate knowledge that allows identifying critical points to propose intervention strategies in that area.

MATERIALS AND METHODS

A descriptive investigation was carried out in family production units of a "milpera" community, at Yaxcabá municipality, state of Yucatán, Mexico, located in the central region of the state, between parallels 20 ° 19' and 20° 49' north latitude and meridians 80° 36' and 88° 56' west longitude, 7 masl altitude and 1475 km^2 total area (INAFED, 2010).

The information was obtained through a questionnaire in a mobile application compatible with Android operating systems, structured by modules (producer data, characteristics of the production unit, characterization of crops, infrastructure, machinery and equipment, and marketing) and evaluation visit to the plots of producer for information validation.

The sample size was obtained by random drawing with replacement, under the maximum variance condition p=50% (p=0.5) and q=50% (q=0.5) following the formula suggested by Snedecor and Cochran (1967):

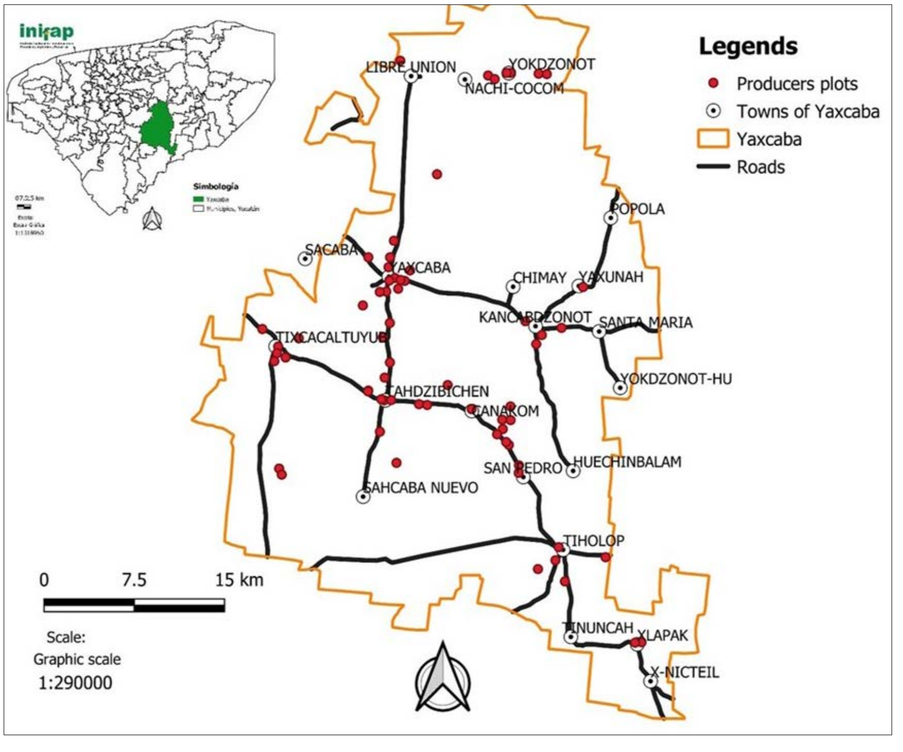

Figure 1. Municipality geographic location and assessed agricultural plots in Yaxcabá municipality, Yucatán, Mexico.

$$n = \frac{\frac{Z^2 p_n q}{d^2}}{1 + \frac{Z^2 p_n q}{N\, d^2}}$$

Where: Z=Confidence level at 95% (1.96), d=Level of precision 10% (0.10), p_n=Proportion of the population from the group of interest, q=(1−p_n), N=Population size (390 registered PRODETER producers) and n=Sample size.

Likewise, workshops were held, and two community participatory diagnosis techniques were used: 1) Brainstorming, to obtain information on factors that limit production and 2) problems prioritization with a double-entry matrix (Geilfus, 1998). The data were analyzed with the Predictive Analytical Software and Solutions (PASS) statistical package version 21, for the description of the variables.

RESULTS AND DISCUSSION

Among the most outstanding characteristics of the interviewed producers 87.5% of the corn producers are also beekeepers, hence the importance of this activity as secondary to this PRODETER. Furthermore, the combination of slash-and-burn agriculture with beekeeping is indicated by Güemes-Ricalde *et al*. (2003) and Pat-Fernández *et al*. (2020) as a complementary activity, not only in milpa systems but in other subsistence activities such as forestry, livestock and backyard animals.

The average age of the producers was 50 years and five years of school. This data coincides with that from Uzcaga *et al*. (2015) for corn producers and that from Pat-Fernández *et al*. (2020) for beekeepers. 97% of the family production units (FPUs) were communal land and 3% privately owned.

In the assessed plots, in addition to corn, a hectare of beans (62.5% black and 6.3% white) and squash were established associated. In this system, there are different variants of slashing-grave-burning-long fallow until the clearing of short fallow (Dzib-Aguilar *et al*., 2016). The sowings were established in dryland farming from April 15 to August 30, however, most producers (64.1%) sowed from June 1 to July 30, the recommended sowing period (Medina and Rosado, 2015). All the producers used creole seeds of which 64% were white, 33% yellow and 3% purple.

These seeds come from variants like "Tuxpeño", "Dzit-Bacal", "Nal-Tel" and combinations of these. It is documented that the use of hybrid seeds and even free pollination improved varieties, have not been successful in the "milpa" production in the region (Dzib-Aguilar *et al*., 2016; Uzcaga *et al*., 2017) since, most of the producers continues to sow their creole seeds due to their taste preferences being the main ingredients in their diet (De los Santos-Ramos *et al*., 2017). Also, selling these seeds represents an important income for small-scale producers (Hellín and Keleman, 2013) (Table 1).

Through the participatory workshops, it was identified that producers perceive their production system to be vulnerable to extreme weather conditions, either due to lack of rain or floods. This is because erratic weather in

Table 1. Characteristics of traditional "milpa" corn production in Yaxcabá municipality, Yucatán, Mexico.

Technological and management		Socioeconomic and cultural	
Types of species	Corn (*Zea Mays*) alternately with: Beans (*Phaseolus* spp.), Pumpkin (*Cucurbita* spp.).	Production objective	100 % subsistence
Varieties used	73% Creoles and 27% Improved Creoles		
Cultivation system	Polyculture	Plot Type	Family
Applied technology	Milpa-roza		
Intensity of space use	It is grown for two to five years.	Production scale (ha)	2.6
Tools	Espeque, coa to weeding, machete		
Fertilization (kg/ha)	78% applied fertilizer. The majority applied a single dose of 16 kg (Nitrogen) + 35 kg (Penta phosphate) 30 days after sowing.	Marketing / Storage	Self-consumption 51% troje, 40% sacks, 7% dairy and, 2% in wooden boxes
Labors	Sowing was carried out with a single row spar. They do weed and use low doses of herbicide.	Yields (t/ha)	0.5

Note: Espeque (XÚUL), a planting stick used to make holes and deposit the seed. The Creole seeds are from the Tuxpeño Breed (X NUUK NAL) with a long cycle, white color, an intermediate cycle Dzit-Bacal breed and early varieties such as Nal-Tel (X MEJEN NAL).

the Yucatan Peninsula, as well as damages caused by hurricanes and deforestation, negatively impacting not only the milpa systems but also the apiculture (Güemes-Ricalde *et al.*, 2003; Martínez-Puc *et al.*, 2018; Dzib-Aguilar *et al.*, 2016). The main identified problems for corn production in the traditional milpa are listed in order of importance in Table 2.

According to Rodríguez-Canto *et al*. (2016) a family consumes 5 kg of corn per day, equivalent to 1825 kg per year. The interviewed producers barely cover their consumption requirements since the estimated production for the spring-summer cycle was 1300 kg. Therefore, they buy corn to cover their needs for the rest of the year.

One factor that impacts performance is the resting period. In the past, the land was cultivated for two to five years, and then the plot was left to rest from ten to one hundred years, so that the natural vegetation could regenerate (Aguilar *et al*., 2003).

Today the dominant lands in the Yucatan Peninsula are five to seven years old, also the ones with the lowest yield (400-500 kg/ha), even with fertilizers addition and adequate weather (Rodríguez-Canto *et al*., 2016).

For 20% of the producers, the value of their production was insufficient to cover their food requirements if corn production was their only activity. Since the estimated value was $1000 at the end of the agricultural cycle, which is lower than the $1149.2 per month of the minimum welfare line for the rural population (CONEVAL, 2020).

In this regard, Rodríguez-Canto *et al*. (2016) mention that 50% of the households dedicated to the milpa system in the Yucatan Peninsula were in income poverty, meaning they did not have sufficient economic resources to achieve minimum well-being.

This situation has fostered a vicious circle among small-scale producers and, since they do not have the necessary means to survive, producers end up depending on low-skilled low-paying jobs, which do little to improve their food security (Pat *et al*., 2010; Rosales y Rubio, 2008).

In this scenario, apiculture plays a priority role within the family economy, since it is a commercial product that

Table 2. Prioritization of the problems for corn cultivation in the traditional milpa system at Yaxcabá municipality, Yucatán, Mexico.

Problem	Description	Classification	Strategy
1. Rain Shortage	Producers are susceptible to adverse weather conditions such as drought, due to insufficient accumulated precipitation per month during the June-August period.	A	Vegetable mulch Sowing dates
2. Lack of irrigation infrastructure	Only 15.6% of the producers have an irrigation system with an average surface area of 2 ha, where watermelon, hot peppers and tomato are grown.	T	Rainwater harvesting. Realif irrigation
3. Low yields	The average yield was 0.5 t/ha and this production does not satisfy the family demand.	A	Improved Native Corn Seeds. Topological arrangement for density increase.
4. Seed availability	The producers used Creole seeds. Most are "own" seeds that they reserve from the previous cycle, which is selected for the size of the ear but without adequate control of the agronomic characteristics.	S	Mass selection to obtain seeds.
5. High cost of agricultural inputs (seed, agrochemicals)	95.3% applied low doses of fertilizer (80 kg/ha from 18-46-00) due to the lack of economic resources for the purchase of inputs.	E	Use of biofertilizers such as: mycorrhiza y *Azospirillum* spp. Composting and use of biosustainable bedding.
6. Delay in payment or delivery of subsidies	During the participatory workshops, information was collected on the timeliness of the resources from the different supports, which frequently arrive late and, therefore, cannot be used efficiently in cultivation.	S	Strengthen the association between producers.
7. Lack of pest control	75% of the plots with corn had the presence of the fall armyworm plague.	T	Uso de *Bacillus thuringiensis* (Bt) for fall armyworm control. Monitoring with pheromones and bioinsecticides.

E=Economic; S=Social; A=Environmental; y T=Technical.

has allows obtaining the monetary income that the milpa systems no longer provides (Rosales and Rubio, 2008). Besides, these resources also finance other productive activities, since on average apiculturists invest 2.25 days for this activity (Martínez-Puc *et al.*, 2018).

However, apiculture is also an activity where the honey is traditionally extracted to obtain both, honey and wax. Most of the 87% of apiculturists carried out their work manually, with a production scale of three apiaries, which coincides with the national average (Magaña *et al.*, 2016) and 30 hives per beekeeper. However, the number of hives can vary over time. For example, Magaña and Leyva (2011) estimated 17.9 hives and Magaña *et al.* (2016) estimated 35.6 hives per beekeeper in Yucatán. Likewise, the other two apiculture-producing entities in the Yucatan Peninsula had reduced their hives over time. Magaña *et al.* (2016) estimated 30.4 beehives for Campeche and 30.6 for Quintana Roo, Mexico, and, recently, Martínez-Puc *et al.* (2018) estimated 20.26 beehives for Campeche, Mexico, and 20.6 beehives for Quintana Roo.

On other hand, a production of 362 kg of honey was estimated per beekeeper, out of which, 50 kg were for self-consumption and 312 kg marketed in different sales points a $19 per kg price, below that registered for the municipality by the SIAP (2018) of $37.1 per kg. The average wax production was 25 kg, for self-consumption. This panorama has not changed and coincides with the primary vocation where productive diversification is limited to honey and wax.

Like the production in milpa systems, apiculture has been undercapitalized by the unfavorable economic conditions in the country (Magaña and Leyva, 2011). This decapitalization has limited the adoption of new technological practices, which means lower returns (Table 3).

The main problem identified by apiculture was the high cost of its inputs and, in sixth place, the labor shortage. In this regard, Magaña *et al*. (2016) showed that in the costs of the structure for honey production in Mexico 67.1% corresponds to variable costs, of these 31.2% corresponds to the wages value and 12.2% to food inputs acquisition such as sugar.

Another identified problem was the commercialization of the honey due to the different factors (Table 4). Studies carried out in the Yucatan Peninsula highlight that apiculturists have no bargaining power in most markets (Magaña and Leyva, 2011). Also, there are two marketing channels: 1) conventional honey for export marketed by apiculturist, local collectors, cooperatives and private trading companies and exporters and 2) conventional honey for the local market, marketed otherwise through apiculturist, local retailers and to the consumer (Pat-Fernández *et al.*, 2020).

Regard pests and diseases, 94.6% of the apiculturist reported experienced a disease transmitted by the Varroa destructor mite. In another study carried out in Yucatán, Martínez-Puc et al. (2018) found that 93.1% of the interviewed apiculturist reported the presence of that disease in their apiaries. However, unlike that study where all the beekeepers knew about the mite, only 35% of the Yaxcabá beekeepers could identify the Varroa destructor mite.

Table 3. Characteristics of honey production in Yaxcabá municipality, state of Yucatán, Mexico.

Technological and management		Socioeconomic and cultural	
Species	Honeybee (*Apis mellifera* L.)	Production objective	13.8% subsistence, 86.2% sale
Applied technology	87.7 % manual, 12.3% mechanical	Type of plot	Family
Tools	Smoked, veil, alzaprima, gloves, boots, extractor, overalls.	Production scale	Number of apiaries: 3, number of hives: 30
Feeding	June-November; with granulated sugar, sugar syrup, or honey	Commercialization	34% contract with the industry, 32% direct to the consumer, 18% collection center, 12% producer organization and 4% foot of plot.
Method used	36% with feeder, 31% with plastic bottles and 33% others.	Yields (kg/hive)	4
Labors	Obtaining queens, changing panels, dividing colonies, changing queens, dealing with colonies, swarming, joining hives and capturing swarms.	Sales volume/year (kg)	312

Table 4. Prioritization of the problem for apiculture in Yaxcabá municipality, state of Yucatán, Mexico.

Problematic	Description	Classification	Strategy
1. High cost of inputs	It affects the sustenance feeding of bees during the period of scarce flowering since it is based on granulated sugar or syrup.	E	Design of competitiveness strategy with a chain approach. Differentiation of honey according to origin and handling.
2. Lack of marketing channels	It was identified that there are two marketing channels: direct sales to the consumer or contract with the industry. However, beekeepers expressed the need to improve 1) sale price, 2) quality, 3) presentation, and 4) added value.	E	
3. Low price of honey	66% of beekeepers considered that the selling price of honey $ 19 per kg was bad.	E	
4. Lack of a collection center	89.3% of beekeepers expressed the need for a collection center to improve the competitiveness of the activity.	S	
5. Lack of wax machine for beeswax in the municipality	25% of beekeepers obtain wax in an artisanal way for consumption. However, they lack the necessary equipment to obtain it more efficiently to allow them to market it.	S	
6. High cost of labor	Due to the demands of the work, labor is scarce and the available one is paid PMX $ 250/day.	E	
7. Lack of knowledge to make other products	Other products and derivatives are not obtained mainly by: 39.3% ignorance, 23.2% technical, 23.2% economic, 12.5% climatic and, 1.8% lack of market.	T	Training to obtain other products from the hive of commercial value (pollen, propolis, creams, soaps, sweets)
8. Lack of pest and disease control	89.5% of the beekeepers reported having illnesses in the colony offspring. Likewise, 35.7% reported incidence of Varroa destructor mite. Varroa destructor.	T	Training in strategies for pest control and sanitary management, strengthening hives

E=Economic; S=Social; A=Environmental; y T=Technical.

In this regard, extensionist work such as those carried out by Martínez and Medina (2011) has been carried out to promote alternative control methods such as organic acids and essential oils, which have shown good control of the mite populations and generate no resistance.

CONCLUSIONS

The milpa system is a cultural activity, its products are destined to satisfy the nutritional needs of the FPU and, therefore, the strategies to strengthen this production system should be oriented towards food security, biodiversity preservation and nutritional health of their population. However, the sociodemographic characteristics of the producers limit them to adopt new practices. Apiculture is one of the components of the milpa system and provides financial resources to FPU to finance other activities. Therefore, strategies should be aimed to further include producers in the apiculture value chain.

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Physical and chemical attributes of prickly pear cactus (*Opuntia ficus-indica*) varieties Copena, Pelon Blanco and Pelon Rojo

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ABSTRACT

Objective: attest and compare the fundamental attributes for fresh raw cactus cladodes and its chemical constituent's quality when dried and grounded for three varieties of prickly pear cactus "Copena", "Pelon blanco" and "Pelon rojo".

Design/methodology/approach: measurements of the physical attributes and chemical constituents were made by using proved and reliable techniques. Data will aid to explore the potential for these cactus materials when being handled from basic to complex processes, considering its need for size and quality of storage and their effect when they interact with processing devices and handling apparatus for the new product being elaborated.

Results: the physical attributes among the three assessed cactus varieties showed slight differences in their parameters, but length, wide and electric conductivity. While for their chemical analysis, cactus cladodes were chopped, dried and grounded. Chemical compounds showed slight differences between the three varieties, but Pelon blanco had a higher fat percentage and the lowest zinc and potassium concentration. None of the varieties had iron.

Limitations on study/implications: there was no management on the prickly pear cactus production. The assessment of the cultivars' attributes was as they were from the field. Stabilization of the chemical constituents of Pelon blanco could be necessary, according to the expected features of new products, or lead to a new line of by-products.

Findings/conclusions: mechanical handling of raw cladodes around the premises is facilitated, and its uses and maintenance are fewer management costs. Flour from each variety was kept at around 10% water content to safeguarding storage. Regard the protein and carbohydrates content, flour of the three varieties ensure integration with other compounds and guarantees new products with high protein content.

Keywords: agri-food, byproducts, physical-chemical, measurement techniques, prickly cactus.

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INTRODUCTION

The nopal (*Opuntia ficus-indica*) is cacti of agronomical importance, both for its fruits and stems, used as forage or consumed as a vegetable (Kiesling, 1995). The "nopal" is scattered throughout various regions of the world (Figure 1). Of the 258 recognized species, 101 are found in Mexico (Luna Vázquez, 2011); out of these, there are 76 wild ones (*sensu stricto*), from which approximately half distribute in the central-north region or southern highlands of Mexico (Reyes-Agüero *et al*., 2005).

According to Vásquez-Alvarado *et al*. (2008), at the highland area of Zacatecas-San Luís Potosí, Mexico, the main cultivated species are: *O. leucotricha* (duraznillo nopal), *O. streptacantha* (cardón nopal), *O. robusta* (tapón nopal), *O. cantabrigiensis* (cuijo nopal), *O. rastrera* (creeping nopal), *O. lindheimeri* (cacanapo nopal), and *O. leptocaulis* (tasajillo nopal). SIAP (2009) documents that the state of San Luis Potosí (SLP) ranks sixth at the Mexican level, with a production extension of 388 ha of vegetable nopal (medium growth cladodes). In the case for prickly pear fruits ("tunas"), the state of San Luis Potosí has 416 ha of cultivated nopal, which means that SLP produces a greater quantity of nopales for prickly pear production.

From the nopal juices can be extracted, as well as nopal powder with a high fiber content which mixed with other flours can be used for cookies, cereals or tortillas. It can also be an ingredient to produce soaps, hand sanitizer and shampoo, yogurt, jam, syrups, bread, nopal flour, weight-loss capsules, reductive gel, moisturizing cream, pickled nopal and toothpaste (Sáenz-Carmen, 2006).

Agribusiness is a cluster of processes in which raw materials whose origin is agricultural, livestock or forestry production are conditioned, preserved or transformed (Ibarra-Alejo, 1986). Agribusiness can be divided into food (transforming raw materials into food with different formats and properties) and non-food (raw materials used for different processes not linked to food). Due to the development of technology and its advances in agriculture, it is called Agroindustry, Agro 4.0 or Smart Agro, where the importance of agro-intelligent industrial processes in the links of the chain value are pointed out, due the fact of the standardizing use of technologies in agricultural holdings, with which the development of the crop is algorithmically modelled to plan its future commercialization. Hence, to integrate the cactus into the agroindustrial processes, a greater knowledge of its attributes is required.

Figure 1. Worldwide geographic distribution of the nopal (FAO, 2006).

Today the world population is around 8000 million, who demand a healthy and sustainably produced diet (Siess Wolfgang, 2020). Therefore, it is convenient to generate food alternatives to provide the constantly growing population, which provide favourable physiological properties for health and reduce diseases risk, taking advantage of the existing biomass. It is important to know the physical and chemical characteristics of the nopal (*Opuntia ficus-indica*) cultivars "Copena", "Pelón blanco" and "Pelón rojo", which comprise the largest crop surface area recorded at the Potosi highlands. These results will orient its destination towards the agroindustry, seen as a tool for standardization and automation of processes, which facilitate their efficient handling and processing, also facilitating obtaining raw materials for the elaboration of high nutritional value products.

MATERIALS AND METHODS

In this study, fresh two years old cladodes from three *Opuntia ficus-indica* cultivars were assessed: Copena, Pelón blanco and Pelón rojo. These were collected during the fall season (September-December). They were dried in a DZF-6090 model oven, for 10 hours at 60 °C to dehydrate the samples. Later, a milling process was carried out to obtain flour, using a Krups

GX 410011 model mill ending in a 0.00381 mm mesh screen (Figure 2).

The values and possible differences exhibited by the physical and chemical attributes between the nopal (*Opuntia ficus-indica*) cultivars, were processed through an analysis of variance (ANOVA) and subsequently by means of contrasts for each parameter, using the STATISTICA software. V.12 (StatSoft, Inc., Tulsa, OK, USA) confronting in all cases to a significance level of $p=0.05$.

The physical dimensions of the cladodes were determined (n=5 measurements) using a ruler (length and width) and a vernier (thickness) with digital caliper (0.001 mm precision). In the length measured from the apex base, the equatorial width was determined in the widest central zone of the cladode and the thickness was measured on the profile of the cladode.

The conductivity depends on the atomic and molecular structure of the material. The unit of electrical conductivity is Siemens (S) which gives the definition of 1 S is the electrical conductivity of a conductor of resistance 1Ω. According to Crespo Villalaz (2004) 1 S * m^{-1} is the electrical conductivity in a homogeneous conductor with a 1 m^2 cross section and a 1 m length, whose conductance is 1 S. The electrical conductivity of the prickly pear cladodes of the Copena, Pelón blanco and Pelón rojo cultivars were assessed with a Kinzo model 18d265 CE multimeter at five different points of the cladode with two repetitions at the same points in each cladode of each variety, in the lower part of cladode, in the center and lateral ends of the cladode and in their upper part. The values obtained by the multimeter in kΩ were converted to mS, following equations:

Figure 2. Nopal cladodes prepared to assess their characteristics.

first conversion to *mS*: $mS = \frac{1}{k\Omega}$

second conversion *mS* to *mS*/*m*

considering the distance coefficient between electrodes, which was 5 cm.

Conversion to $mS/m: \frac{mS}{m} = mS * 20$

Where: *mS*=millisiemens and *k*Ω=kilo Ohm.

The determination of internal friction and internal friction angle were determined for the flours of the three nopal cultivars. The internal friction and the internal friction angle were determined using the formula:

$$\tan\phi = \mu_i = \frac{h}{r}$$

Where: *h* corresponds to the height of the inverted cone formed by the flour and *r* to the corresponding radius.

To determine the density of the cladodes, 10 L of water were placed in a square polyethylene container measuring 83 cm × 50 cm × 35.4 cm (length, width and height), subsequently the water level in the container was noted and each cladode was introduced into the container. The reached height with the cladode was again marked, five repetitions per cultivar. The densities were determined using the equation:

$$\rho = \frac{m}{v}$$

Where: *m* corresponds to the weight in kg of the nopal cladode and *v* corresponds to the displaced amount of water in m^3.

The moisture content of the nopal flour was determined following to the AOAC (1990) technique, with:

$$H° = (Ph - Ps)/Ps \times 100$$

Where: *Ph*=weight of the fresh sample (g) + weight of the empty tray (dry) (g); *Ps*=tray weight (g) + dry sample (g).

The quantification of fat in the flour of the cultivars was carried out following the AOCS 920.39 technique, using a Soxhlet ST243 Soxhlet™

Extraction unit. Three repetitions were done, using the formula:

$$\% \text{ Grasa} = \frac{Vaab - Vab}{h} * 100$$

Where: *Vaab*=Weight in g of the aluminum beaker + oil + three borosilicate beads (b). *Vab*=Aluminum cup (Va) + three borosilicate beads (b) *h*=flour.

The determination of proteins in the flours was carried out taking as reference the Standard NMX-F-068-S (1980). which determine of the total nitrogen of the sample by sulfuric acid digestion. The total nitrogen (%) present in the sample was calculated using the equation:

$$N\% = (V * N * 0.014 * 100) / m$$

Where: *N%* corresponds to the nitrogen percentage (%), *V* to the hydrochloric acid volume of used in the titration (ml), *N* the normality of hydrochloric acid, *m* the mass of the sample (g), 0.014=nitrogen milliequivalent.

The proteins percentage (%) was obtained by multiplying the (%) of nitrogen obtained by the corresponding factor.

The carbohydrate content determination was carried out following the standard NMX-F-066-S (1978). The determination of direct and total reducers in the feed with the equation:

$$A(\%) = 25000 * T\ V * P$$

The phosphorus in de cladodes determination was carried out based on the phosphorus method by spectrophotometry, which is a quantitative titration colorimetric method. The method is based on the formation of a hetero polyacid with a vanadate-molybdate reagent (yellow in color and soluble in water) that absorbs light at 430 nm, the equipment used was a visible range spectrophotometer, model Genesys 105 vis. The determination of Zn, Fe, K was carried out by atomic absorption spectrophotometry, using the Aurora Instruments-1200 equipment.

RESULTS AND DISCUSSION

The results of the sizes of the prickly pear cladodes in the three cultivars (Copena, Pelón blanco and Pelón rojo) is shown in Table 1. Where the five determinations for each of the parameters described are included, as well as their mean and respective standard deviation.

The Copena and Pelón blanco cultivars do not show a significant difference (p>0.05), the Pelón rojo cultivar is the one with the smallest cladodes (p<0.05). Regarding width, the cv. Copena with 26.20 cm is significantly bigger compared to the Pelón blanco with 22.60 cm and Pelón rojo vcultivars with 21.10 cm (p<0.05). Regard thickness, there is no significant difference (p<0.05) regardless of the variety. The foregoing presupposes the ease and feasibility of the technical and technological application, since the length, width and thickness dimensions of the evaluated varieties meet the characteristic parameters of the nopales from the *Opuntia ficus-indica* genus, measured in 38 crops aged between 2 and 3 years (Reyes-Agüero *et al*., 2005).

The electrical conductivity directly depends on the atomic structure of the material, as well as on the temperature at which it is found or the state in which it is (liquid, solid, gaseous) and is representative of the thermal, optical, acoustic conductivity, etc., hence its importance to define technological processes. The obtained results in the *Opuntia* cladodes are shown in Table 2, where it is observed that the electrical conductivity of the cv. Pelón rojo with a value of 3.27 was significantly lower

Table 1. Size of the *Opuntia ficus-indica* prickly pear cladodes.

Variety	Length (cm)	Width (cm)	Thickness (cm)
Copena	45.00	26.00	3.60
Copena	48.00	33.00	4.20
Copena	47.50	20.50	1.80
Copena	46.00	24.50	2.00
Copena	42.00	27.00	1.90
Average	45.70 (2.39)^a	26.20(2.54)^a	2.70(1.12)^a
Pelón Blanco	44.00	23.00	2.50
Pelón Blanco	34.00	19.00	2.00
Pelón Blanco	43.00	26.00	2.40
Pelón Blanco	42.00	24.00	1.70
Average	42.20 (5.12)^a	22.60 2.70)^b	2.26 (0.40)^a
Pelón Rojo	36.50	19.00	2.00
Pelón Rojo	32.00	19.50	1.50
Pelón Rojo	34.50	20.00	2.00
Pelón Rojo	45.00	25.00	2.20
Pelón Rojo	39.00	22.00	2.00
Average	37.40 (4.97)^b	21.10 (2.46)^b	1.94 (0.26)^a

a & b for the same analyzed parameter, a different superscript shows a significant difference between varieties. (p<0.05).

Table 2. Electric conductivity of cactus prickly (*Opuntia ficus-indica*).

V	kΩ	mS	mS/m	V	kΩ	mS	mS/m	V	kΩ	mS	mS/m
1	5.00	0.20	4.00	2	5.00	0.20	4.00	3	7.00	0.14	2.86
1	5.00	0.20	4.00	2	4.00	0.25	5.00	3	8.00	0.13	2.50
1	5.00	0.20	4.00	2	4.00	0.25	5.00	3	6.00	0.17	3.33
1	5.00	0.20	4.00	2	4.00	0.25	5.00	3	6.00	0.17	3.33
1	5.00	0.20	4.00	2	5.00	0.20	4.00	3	6.00	0.17	3.33
1	5.00	0.20	4.00	2	4.00	0.25	5.00	3	6.00	0.17	3.33
1	6.00	0.19	3.33	2	4.00	0.25	5.00	3	6.00	0.17	3.33
1	3.50	0.29	5.71	2	4.00	0.25	5.00	3	5.00	0.20	4.00
1	5.00	0.20	4.00	2	4.00	0.25	5.00	3	6.00	0.17	3.33
1	3.50	0.29	5.71	2	5.00	0.20	4.00	3	6.00	0.17	3.33
∑	4.80	0.22	4.28[a]		4.30	0.24	4.70[a]		6.20	0.17	3.27[b]
Δ	(0.75)	(0.04)	(0.78)		(0.48)	(0.02)	(0.48)		(0.79)	(0.02)	(0.38)

V=cactus prickly variety, 1=Copena; 2=Pelon Blanco, 3=Pelon rojo , ∑=average, Δ=deviation; a & b for the same analyzed parameter, a different superscript shows a significant difference between varieties. ($p<0.05$).

compared to the Copena and Pelón Blanco cultivars, which reported values of 4.28 and 4.70 respectively ($p<0.05$).

Table 3 shows the results obtained from the internal friction μ_i / - /.

The angle of internal friction which corresponds to the angle whose tangent is the relation between the sliding resists force, along a plane, and the normal force applied to said plane and depends on the forces that intervene in the flow of the powder, such as gravity, friction, cohesion (Crespo Villalaz, 2004). With values of 15.65, 16.24 and 14.79 for the Copena, Pelón blanco and Pelón rojo varieties respectively, they show no significant differences ($p>0.05$).

The above indicates that they are free-flowing powders. When the attraction forces between the particles, that is to say, cohesion is high, there are problems with the flow of the powders, which can present flow problems in the silos. Hence, technological applications represent reduction in processing costs, since approximately one third of energy resources are lost due to friction, in addition to extending the useful life of the machinery.

Density is an inherent characteristic for both solids and liquids and is related to buoyancy. Table 4 shows the results obtained for the humidity determinations of the cladodes of *Opuntia ficus-indica*. The results of 0.82, 0.81 and 0.92 g cm^{3-1} for the Copena, Pelón blanco and Pelón rojo cultivars respectively, which show that there is no significant difference between their densities ($p>0.05$).

The moisture content determination, particularly for dehydrated or dry foods, is of utmost importance, since if the moisture content is high, the shelf life of the flour will decrease significantly, due to the proliferation of fungi and bacteria, as well as chemical reactions. (*i.e.*, enzymatic reactions) and physical such as fluidity change, condensation, corrosion, adhesion, etc.

Table 3. Internal friction μ_i /-/ for each studied variety.

Characteristic	Copena	Pelón blanco	Pelón rojo
Height (cm)	1.29 (0.15)	1.34 (0.16)	1.24 (0.19)
Wide (cm)	9.18 (0.19)	9.25 (0.45)	9.37 (0.36)
Radious (cm)	4.59 (0.10)	4.62 (0.22)	4.68 (0.18)
Internal friction μ_i	0.28 (0.28)[a]	0.29 (0.04)[a]	0.26 (0.04)[a]
Angle of internal friction /tan/	15.65 (1.94)[b]	16.24 (2.31)[b]	14.79 (2.40)[b]

**all average values are displayed n=100 repetitions; a & b for the same analyzed parameter, an equal superscript shows that there is not a significant difference between varieties. ($p>0.05$).

Therefore, it is recommended that the maximum humidity percentage in dehydrated products is not greater than 10% for long-term storage. The obtained moisture percentages in *Opuntia ficus-indica* flours are shown in Table 5. The cv. Pelón rojo had the lowest moisture content with a value of 5.01%; However, the difference is not significant compared

Table 4. Density of cactus prickly cladodes for varieties Copena, Pelon blanco and Pelon rojo.

Variety	Density (g cm^{3-1})	Variety	Density (g cm^{3-1})	Variety	Density (g cm^{3-1})
Copena	0.92	Pelón blanco	1.08	Pelón rojo	1.11
Copena	0.66	Pelón blanco	0.64	Pelón rojo	0.49
Copena	0.90	Pelón blanco	0.33	Pelón rojo	0.85
Copena	0.81	Pelón blanco	0.92	Pelón rojo	0.96
Copena	0.83	Pelón blanco	1.08	Pelón rojo	1.17
Average	0.82[a] (0.10)		0.81[a] (0.32)		0.92[a] (0.27)

[a] for the same analyzed parameter, an equal superscript shows that there is not a significant difference between varieties. ($p>0.05$).

to the Copena and Pelón blanco cultivars with values of 6.26% and 6.11% ($p>0.05$) respectively.

The results of the fat determinations are shown in Table 6, in which it is observed that the cv. Pelón blanco with 4.5% fat was significantly higher than the Copena with 2.45% and Pelón rojo cultivars with 2.90% ($p<0.05$).

The obtained results for crude protein or total protein are shown in Table 7, where it is to be noted that there is no significant difference between the protein determined percentages for the three cultivars ($p>0.05$).

From the carbohydrates percentages (Table 8) it is observed that, regardless of the assessed variety, there are no differences ($p>0.05$); 15.79% for the cv. Copena, 15.69% for the cv. Pelón blanco and 14.57% for cv. Pelón rojo. These results are similar to those reported by Castillo *et al*. (2013), for *Opuntia ficus-indica* nopal flour cv. Millar, it also indicates that this variety does not have an effect on the amount of proteins present in nopal flour.

Regard the phosphorus results, also contained in Table 7, it can be seen that the cv. Copena contains 0.030% (300 mg kg^{-1}) of phosphorus, which is significantly higher than that presented by the Pelón blanco with 0.010% (100 mg kg^{-1}) and cv. Pelon rojo with 0.013% (130 ppm mg kg^{-1}). With regards the results of the zinc determination, shown in Table 11, it is observed that the cv. Copena exhibited a value of 4 mg L^{-1} and the Pelón rojo variety 3.8 mg L^{-1}, both results are higher than those obtained for the Pelón blanco variety with a value of 0.005 mg L^{-1} ($p<0.05$). Iron was not registered in the samples.

Zinc is a vital mineral in the diet relates to cell division and growth, healing, carbohydrate metabolism, as well as growth, neurological development, and the immune system (Grandy *et al*., 2010). Potassium is a mineral that your body needs to properly function. The results obtained for this element are also concentrated in Table 8, where it is observed that the cv. Copena with 14000 mg/l or ppm and the Pelón rojo variety with 11 533.33 mg L^{-1} are significantly higher than the Pelón blanco variety which contains 4933.33 mg L^{-1} ($p<0.05$).

Finally, it is clearly observed in Table 8 that the nopal is a product lacking iron at least for the analyzed varieties. Although, it is noted that it was not possible to find reports of the iron content in nopal.

The physical attributes, the cv. Pelón rojo was the one with the smallest cladode size, the cv. Copena the largest width and in terms of thickness, no significant differences between the three were

Table 5. Moisture content (%) of cactus prickly flour (Copena, Pelon blanco & Pelon rojo).

Variety	Moisture content (%)	Variety	Moisture content (%)	Variety	Moisture content (%)
Copena	5.55	Pelón Blanco	5.91	Pelón Rojo	5.42
Copena	5.37	Pelón Blanco	6.7	Pelón Rojo	4.35
Copena	7.85	Pelón Blanco	5.73	Pelón Rojo	5.25
Average	6.26[a]		6.11[a]		5.01[a]
Deviation	(1.38)		(0.52)		(0.50)

a for the same analyzed parameter, an equal superscript shows that there is not a significant difference between varieties. ($p>0.05$).

Table 6. Percentage of fat from cactus prickly flour.

Flour	Extract (%)	Flour	Extract (%)	Flour	Extract (%)
Copena	4.14	Pelón Blanco	4.54	Pelón Rojo	4.04
Copena	1.44	Pelón Blanco	4.48	Pelón Rojo	2.12
Copena	1.76	Pelón Blanco	4.47	Pelón Rojo	2.53
Average	2.45		4.50		2.90
Deviation	(1.47)a		(0.00)b		(1.02)a

[a] & [b] for the same analyzed parameter, a different superscript shows a significant difference between varieties. ($p<0.05$).

Table 7. Content of total protein, carbohydrate and phosphorous of cactus prickles' flour.

Variety	Protein (%)	Carbohydrate (%)	Phosphorous (%)
Copena	5.65	16.09	0.03
Copena	5.96	15.49	0.03
Copena			0.03
Average	5.81	15.79	0.03
Deviation	(0.22)[a]	(0.42)[a]	(0.00)[a]
Pelón Blanco	6.42	16.15	0.01
Pelón Blanco	6.37	15.22	0.01
Pelón Blanco			0.01
Average	6.40	15.69	0.01
Deviation	(0.04)[a]	(0.66)[a]	(0.00) [b]
Pelón Rojo	6.20	14.4	0.01
Pelón Rojo	6.70	14.73	0.01
Pelón Rojo			0.02
Average	6.45	14.57	0.013
Deviation	(0.35)[a]	(0.23)a	(0.006)[b]

a & b for the same analyzed parameter, an equal superscript shows that there is not a significant difference between varieties. ($p>0.05$).

Table 8. Content of zinc and potassium in flour from cactus prickly varieties Copena, Pelon blanco and Pelon Rojo.

Variety	Zinc ($mg\ L^{-1}$)	Potassium ($mg\ L^{-1}$)
Copena	4.00	13000
Copena	4.00	12800
Copena	4.00	16200
Average	4.00	14000
Deviation	(0.00)a	(1907.888)a
Pelón Blanco	2.00	4400
Pelón Blanco	0.00	5000
Pelón Blanco	0.00	5400
Average	0.005	4933.33
Deviation	(0.006)b	(503.32) b
Pelón Rojo	5.20	12400
Pelón Rojo	2.80	10600
Pelón Rojo	3.40	11600
Average	3.80	11533.33
Deviation	(1.25)a	(901.84) a

a & b for the same analyzed parameter, a different superscript shows a significant difference between varieties. ($p<0.05$).

observed. Regard electrical conductivity, the cladodes of the cv. Pelón rojo showed the lowest values, suggesting a lower concentration of electrically conductive salts. Also, internal friction and internal friction angle did not show significant differences. This parameter is important in agro-industrial processes since high frictions represent high energy costs and equipment wear out. Likewise, the high angles predict handling problems of the flour inside the hoppers or during its dosage, therefore, the results obtained indicate that there will be no wear effects on the machinery used in its handling, transport or transfer. Finally, regarding density, there are no significant differences and in any cases the densities obtained were low and very close to that of water, so the cladodes will float, facilitating their handling.

The determined moisture content for the flours did showed no significant differences, in all cases the moisture content was low (less than 10%), which guarantees that there will be no microbial development or deterioration of its physical or chemical properties. Regard the fat percentage, this was higher for the cv. Pelón blanco; however, regardless of the variety, the values found were higher than those reported in the literature, which suggests that the geographical location of production or the age of the cladode influence the percentage of present fat. Regard the percentage of protein and carbohydrates, there are no differences between the cultivars evaluated. These results are favorable since the use of these nopal flours could result in food with a high protein content, compared to other varieties, and is an alternative for the development of specific foods for malnutrition at a lower cost, as it is an abundant raw material. Regard the phosphorus content; the cv. Copena has a higher capacity to develop this compound. While, in the zinc and potassium concentration, the cv. Pelón blanco showed a significantly lower concentration, which suggests that this cultivar has limited capacity for the synthesis of these compounds. Finally, in the three cultivars studied, iron was an absent mineral.

CONCLUSIONS

In the three varieties of nopal studied, there were no significant differences in internal friction and internal friction angle, in thickness and densities were low and similar to that of water. Although, it was found that; the Red Pelón variety showed the lowest electrical conductivity and the smallest cladode size among those. While the Copena variety was the one with the greatest width. In the flour, The three varieties did not show significant differences in the content of proteins and carbohydrates, as well as in the humidity, with a low value of 10% and there was no presence of iron. On the other hand, the variety Pelón blanco had the highest percentage of fat and the lowest concentration of zinc and potassium, while the variety Copena obtained the highest concentration of phosphorus.

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Plastic colored paddings and its effect on the foliar micromorphology of husk tomato (*Physalis ixocarpa* Brot.)

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ABSTRACT

Objective: To assess the effect of colored plastic paddings on the foliar micromorphology of husk tomato (*Physalis ixocarpa* Brot.).

Design/methodology/approach: A completely randomized statistical model was used with five treatments (black, white, blue, red and green paddings) with three repetitions each, 95% reliability and Tukey's mean test ($P \leq 0.05$). To quantify the normalized difference vegetation index (NDVI) a portable GreenSeeker® sensor was used. To measurement of total soluble solids a Atago® Digital refractometer, the density and stomatal index, length and width of stomata were determined with a Carl Zeiss microscope with an integrated camera and the AxionVisionRel measurement software 4.8.

Results: The results show no significant differences in the NDVI and total soluble solids. The micromorphological variables of adaxial stomatal density and adaxial stomatal index were superior in the blue paddings and exceeded black paddings in 95 % and 50 % respectively. The rest of the micromorphological variables were statistically similar, the yield per plant was statistically similar in the black, white, red and green, while blue paddings yield less.

Study limitations/implications: blue paddings improve micromorphological characteristics, but not the yield of husk tomato crops.

Findings/conclusions: Some of the foliar micromorphological characteristics of the husk tomato crop are modified by colored plastic paddings; however, the improvement in these variables does not necessarily improve the crop yield, probably due to the absorbed and reflected radiation by the colored plastic paddings.

Keywords: *Physalis* sp., stomatic density, stomatic index, epidermal cells.

INTRODUCTION

Husk tomato (*Physalis ixocarpa* Brot.) is a vegetable of great economic importance in Mexico. Between 2012 and 2019, Mexican exports of it increased by nine thousand tons on average per year, the United States the main export destination. In 2018, 42,464 hectares were planted and a production of 830 thousand tons was obtained, with a value of 4,352 million pesos. The states that

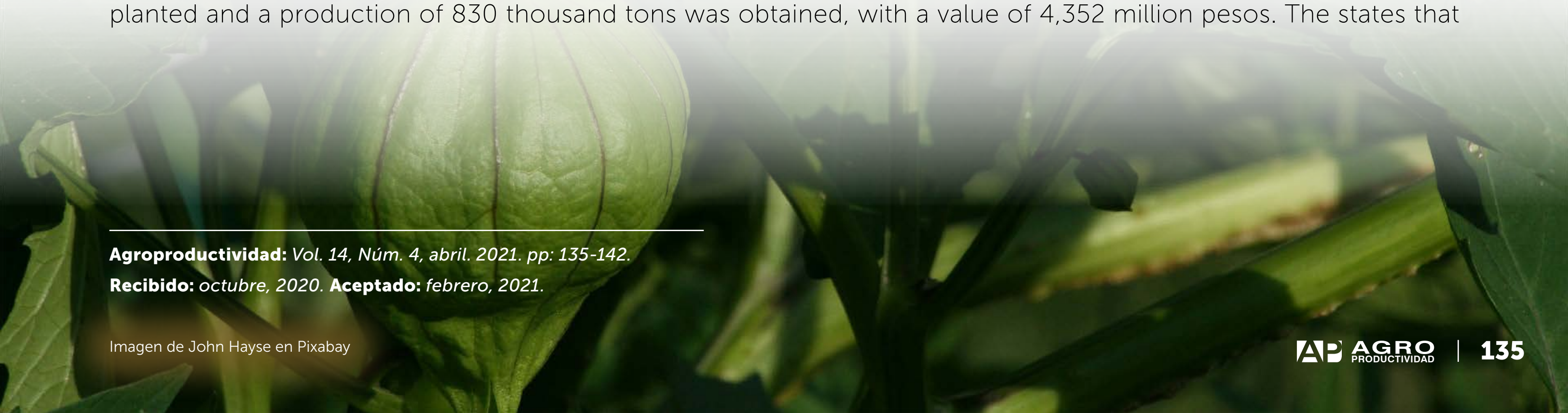

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Imagen de John Hayse en Pixabay

lead the production are Sinaloa, Jalisco, Zacatecas, Michoacán and Puebla (SIAP, 2019). Its importance also lies in its nutritional value, given that it represents a concentrated source of bioactive elements and micronutrients (Vargas *et al*., 2015). However, like any crop, the species faces problems, which have to be addressed with technical or technological innovation that enhances its production. One of these long-time used innovations is plastic. The most used paddings are black and white, which allows water-saving and increased yields (Canul *et al*., 2017), decreases weeds incidence in the crops and increases soil temperature (Quintero, 2015; Ruiz *et al*., 2014). However, paddings are also manufactured in white, silver and to a lesser extent blue, green, red and brown. The above, seek and provide plants with adequate radiation and temperature to enhance their maximum development and productivity (Oliva, 2015), since plants are photosynthetic organisms and depend on solar radiation quality to obtain energy and transform it into carbohydrates (Ganesh *et al*., 2013).

Radiation is the main factor regulating the different growth stages, development and the vital physiological process throughout a plant's life cycle. In response to radiation, plants developed different structures (photoreceptors) for their perception, through which they can assess the radiation quality (wavelength), intensity, duration and direction (Heijde and Ulm, 2012). Studies related to the quality of radiation under photo-selective meshes indicate that the red mesh transmits more total solar radiation, photosynthetic, red, far-red and infrared than the black mesh, while the aluminated mesh transmits more ultraviolet-A light, therefore the blue mesh consequently more blue light and photosynthetically active radiation. In general, under these colored covers, the relative humidity and temperature of the upper leaves increase by 0.2-0.9 °C, as well as their photosynthetic properties: transpiration, stomatal conductance and CO_2 assimilation (Ayala *et al*., 2013). Other studies indicate that photoselective plastics improve the environment and therefore the physiological processes in plants, which translates into higher productivity compared to traditionally marketed plastics (Ramos *et al*., 2017; Alsadon *et al*., 2016). Hogewoning *et al*. (2010) point out that for photosynthesis to adequately happen, without any alterations, it needs a minimum of 7% blue light and, on the contrary, when there is only red light, the photosynthetic process diminishes and affects growth and development. Therefore, there must be a combination of both for photosynthetic processes to be carried out efficiently. Similar negative effects occur if wavelengths of less than 300 and greater than 900 nm and climatic-environmental factors are equally involved (Casierra *et al*., 2011).

To express their maximum phenotypic potential, crops need optimal radiation ranges, which vary depending on the species. To address these particular radiation demands and achieve better use by crops, different plastic color covers and paddings are offered throughout the horticultural market, the above is reflected in increased yield and improvements in the morphological characters of the plant and fruit quality, as previously mentioned. However, the effect of those films and their coloration on the micromorphological component of the plants is not studied. Therefore, in this work, the effect of the coloration of plastic pads on the foliar micromorphology and some performance components of a husk tomato crop was assessed.

MATERIALS AND METHODS

Experimental site location

The experiment was established in a experimental field at the Horticulture Department, Universidad Autónoma Agraria Antonio Narro (UAAAN), Saltillo, Coahuila, Mexico; located at 25° 21′ 24″ N and 101° 02′ 05″ W, an altitude of 1,762 m above sea level, mean annual rainfall of 400 mm, mean annual temperature between 12 and 18 °C, and a BS_0 k(x′) dry temperate climate. The used vegetable material was of the "Siquerios F1" variety husk tomato from the Harris Moran seed house.

Seedlings production

For the seedlings production, 200-cavity polystyrene trays were filled with peat and perlite substrate in a 70:30% proportion, previously moistened to field capacity. One seed per cavity was sown at an approximate 0.5 cm depth and covered with a thin layer of the same mixture substrate, later it was covered with black plastic and kept in a greenhouse to induce germination. After 72 hours the plastic cover was removed and left in the greenhouse for the emergence and the seedlings growth. The seedlings were fertilized with triple 20 (20-20-20) soluble N-P_2O_5-K_2O, at a 0.8 g L^{-1} rate, the first application 6 days after emergence (DAE), the second, third and fourth at 13, 19 and 26 DAE respectively. The seedlings were ready for transplant 35 days after sowing.

Field establishment and crop management

The crop was established during the Spring-Summer 2019 cycle, in 25 cm high and 30 cm wide, by 25 m long seedbeds. The distance between plants within the planting beds was 30 cm in a single row, and 1.8 m between beds, covered with the colored plastic pads that were the tested treatments: black, white, red, blue and green. The plants were arranged under a completely randomized experimental arrangement with five treatments and three repetitions each, with five plants for repetition. Fertilization took place every third day via a drench, with global N-P-K fertilization of 55-45-35 kg/ha respectively. Drip irrigation was daily applied, which for one hour and a flow rate of 0.5 L/h for each dropper, with 20 cm distances between droppers. For the pests prevention and control (cochineal and snail) weekly applications of agricultural lime were made at the base of the stem of each plant (5 g approximately), the first three weeks. For whiteflies, ROMA® biodegradable detergent soap was sprayed at a rate of 5 g/L each week.

Determination of the normalized difference vegetation index (NDVI)

The normalized difference vegetation index was determined with a GreenSeeker® brand portable sensor, on fully developed mature leaves with the same orientation, randomly sampled (the third most developed leaf from the apex down), in three plants for each repetition. The sensor was placed on the adaxial side of the leaf to later record the data.

Total soluble solids (TSS) determination in petioles

For the determination of the total soluble solids in petioles, leaf petiole was used to determine the NDVI. Each petiole was removed from the plants with a scalpel, later in the laboratory, each sample was macerated in a porcelain mortar, until its sap was obtained, from which a drop was placed in an Atago® digital refractometer, their data recorded in Brix degrees.

Epidermal sampling and determination of foliar micromorphology

The photographs to count and the micro-morphological analysis were carried out at the Citogenética laboratory at the Departamento de Fitomejoramiento of the Universidad Autónoma Agraria Antonio Narro. The epidermal samples were collected 50 days after transplant. Epidermal impressions were made on fully mature leaves with the same orientation and from three useful plants. With a brush, transparent PVC glue was applied in an approximate 2 cm^2 area. In the middle of the leaves and in secondary veins, the adaxial and abaxial sides. After the glue dried (approximately 2 min later), the glue layer was removed with transparent adhesive tape, which was then placed on a glass slide. Three photographs were taken at random of each epidermal impression, for a total of nine photographs per repeat and 27 for each treatment, in a Carl Zeiss microscope with an integrated camera (Pixera Winder Pro). With the 10X objective, the adaxial and abaxial stomatal density (SD) was determined by counting the existing stomata in the photographed area (0.3965 mm^{-2}) following formula:

$$DE = \frac{\text{Number of stomata}}{\text{area of the photograph } (0.3965\, mm^{-2})}$$

to obtain the number of stomata per 1 mm^{-2}. For the stomatal index (EI), photographs of the adaxial and abaxial areas were taken with a 40X objective. With them, the stomatal index was estimated with the following equation:

$$EI = \left(ED / \left(ED + ECD\right)\right) * 100$$

where: ED=stomatal density and ECD=epidermal cell density, which were also assessed (Salisbury and Roos 2000).

The area of the photograph was 0.0240 mm^{-2} and then adjusted to 1 mm^{-2}. With the photographs taken with the 40X objective, the length and width of the stomata were measured, recorded in micrometers, for which the Axion Vision Rel.4.8 software was used.

Crop yield

To calculate the crop yield, the filled fruits were harvested in a bag to contain them. To determine the yield per plant, the fruits were weighed on an OHAUS® Scout®-Pro digital scale and the total of the three harvests was added. At the same time, the number of fruits per plant was counted. To calculate the average fruit weight, the total yield of each plant was divided by the total number of fruits that plant.

Statistical analysis of the data

For the statistical analysis of the foliar micromorphology, NDVI, total soluble solids and some yield components, a completely randomized statistical model was used with five treatments and three repetitions each, with a reliability of 95% and the Tukey's test ($P \leq 0.05$), with the SAS® statistical software version 9.02, where the treatments were the black, white, red, blue and green paddings.

RESULTS AND DISCUSSION

The averages of NDVI and total soluble solids are shown in Table 1. The amount of NDVI evaluated in husk tomato leaves was not significantly affected by the quantity and quality of solar radiation absorbed and reflected by the paddings. although the 0.87 NDVI average of the white and red paddings is an increase compared to 8.7% of control. These values are high compared to 0.68 NDVI obtained in watermelon crops (Saiz *et al*., 2017), and 0.14 and 0.35 found in two coriander varieties (Ortiz and Torres, 2018). The high NDVI values found in the husk tomato plants grown with the colored paddings, were probably due to the applied nutrition since this variable directly correlates with the amount of N in the plant and therefore with its greenness, which can also be interpreted as chlorophyll content (Padilla *et al*., 2014 and 2017). According to Hernández *et al*. (2017), chlorophyll content in plants increases when using light-colored paddings and directly attributed it to a higher incidence of total solar radiation and photosynthetically active radiation on the plants. The results were found to correspond to that reported by Paredes *et al*. (2019), with much higher photosynthetically active radiation in red mesh followed by white one. In the total soluble solids in leaf petioles variable, no significant differences were found between treatments. Although the average of the red padding stands out with 2.18 °Brix, followed by the blue with 0.99 °Brix. The °Brix indicates the amount of soluble solids in a plant sample, generally sugars (Gutiérrez *et al*., 2017), since the more photosynthesis a plant performs, the more C it will be fixing to convert them into carbohydrates and transport them to areas of demand (von Caemmerer and Furbank, 2016).

Table 1. Variance and comparison of means of NDVI and total soluble solids in husk tomatoes grown with colored plastic padded.

Treatments (Padded)	NDVI	SST (°Brix)
Black (Control)	0.80±0.12 a[&]	0.96±0.32 a
Red	0.87±0.03 a	2.18±0.81 a
White	0.87±0.03 a	0.97±0.60 a
Blue	0.81±0.14 a	0.99±0.21 a
Green	0.86±0.04 a	0.97±0.55 a
Significance	ns	ns
DFE	8	8
CV (%)	10.36	49.09

ns=not significant, DFE=degrees of freedom of error, CV=coefficient of variation, &=mean followed by the same letter in the columns are statistically equal Tukey $P \leq 0.05$, TSS=total soluble solids.

The means test showed no significant differences between treatments in the variables of adaxial and abaxial epidermal cell density, or abaxial stomatal index (Table 2). This contrasts with that reported by Peralta *et al*. (2016), who had statistically significant differences in the stomatal index in grafted cucumbers but coincides with that by Camposeco *et al*. (2018) who found no significant differences in the density of epidermal cells of the adaxial part in grafted and ungrafted peppers. Therefore, it is inferred that colored plastic paddings have no significant effect on the previously described variables in husk tomato cultivation.

Table 2. Variance and comparison of means, of three foliar epidermal characters evaluated in husk tomato cultivated with different padded colors.

Treatments (Padded)	Adaxial	Abaxial	
	ECD (Cell mm^{-2})	SI (%)	ECD (Cell mm^{-2})
Black (Control)	512.35±19.27 a[&]	28.73±3.67 a	620.37±71.87 a
Red	561.73±35.05 a	32.77±0.66 a	527.78±48.33 a
White	569.44±12.24 a	30.12±1.32 a	606.48±25.77 a
Blue	575.62±23.32 a	31.24±5.66 a	728.40±192.91 a
Green	557.10±46.37 a	31.03±0.09 a	620.37±61.12 a
Significance	ns	ns	ns
DFE	8	8	8
CV (%)	5.72	9.85	15.94

ns=not significant, DFE=degrees of freedom of error, CV=coefficient of variation, &=mean followed by the same letter in the columns are statistically equal Tukey $P \leq 0.05$, SI=stomatic index, ECD=epidermal cell density.

In the comparison of the mean of adaxial and abaxial stomatal density and adaxial stomatal index, significant differences (Tukey; $P \leq 0.05$) were observed between treatments (Figure 1). This result coincides with Peralta *et al*. (2016), who report statistically significant differences in adaxial and abaxial stomatal index and density in grafted cucumbers. Similar results were documented in grafted and ungrafted watermelons (González *et al*., 2017) and in grafted peppers (Camposeco *et al*., 2018). With the above differences, it is observed how the plants grown with blue paddings are favored in

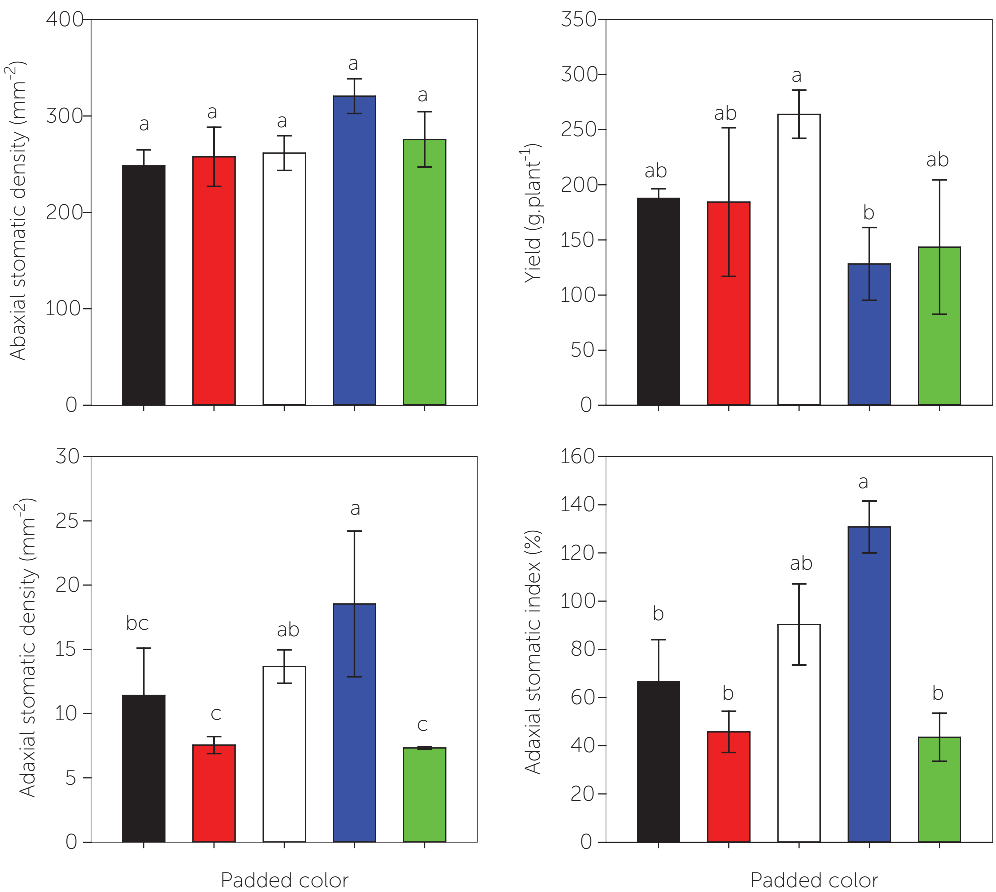

Figure 1. Means comparison (Tukey; P≤0.05) of micromorphological foliar variables and yield per plant in husk tomato grown in colored plastic paddings.

the aforementioned variables. Particularly in stomatal density, which surpassed black paddings by 95% and the red and green paddings up to 150%, their stomatal index reflects a similar trend. These results suggest that colored plastic padding has an effect on these variables and that the radiation absorbed and reflected by each of the colors of the plastic padding is probably different. Photosynthetically active radiation is much higher in red mesh than in blue mesh, leaving the white mesh in the middle of these, with a similar effect with respect to the average temperature (Paredes *et al.*, 2019). Higher stomatal density directly correlates with the net CO_2 assimilation rate, respiration rate, and stomatal conductance, while reducing stomatal resistance (Ayala *et al.*, 2015). This influences the physiological efficiency of the leaves to assimilate CO_2 and transform it into assimilates that are transported to the demand areas, which translates into greater productive efficiency for the plants. In addition, these conditions also favor the efficiency in the use of water and the tolerance of plants to salinity stress (Salas *et al.*, 2001). However, the above does not fully agree with the yield, since for this variable the best yield per plant was obtained with the white padding and surpassed the blue by 85%. Similar effects were reported in piquín chili when the weight of the fruits increased under white mesh and exceeded that of blue one by 7% (Paredes *et al.*, 2019). The pearl color, red and aluminated meshes represent viable options to increase yield (Ayala *et al.*, 2013).

The yield components evaluated are shown in Table 3. Regard the number of fruits per plant, no significant differences were found between treatments. However, the highest values were observed in the white padding, which exceeded the control by 36%, while the lowest number of fruits was obtained in the green padding. The foregoing concurs with that described by Ayala *et al.* (2015) since peppers cultivated in white mesh produces a greater number of fruits. Paredes *et al.* (2019) documented a similar effect in chile piquín cultivation. These increases in fruit production are caused by favorable conditions for plant growth, caused by the plastic paddings, compared to production without paddings in open field (Li *et al.*,

Table 3. Variance and comparison of means of yield variables in husk tomatoes cultivated with colored padded.

Treatmentes (Padded)	NFPP	AWF (g)
Black (Control)	5.50±2.50 a[&]	39.46±18.17 a
Red	4.78±1.35 a	38.11±3.48 a
White	7.52±0.39 a	35.06±1.31 a
Blue	4.54±1.28 a	29.23±7.99 a
Green	3.56±0.41 a	39.48±13.66 a
Significance	ns	ns
DFE	8	8
CV (%)	29.59	30.09

ns=not significant, DFE=degrees of freedom of error, CV=coefficient of variation, &=mean followed by the same letter in the columns are statistically equal Tukey P≤0.05, NFPP=number of fruits per plant., AWF=average weight per fruit.

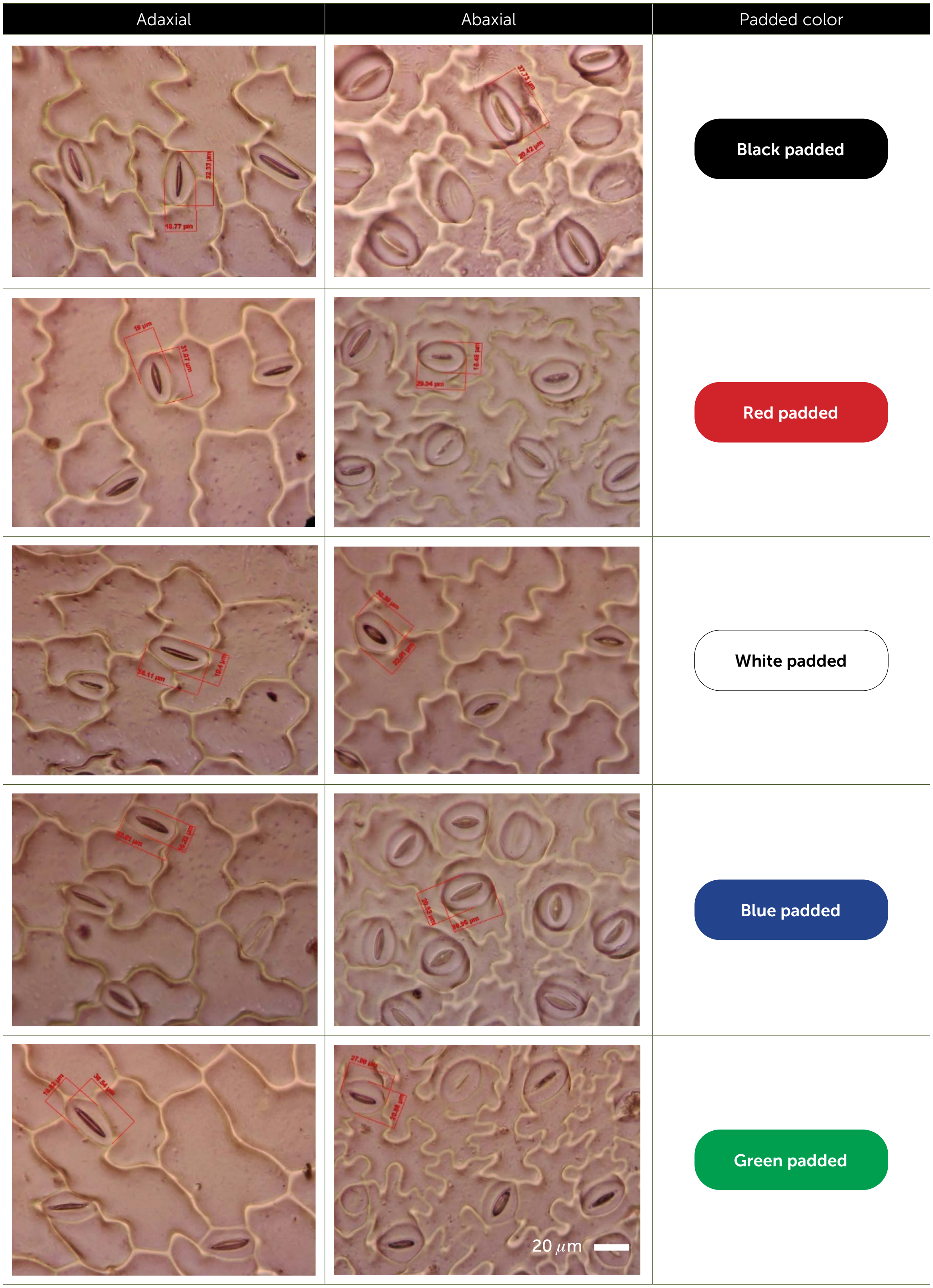

Figure 2. Epidermis impressions of the adaxial and abaxial part of husk tomato leaves cultivated with colored paddings.

2015). In average, fruit weights have no significant differences between treatments and the control, although the highest average values were observed in the green padding and the control, with 39.48 and 39.46 g respectively. Therefore, compared with Rodríguez *et al*. (2011), under protected agriculture conditions, husk tomato var. Querétaro obtained the highest average fruit weight with 37.65 g, similar to that in this experiment with colored paddigs, while Valdivia *et al*. (2016) documented that in *Physalis pubescens*, up to 730 g per plant were obtained.

CONCLUSION

With the colored plastic paddings, some of the foliar micromorphological characteristics of the husk tomato crop are modified. The adaxial and abaxial stomatal density, as well as the adaxial stomatal index, are favored by blue plastic paddings. However, an improvement in these variables does not necessarily increase the yield of this crop.

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In vitro anthelmintic activity of *Musa balbisiana* Colla (square banana) against *Haemonchus contortus* eggs

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ABSTRACT

Objective: To evaluate the anthelmintic activity of aqueous and ethanolic extracts of *Musa balbisiana* Colla, against *H. contortus* eggs.

Design/methodology/approach: The anthelmintic activity was evaluated using an egg hatching inhibition test. The aqueous extracts from leaves, peels and roots were obtained by infusion and subsequently lyophilized. Ethanolic extracts were obtained by maceration and later concentrated in a rotary evaporator. Spectroscopic, phytochemical, chemical and total polyphenol content analyzes were performed. The 50% lethal concentration to inhibit *H. contortus* eggs from hatching was calculated following a Probit analysis.

Results: The identified functional groups in the FT-IR analysis were hydroxyl (−OH) and methyl groups (CH_3). The proximal analysis revealed significant differences in the dry matter percentage ($P<0.05$). No significant differences were found in the protein content ($P>0.05$). The egg hatching inhibition rates at the highest concentration 4.8 mg/mL were 100% for the aqueous and ethanolic extracts from leaves, and 93.7 and 62% for the peel and roots, respectively.

Study limitations/implications: Further studies are required in *in vivo* systems.

Findings/Conclusions: With a LC_{50} of 225 μg/mL and a 95% confidence interval, with a range between 33 and 418.4 μg/mL, the aqueous extract from the leaves was the most active.

Key words: Anthelmintics, Haemonchus contortus, Musa balbisiana, gastrointestinal nematodes, bioactive plants.

INTRODUCTION

Haemonchus contortus represents the most frequent nematode in both temperate and tropical regions, induces large economic losses and has shown resistance to available anthelmintics. This nematode is considered one of the most pathogenic parasites due to its hematophagous habits, high prolificacy and high prevalence (Jasso Díaz *et al*., 2017). The treatment of hemoncosis depends on repeated applications of commercial synthetic anthelmintics, such as benzimidazoles, imidazothiazoles, macrocyclic lactones (ivermectin, moxidectin, nemadectin and doramectin) and lately aminoacetonitrile (monepantel) and spiro-indoles (derquantelindoles). (García-

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Bustos *et al*., 2019). Its indiscriminate and inappropriate use has led to emerging resistant populations of gastrointestinal nematodes (GIN) (Muchiut *et al*., 2018). Another important issue related to treatments with synthetic chemicals is that their residues can be found in animal products such as meat and milk (Kang *et al*., 2017).

Given the impact of GIN infections in small ruminants and the increasing anthelmintic resistance, there is an urgency to develop strategies to identify new compounds for the sustainable and effective control of GIN. One of those strategies is the treatment of bioactive plants with anthelmintic activity. There are two mechanisms responsible for the anthelmintic effects of bioactive plants. One is the direct interaction of the active compounds of the plant with the parasite. The second is through interaction with the host's immune system (Zajícková *et al*., 2020). *Musa balbisiana* Colla (genome B), belongs to the Musaceae family, which has three genera, *Musa*, *Ensete* and *Musella* (Mathew and Singh, 2016). *Musa* spp. has been used in traditional medicine in America, Asia, Oceania, India and Africa (Pereira and Maraschin, 2014). All parts of the plant including its roots, pseudostem, stems, leaves, and flowers have long been used to treat various ailments.

Although there is not enough information on *M. balbisiana* on its usage, biological and pharmacological activity. Nonetheless, there is information on *M. acuminata*. Among the reported applications for this species is are antioxidant, antidiabetic, hypolipidemic, anticancer, antimicrobial, especially anti-HIV and antiparasitic (Sarah and Singh, 2016).

The secondary compounds identified in the *Musa* species include alkaloids, dopamine, steroids, phenols, flavonoids, saponins, tannins and terpenes (Vilela *et al*., 2014; Pereira and Maraschin, 2015). Some of these secondary compounds have been tested and shown anthelmintic effects. Therefore, the objective of this study was to evaluate the anthelmintic activity of aqueous and ethanolic extracts from *Musa balbisiana* Colla against *H. contortus* eggs.

MATERIALS AND METHODS

Collection of plant material

The studied *M. balbisiana* plant material was collected at the Ranchería Habanero 1st section of Cárdenas municipality, estate of Tabasco. The site is located between the coordinates 17° 97′ 08′′ north latitude and 93° 32′ 05′′ west longitude. A total of 3 kg of material were collected, corresponding to 1 kg for each organ of the plant (leaves, root and peel) of young plants.

Extracts obtention

Five g of dry and ground material from each of the *M. balbisiana* organs were placed in a beaker, to which 100 mL of distilled water were added and boiled for 5 min. Subsequently, the resulting solution was filtered and then placed in flasks for deep-freezing at −18 °C and lyophilization (LABCONCO® model 117). The ethanolic extract of leaves was obtained using 50 g of ground plant material and 500 mL of ethyl alcohol (98% purity) and macerated for 24 h. Subsequently, the solution was filtered and concentrated on a BUCHI® brand rotary evaporator; this process was repeated three times to extract the greatest number of compounds. The extract was then stored at 4 °C until its use.

Phytochemical and chemical analysis

For the detection of secondary metabolites (alkaloids, sterols, flavonoids, saponins, tannins) from *M. balbisiana*, the following qualitative tests were used: foam test (saponins), Stiasny reaction (tannins), Liebermann-Burchard test and Salkowski (sterols), Wagner test (alkaloids) and hydrochlorination reaction (flavonoids). These tests are based on the visual observation of color change and/or the formation of precipitates after adding a specific reagent. The chemical composition such as moisture content, crude protein and ashes were determined following the standard methods described by the A.O.A.C. (2000).

Extractable polyphenols (EP) determination

The total phenols content in the extract was quantified following the Folin-Ciocalteu spectrophotometric method with some modifications. The results were expressed as gallic acid equivalents (GAE) (mg/GAE g^{-1} BS) (Makkar *et al*., 1993).

Infrared analysis

To assess the presence of some functional groups present in these extracts, an infrared analysis with a Fourier transformation (FTIR) THERMO SCIENTIFIC® was carried out.

GIN egg hatch test

To obtain eggs, a sheep artificially infected with an *H. contortus* resistant strain was used. The eggs recollection was carried out according to the method by Coles *et al*. (1992). Four *M. balbisiana* extracts concentrations (4.8, 2.4, 1.2, 0.6 mg/mL) were used, as well as a positive control (Tiabendazole 10 μg/mL) and negative control (water), distributed in plates of 24 wells, four replicates were made per concentration and the control; each plate was incubated at 27 °C for 48 h. Subsequently, a Lugol drop was added to stop the hatching and then proceed to count the eggs and larvae with a VELAB® brand microscope.

Table 1. Chemical compounds found the aqueous extracts of *M. balbisiana*.

Extract	Alkaloids	Sterols	Flavonoids	Saponins	Tannins
Leaves	–	++	++	–	++
Peel	++	+++	++	–	++
Root	+	++	–	+++	–

+ = Weak presence; ++ = Moderate; +++ Abundant; + = Negative.

Statistical analysis

To know the difference between the inhibition percentages means of the treated groups and the positive control, an analysis of variance was performed and subsequently, a Tukey's multiple means comparisons test (5%) were performed, with the SPSS version 15.0 statistical software. The LC_{50} was determined through a Probit analysis using the PoloPlus 2003 statistical package.

RESULTS AND DISCUSSION

Phytochemical and chemical analysis

The phytochemical screening found a moderate presence of sterols, flavonoids and tannins in leaves. These findings coincide with those from Yingyuen *et al*. (2020) who report flavonoids presence in ethanolic extract of *M. balbisiana* leaves, even isolated a flavonoid called Rutin. Other compounds found in the peel are sterols and alkaloids and tannins in moderate presence of saponins and sterols were detected in the roots (Table 1). The studies by Marie-Magdeleine *et al*. (2014) coincides with the compounds found in this study and those observed in the leaves and stems extracts of *M. paradisiaca*. Vilela *et al*. (2014) evaluated the chemical composition from extracts of 10 banana cultivars, finding that they were mainly composed of free fatty acids (C12 – C30) and sterols, followed by lower quantities of long-chain aliphatic alcohols (C16 – C30), among others.

Table 2. Proximal chemical composition and extractable polyphenol content of *M. balbisiana*.

M. balbisiana	DM (%)	A (%)	CP (%)	EP (mg GAE/g^{-1})
Leaves	31.87c	10.86b	.90a	.0616b
Peel	12.79b	8.81a	2.35a	.0498a
Root	5.72a	12.45c	0.24a	.0685b

DM: dry matter; C: ashes; CP: crude protein; EP: extractable polyphenols; GAE: gallic acid equivalents. Different letters in the same column significantly differ P<0.05.

Regard the DM content of *M. balbisiana*, the highest content corresponded to the leaves (31.87%), followed by the peels (12.79%) and the lowest value was for the roots (5.72%). In relation to the protein, the peels showed the highest content (2.35%), the lowest corresponded to the roots with 0.24% (Table 2). Nunes-Oliveira *et al*. (2014) reported 3.5% protein content in the pseudostem, higher than that found in the peels in this study. The protein content varies depending on the plant organ, genome type, variety, altitude, climate and can increase in the fruits during the ripening process. The extractable polyphenol content was lower than that reported by Rosales *et al*. (2014) (1.59 - 0.23 mg GAE/g) in plantain.

Infrared analysis

The analysis of the leaves interferogram (Figure 1), peels and roots of *M. balbisiana*, shows functional group bands for the identified compounds in the phytochemical analysis (Table 1). The intense band observed at 3235 cm^{-1} is characteristic of hydroxyl groups (–OH) commonly present in phenolic compounds, such as tannins, flavonoids and alkaloids in the three assessed plant organs (Domínguez, 1979; Castañeda *et al*., 2017). The wavenumber at 2956 cm^{-1} corresponding to the leaf (solid line), is assigned to the C-H bond of methyl groups (CH_3) associated with flavonoids; the band at 2923 cm^{-1} both in leaves, peels and roots is associated with C-H stretching of methylenes (CH_2) linked to sterols (Castañeda *et al*., 2017). In the 1609 cm^{-1} region, the elongated bands are characteristic of C=C functional groups present in alkaloids, identified in the peels and roots. In the 1048 cm^{-1} C-O region (single elongation links) associated with saponins present in the roots (Anzora and Fuentes, 2008; Castañeda *et al*., 2017).

Egg hatching test

The *in vitro* evaluation of *M. balbisiana* showed that the aqueous and ethanolic extracts of the leaves have strong *in vitro* anthelmintic activity on *H. contortus* eggs hatching. All organs and the different tested concentrations showed some effect, from 32.6% for the ethanolic extract of the leaves at a 1.2 mg/mL concentration to 100% efficacy of the same extract at a 4.8 mg/mL concentration (Figure 2). These can be seen that at the highest evaluated concentration, where 100% efficiency was obtained, both from the aqueous extract and the ethanolic extract of leaves. The aqueous extracts of leaves, peels and roots showed a dose-dependent effect.

Studies in different *Musa* species report different egg hatching inhibition percentages. Aline *et al.* (2019) evaluated a hydroalcoholic extract of *M. paradisiaca* flowers on gastrointestinal parasites, reporting a 78.48% inhibition at a 5 mg/mL concentration. In another study by Marie-Magdeleine *et al.* (2014) evaluated aqueous, methanolic and dichloromethane extracts of leaves and stems of *M. paradisiaca*, against *H. contortus* eggs. They found a mean inhibition of 48.5%. Neuwirt *et al.* (2015) reported a 100% inhibition in GIN eggs, with alcoholic extracts of *Musa* spp., using a 180 mg/mL concentration, a considerably higher quantity than that used in this study.

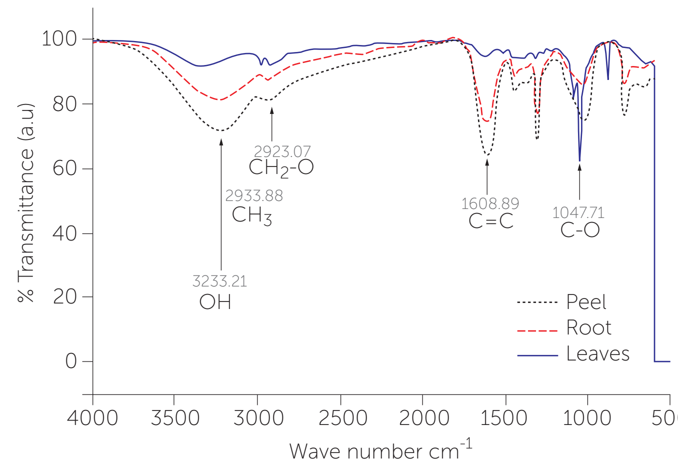

Figure 1. Interferogram of *M. balbisiana* leaves, peel and root extracts.

The observed anthelmintic effect of the aqueous extract of *M. balbisiana* leaves reveals that the responsible active compounds of the anthelmintic activity are relatively polar. The hatching inhibition by polar extracts of tropical plants has been associated with two action mechanisms (Vargas-Magaña *et al.*, 2014; Chan-Pérez *et al.*, 2016): a) true ovicidal activity that prevents the eggs from developing beyond the morula stage, similar to that observed when benzimidazole is used, which causes shrinkage and morula damage compared to negative controls; b) unhatched larvae, a fully developed larva cannot hatch from the egg. Both modes of action ultimately result in a reduction in the hatched larvae number from the eggs. Both must be evaluated to understand the anthelmintic mechanism associated with the secondary compounds of these plant extracts.

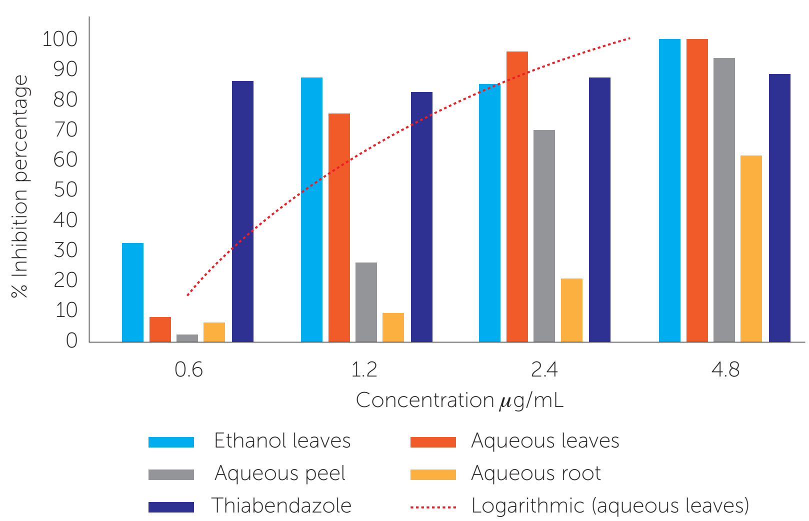

Figure 2. Mean *H. contortus* egg hatching inhibition by *M. balbisiana* extracts.

The mean lethal concentration of the extracts is shown in Table 3. The aqueous extract had the lowest CL_{50} (225 μg/mL), followed by the ethanolic extract with twice the concentration (481.7 μg/mL).

Table 3. Lethal concentration required to inhibit to 50% (LC_{50}) of the hatching of eggs of *H. contortus* and lowers and higher confidence limits than 90% and 95% of the extracts of leaves, skin and roots of *M. balbisiana*.

Extract	LC_{50} μg mL^{-1}	Confidence limits 90% μg mL^{-1}		Confidence limits 95% μg mL^{-1}	
		Lowers	Higher	Lowers	Higher
Ethanol from leaves	481.7	320.6	603.8	276.7	627.9
Aqueous from leaves	225.0	60.8	385.7	33.0	418.4
Aqueous from peel	1500.6	1216	1794	1146	1869
Aqueous from root	2900.0	2358	3828	2256	4169

CONCLUSIONS

The aqueous and ethanolic extracts of *M. balbisiana* leaves showed 100% efficacy on *H. contortus* eggs. The compounds that could be involved in its anthelmintic activity are sterols, flavonoids and tannins.

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Physicochemical and microbiological evaluation of traditional queso molido (ground cheese) during maturation

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ABSTRACT

Objective: To evaluate the changes in the main microorganisms groups and the physicochemical properties of Queso Molido (Ground Cheese) from the Central Mexican Highlands, during a 90 days maturation period.

Methodology: The fat, protein, moisture, ash and chloride contents, acidity and pH were analyzed. Microbiological analyzes of total coliforms, lactic acid bacteria, yeasts and *Staphylococcus* were also assessed. An ANOVA and a principal component analysis were performed to analyze the effect maturation had on the physicochemical and microbiological characteristics.

Results: Both the physicochemical and microbiological parameters showed significant differences ($p<0.05$) during the evaluated maturation period. The protein concentration increased, fat and acidity at the end of maturation, along with the absence of coliform bacteria, a decrease in lactic acid bacteria (LAB) and a high concentration of *Staphylococcus* and yeasts.

Limitations: It is necessary to evaluate these variables in other locations and similar production systems in other latitudes of the country.

Conclusion: The maturation of Queso Molido does not improve its microbiological quality.

Keywords: Main components, raw milk, fresh cheese, traditional.

INTRODUCTION

The onset of the Official Mexican Standard. Products and services. Milk, milk formula, combined dairy products and dairy derivatives. Sanitary provisions and specifications (NOM-243-SSA1-2010), prohibits cheese production from raw milk, specifically due to problems in their microbiological quality, which may present alterations for the consumer's health. Prates *et al*. (2017) indicate that fresh cheese consumption has been associated with foodborne disease outbreaks in different parts of the world, due to the potential survival of pathogenic bacteria in the unpasteurized milk cheeses. Because of that, there is an undeniable concern regarding the (artisan) production systems, that to date, use this method for the elaboration of their products, a situation shared both nationally and internationally (Alvarado *et al*., 2007; Ercan *et al*., 2014; Cámara *et al*., 2017).

The importance of artisan cheese production worldwide involves specific characteristics to each one depending on their region (Martins *et al*., 2015), its connection with its regional culture, territory, history and lifestyle (De la Rosa-Alcaraz *et al*., 2020), which distinguish them as a product with typical aromas and flavors, conferred by the

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milk's microorganisms (Ordiales *et al*., 2013). These peculiarities are affected by pasteurization and starter cultures. Furthermore, most producers do not have enough technology to improve the quality of their products. Despite this, the manufacture of these cheeses on a small scale has taken on greater importance, as they are highly accepted products by consumers, as well as an important economic source (Longaray *et al*., 2012).

The cheese maturation process is an alternative to address the health problems associated with this kind of fresh cheeses made from fresh unpasteurized milk. This process comprises a period in which the cheese remains stored at a certain temperature and relative humidity conditions. Depending on the cheese type, their final characteristics (physicochemical and microbiological) directly depend on the natural microflora of their milk, given that its bacterial population is high and due to the effect of the proteolysis and lipolysis associated with the maturation, that gives these cheeses their characteristic flavors and aromas (Sant'Anna *et al*., 2018).

Various studies have shown that after a maturation period of at least 60 days, this product is suitable for consumption (Mas *et al*., 2002). Other sources indicate that just two weeks of maturation is enough to achieve a safe cheese (Cámara *et al*., 2017; González *et al*., 2019), due to the effect lactic acid bacteria that prevail during maturity and that acts as a natural selector inhibiting pathogens (Caridi *et al*., 2003), coupled with pH decrease (Ercan *et al*., 2014).

In the Central Highlands of Mexico, the so-called queso Molido Cheese is produced with raw cow's milk, following a traditional process. This cheese is a fresh, soft paste, not pressed. Its presentation is in the form of a low cylinder, with a weight ranging between 200 g to about 1 kg (Cervantes *et al*., 2006).

To place fresh cheese in a market with greater added value, there is the proposal to pass it through a maturing process. Therefore, this study focused on evaluating the main microorganisms groups, as well as their physicochemical characteristics of queso Molido Cheese during a 90 days maturation period.

MATERIAL AND METHODS

Experiment location

The experimental study took place in the Central Highlands of Mexico, located between the coordinates 20° 06'' north and 99° 50'' west. The altitude is 2400 m above sea level and a maximum temperature of 24.3 °C, a minimum of 2.3 °C and a mean of 13.2 °C, semi-cold, subhumid climate, with rains in summer, its average annual rainfall is 699.6 mm (INAFED, 2015).

Cheese samples

A batch of 12 pieces of Queso Molido (ground cheese) of an approximate weight of 250 g each was evaluated. The samples were refrigerated at 4 °C, and wrapped in poly-paper, maintaining the same conditions for all cheeses. Four maturation periods were evaluated: 1) 1 day, 30 days, 60 days and 90 days after been elaborated. Of each period, three cheese pieces were evaluated. The samples were transported at 4 °C and kept refrigerated for later analysis, according to the aging period.

Physicochemical analysis

The fat (933.05), protein (991.2), moisture (926.08) and ash (935.42) were determined following the official AOAC methods (1990). The acidity was estimated using 0.1 M NaOH/phenophthalein as an indicator; pH using an Orion 520A potentiometer (Montes de Oca-Flores *et al*., 2009) and chlorides with the Volhard method (NMX-F-360-1981). All analyzes were done by triplicate.

Microbiological analysis

At each stage, 10 g cheese was aseptically sampled from the center of the sample and placed in 90 mL of peptone solution (AOAC 966.23). Total coliforms were assessed following the NOM-113-SSA1-1994; lactic acid bacteria following Lancelle and Vasek (2002); yeasts following the AOAC 997.02; staphylococcus following the NOM-115-SSA1-1994. Microbial counts were performed in a colony counter and calculations were performed to obtain colony-forming units per gram (CFU/g).

Statistical analysis

The microbiological counts were transformed to $\log_{10}$ cfu/g. An ANOVA by completely randomized blocks was performed to evaluate the differences in the physicochemical and microbiological parameters. The existing differences were calculated using the Tukey test ($p \leq 0.05$), using the statistical package Statgraphics 18.

RESULTS AND DISCUSSION

Physicochemical properties during Queso Molido maturation

There were significant differences ($p \leq 0.05$) in all the physicochemical properties of Queso Molido during the maturation period (Table 1).

Table 1. Physicochemical composition during the maturation period of Queso Molido.

	Maturation of the cheese (days)				EEM
	1	30	60	90	
Fat (%)	20,55[a]	22,0[ab]	22,9[ab]	25,41[b]	1,76
Protein (%)	18,53[a]	18,93[a]	18,94[a]	21,75[b]	0,27
Moisture (%)	49,97[bc]	50,35[c]	48,71[b]	46,62[a]	0,6
Ash (%)	1,98[c]	1,87[b]	1,9[bc]	1,62[a]	0,03
Acidity (°D)	21,44[a]	26,11[b]	21,88[a]	25,56[b]	1,11
pH	4,67[a]	4,6[a]	5,34[b]	5,1[b]	0,14
Chlorides (%)	3,4[b]	1,67[a]	1,95[a]	1,72[a]	0,15

SEM=Standard error of the mean. a, b, c=Different letters in the same column indicate statistical differences ($p \leq 0.05$).

The percentages of fat and protein behaved in a similar way during the first three maturation periods (1 to 60 days), the last period with the highest percentage. Brandielli *et al*. (2019), in a cheese from pasteurized cow's milk, during its maturation stages (0, 60 and 120 days) reported differences in the protein and fat percentages, with the highest concentration at the end of the period (24.09 and 28.1 %, respectively).

The moisture percentage behaved inversely decreasing at the end of maturation period (49.97-46.62%), a fact that promotes an protein and fat content increase.

In determining the milk acidity, various methods are used, which give different interpretations. For example, pH measures actual or acquired acidity and titratable acidity measures both natural and actual or acquired acidity. The latter, measured through titration with a NaOH solution, which according to its concentration allows to express the acidity under different scales regard to the NaOH concentration: in Dornic degrees (°D) if the concentration of NaOH is 0.11 N, Thörner degrees (°Th) if the solution concentration is 0.1 N, Sohxlet-Henkel degrees (°SH) if the solution concentration is 0.25 N (Pulgar, 1988).

The acidity concentration increased at the end of maturation (21.44-25.56 °D), although it presented its maximum value on day 30 (26.11 °D), observing an inconsistent behavior. Dervisoglu and Aydemir (2007) reported a progressive increase in acidity for each of the stages, until the end of maturation (120 days) and as a consequence a pH decrease due to the production of lactic acid by the effect of lactic bacteria (Dalla *et al*., 2008). The opposite was obtained in this research with a pH increase (4.67 to 5.1). Mas *et al*. (2002) and Temizkan *et al*. (2014) reported increased pH values at the end of the maturation. Kongo *et al*. (2009) indicate that this behavior may be related to secondary proteolytic activity by bacteria and yeasts and as a consequence of the accumulation of free fatty amino acids and ammonia.

There was a decrease in the percentage of chlorides at the end of the maturation (3.4-1.72), a situation that may be related to ash decrease. On the contrary, Çetinkaya and Fatih (2019) reported an increase in chlorides at the end of it. Lima *et al*. (2008) compared the salt and moisture content and/or water activity in the maturation process, mentioning that there is an inverse relationship between these, a behavior not observed in this research.

The decrease in the ash percentage (1.99-1.62) does not coincide with that reported by Arenas *et al*. (2015) and Cakır and Cakmakc (2018) who found progressive increases until the end of it, due to the effect of decreased humidity.

Table 2. Microbiological composition during the maturation period of Queso Molido (log_{10})

	Maturation of the cheese (days)				EEM
	1	30	60	90	
CT	6,2[c]	4,19[b]	5,85[c]	0,0[a]	0,25
BAL	9,59[c]	7,69[a]	8,31[b]	7,66[a]	0,09
Lev.	9,59[d]	7,66[a]	8,80[c]	8,53[b]	0,09
St.	7,14[c]	5,96[a]	6,50[b]	7,44[c]	0,19

SEM=Standard error from the mean.
a-d=Different letters indicate statistical differences ($p<0.05$).
TC=Total Coliforms.
LAB=Lactic Acid Bacteria.
St.=*Staphylococcus*.

Microbiological properties during the maturation of Queso Molido

The microbiological properties are shown in Table 2. All the parameters evaluated in the maturation process showed significant differences ($p \leq 0.05$). High values were observed at the beginning regard total coliforms, yeasts and *Staphylococcus*, a factor that could be related to mishandling and the conditions during the transport of the raw materials.

Staphylococcus and yeast colony-forming units decrease by the end of the maturation process (7.44 and 8.53, respectively), although this decrease cannot be considered sufficient compared to a product for direct human consumption. The maximum permissible limits by Mexican regulations are 100 cfu/g and 500 cfu/g respectively. In our study, the greatest decrease occurred at 30 years of maturation, possibly due to a greater increase in acidity during the same stage (26.11 °D) and at the lowest pH (4.6), increasing again during the last two periods.

There were no total coliform counts in the last maturation period (90 days). Ceylan *et al*. (2007) reported a decrease at day 30 and 90 of maturation (<1 cfu/g), in a cheese made with unpasteurized milk, while Dolci *et al*. (2010), obtained 1.4 cfu/g at day 90 and <5.0 cfu/g up to the day 150 of maturation.

There was a decrease in ALB at the end of the maturation period (9.6-7.67 log). Similar behaviors were reported by Cakır and Cakmakc (2018) in relation to bacteria of the *Lactobacillus* and *Lactococcus* genera, due to the increase in salt concentrations and acidic during maturing, in addition to low pH (4.04-4.29) (Bontinis *et al*., 2008). For this research, there was only an acidity increase (21.4-25.5), not the case of the salt percentage (3.4-1.7).

CONCLUSIONS

Although by the end of the maturation period the complete decrease of coliform bacteria is observed, it is not due to the effect of the physicochemical properties. The presence of *Staphylococcus* and yeasts at the end of maturation in cheeses indicate that they are not suitable for consumption, since they represent a health risk to consumers. The above indicates that the 90 days of maturation period is not enough time for the product to be considered suitable for consumption. Although at the end of the maturation period they showed a slight decrease in pathogenic bacteria, it is important to improve the transport conditions of the raw materials, in addition to better control of its storage conditions.

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Economic Impact and Feasibility of Striped Catfish Farming (*Pangasius hypophthalmus*) in Mexico

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ABSTRACT

Objective: To assess the productive behavior of *Pangasius hypophthalmus* in actual rural aquaculture farming conditions for the state of Veracruz, Mexico.

Methodology: The study had a duration of 331 days in a circular pond of 135 m^3, with no aeration. 2000 juveniles were bred upon attaining 7.9 g; they were fed once a day, four days a week. Their weight and length were assessed every 15 days.

Results: The growth of *P. hypophthalmus* reached 900 g in 150 days at temperatures between 26 y 34 °C, with growths of 100 g in 150 days at temperatures between 22 and 26 °C. An average final weight of 1254 kg and a survival of 87.8% were attained for a total production of 2.2 t. These organisms may attain 2 kg per year at 26 to 35 $°C^{-1}$.

Study limitations: For a period of 153 days, water temperatures greater than 26 °C limited the growth of this fish.

Conclusions: The *Pangasius hypophthalmus* species represents an aquaculture alternative with high potential for tropical areas of Mexico, mainly where electric power availability is limited.

Keywords: aquaculture; Mexican tropic, employment.

INTRODUCTION

Mexico imports US$129 million per year in frozen striped catfish from Vietnam (VASEP, 2020). The amount spent on striped catfish fillets amounts to MX$204.25 million per month, which equals to 55 203 monthly minimum wages (MX$3 700), upon considering import price (self-estimates with information from VASEP, 2020). Should consumer price be considered, this amount doubles to 110 606 monthly minimum wages. On the other hand, the import of striped catfish fillet accounted for 150 mil t in 2015; nevertheless, it was decreased to 100 mil t in 2019, and Mexico was a country with 130 million inhabitants and the biggest importer of striped catfish on the planet only second to the United States (US), which has 327.2 million inhabitants (VASEP, 2020). (Figures 1 and 2). The world per capita consumption of fish amounts to 20 kg $year^{-1}$ (FAO, 2020c).

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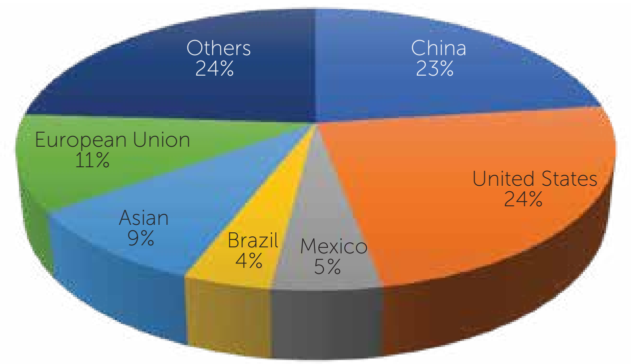

Figure 1. World *Pangasius* Imports from Vietnam (Percent). Source: Vietnam Association of Seafood Exporters and Producers (VASEP, 2020).

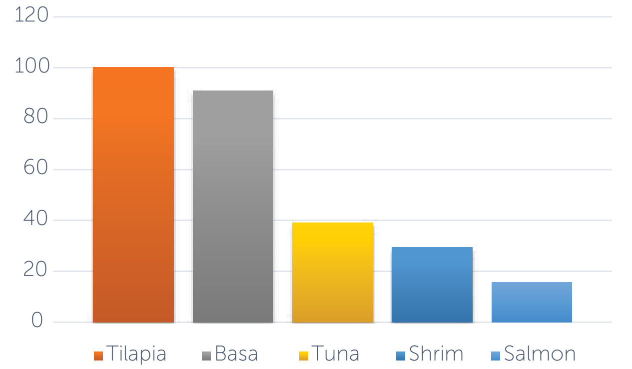

Figure 2. Mexican Imports of Fish and Seafood 2017 (Thousand t). Source: Ministry of Economy (2018).

Mexico has a *per capita* fish consumption of around 10 kg yr^{-1}, one of the lowest on the planet, despite having a great productive potential, in view of the amount of natural resources (water, light and temperature) that it has. Should Mexico wish to attain the 2030 United Nations Goal of consuming 36 kg of fish *per capita* per $year^{-1}$ (FAO, 2020b), it needs to decrease its import, quadruplicate its supply and increase its aquaculture production 10-fold (Platas *et al*., 2017).

Pangasius hypophthalmus (Pangasiidae Family), commonly marketed in Mexican markets as striped catfish fillet, is a tropical fish that originates from Vietnam's Mekong River and Thailand's Chao Phraya River (FAO, 2020a). Its farming began in Vietnam in the decade of 1970 from juveniles captures from the rural medium. Striped catfish aquaculture began in 1996, with the development of controlled reproduction techniques (Phan *et al*., 2009). After one decade, it grew from a small backyard production to an industry producing more than 1.4 million t per year and generates more than 1.8 million rural jobs, with performances from 200 to 400 t ha^{-1} (De Silva & Phuong, 2011). Vietnam grew from 10 000 to 1.3 million t in 10 years (Figure 3).

The striped catfish has an increasing trend which will place it as an aquaculture species with greater production and consumption on the planet in the future. Above all, its production potential in units lower than 1 ha requires little capital; it is a mass consumption product by population with scarce resources, rich in high-quality protein and omega 3 and 6. (Platas *et al*., 2014).

Mexico is the fourth world importer of striped catfish only behind China and the US, although it shows a greater per capita consumption than the first two countries, as it consumes more than 150 mil t of fillets per yr^{-1}. (Platas *et al*., 2014). Nevertheless, Mexico does not produce striped catfish, reason why it imports 100% of its consumption and it is the second importing country behind the US (Figure 5). Should it be considered that 3 kg of live weight are needed for producing 1 kg of fillets, Mexico would import more than 300 000 t of whole fish from Vietnam. In Mexico, 1.0 t of whole striped catfish is sold at MX$70 000 (self-research in supermarkets of Veracruz City, Mexico, April 2019), which would represent the yearly rural income of one person. This represents thousands of jobs that Mexico pays to Vietnam producers, which could be

As a commercial aquaculture species, production, and distribution levels for *Pangasius* in world markets attain values nearby those of other species widely farmed, such as tilapia, white shrimp, and salmon. FAO (2018) reports that humanity consumes around 150 million t of fish and seafood. Currently, Vietnam is the greatest producer for this species and exports to more than 130 countries (Figure 4).

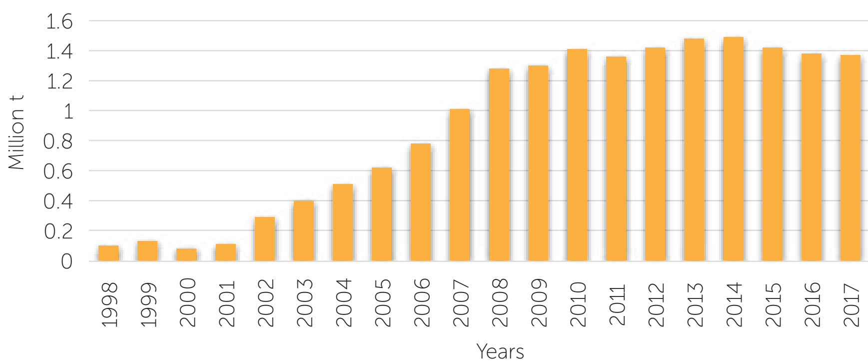

Figure 3. Vietnam *Pangasius hypophthalmus* Production 1998-2017. Source: VASEP (2020).

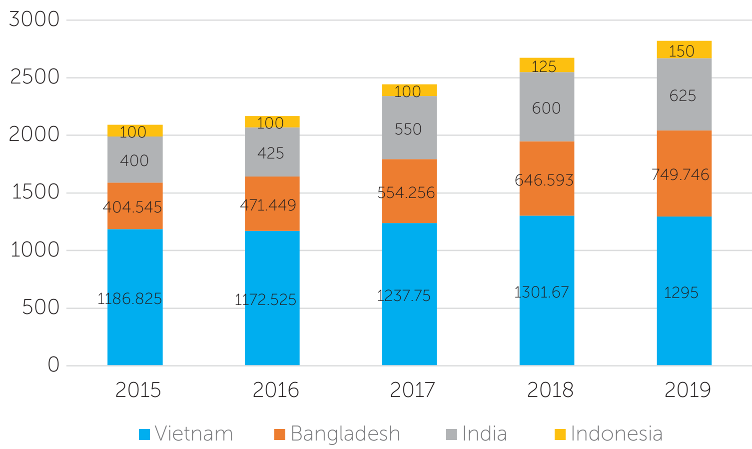

Figure 4. *Pangasius* production in selected countries (Thousand t). Sources: Global Aquaculture Alliance (2020).

created in Mexico. Striped catfish production would have a great economic and social impact in poor rural regions of the country.

The biological features of *Pangasius* are the baseline of its high production and have favored that it had reached world markets in little time; also, they make it an aquaculture alternative with great potential for tropical regions of Mexico (Platas *et al.*, 2014). According to McGee (2009), this species has a rapid growth at 26 and 35 °C, its growth is reduced at 20 and 25 °C and it does not perform well under 20 °C. The farming adapts to high densities and direct oxygen may be extracted from atmospheric air, reason why no artificial aeration is required for the intensive farming thereof. It may also accept foodstuffs based on agricultural products and sub-products with no requirement of high animal protein content; also, it has a compensatory growth (Rohul *et al.*, 2005). These features considerably reduce production costs and allow their farming in zones where electric power is limited or absent. *Pangasius* gathers biological features that allow it to adapt to low investment handling conditions, such as alternate feeding, no aeration and low maintenance. Natural conditions in Mexico are similar to those of Vietnam; the south-southeastern part of the country is a priority economic zone for rural development public policy and has sweet water; earth ponds for the production of this fish may be produced there. In Gulf of Mexico coastal zones, the only limitation would be a variation of low temperatures during winter, which is brought about by North winds.

Therefore, this study had the objective of assessing the productive behavior of *Pangasius hypophthalmus* in actual rural aquaculture farming conditions for the state of Veracruz.

MATERIALS AND METHODS

The study was made on a tilapia (*Oreochromis niloticus*) farm, located in the municipality of Paso de Ovejas, Veracruz, Mexico (19.293375 N, 96.370759 O, 13 masl). The commercial operation allocated a circular geomembrane pool of 12 m in diameter, 135 m^3 in capacity and with no aeration for the experiment. In autumn (30 August), with a water temperature of 30.5 °C, 2000 juveniles were farmed, and they had an average humid weight of 7.9±0.48 (standard error) g. They were fed on alternate days, once per day, 4 days per week. Commercial food with 35% protein and 8% fat was used. Before each feeding, water was discharged from the main drain for 3 min to partially remove accumulated sediment, and then the level was replaced with well water. A replacement of 20 to 30 % of water was performed once per week, depending on turbidity conditions. This handling procedure was performed for the 331 days of duration of the study. During feeding days, water temperature information was taken. A random sample was captured every 15 days for 30 individuals to assess standard weight and length.

RESULTS AND DISCUSSION

The water temperature record evidenced the stationary variation of temperature (Figure 6), which was important for this study.

The study began on 30 August (day 0), with a water temperature of 30.5 °C. As of this date, the water temperature was gradually decreased for 66 days until reaching 26.1 °C. On 19 November (day 81), the

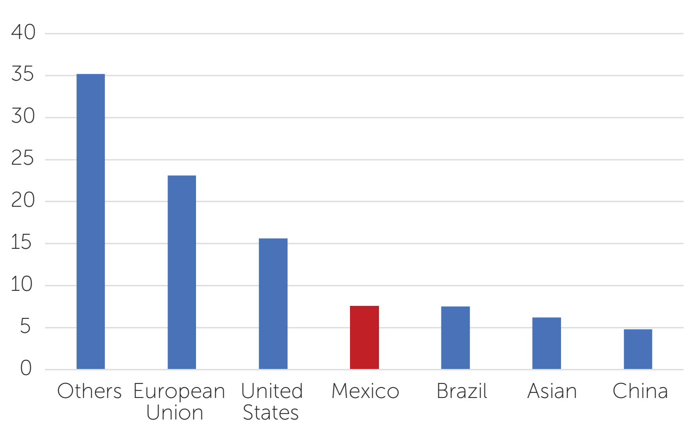

Figure 5. Vietnam's top *Pangasius* fish importing countries (Percent). Source: VASEP (2012).

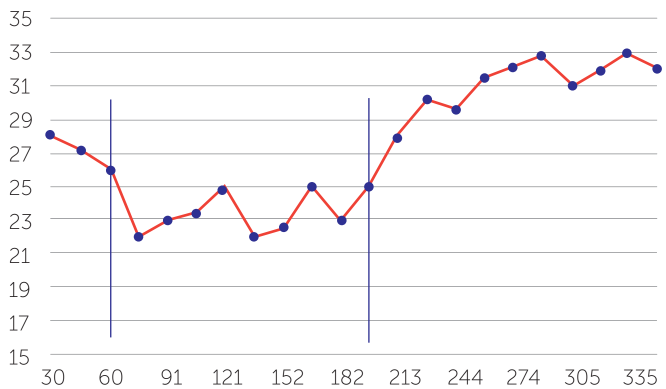

Figure 6. Water temperature (C) for the period of the *Pangasius hypophthalmus* growth trial on a rural farm in Veracruz state, Mexico. Short vertical lines delimit the winter period with temperatures below 26 °C.

temperature decreased rapidly down to 22 °C. This fall in temperature was due to the entrance of strong north winds derived from cold fronts characteristic of the central Veracruz region in winter. The gradual temperature recovery pattern, followed by a decrease thereof, repeated itself in winter. When spring began (21 March, day 203), a rapid temperature increase was produced up to 30 °C, followed by a gradual increase until 34 °C were reached on 24 May (day 268). This yearly variation of 12 °C, with a maximum of 34 °C and a minimum of 22 °C, influenced the growth of striped catfish.

Growth patterns in humid weight (Figure 7) truly reflected the temperature trends. *Pangasius* growth may be divided into three clear periods - the first appears before winter, with temperatures >26 °C, where an increase in average weight of 1.73 g per day^{-1} is seen. During the second period, corresponding to winter and temperatures <26 °C, fish grew 0.77 g per day^{-1} only. During the third period, with temperatures ≥30 °C, fish grew 7.3 g per day^{-1} in average; this growth rate is similar to that recorded by Cremer *et al*. (2002). In this period, fish grew from 217.1 g to 1254 g in 142 days; that is, a live weight increase of 1.04 kg per fish in 4.7 months. This is an accelerated growth if compared with the typical tilapia growth, which grows in the same farm and usually reaches 0.5 kg in 6 to 7 months, which is attained with greater handling, feeding and supplementary aeration (Rakocy, 1989).

The accelerated growth of *Pangasius*, even without requiring aeration and under limiting feeding conditions alternated once per day for 4 days per week, represents an extremely simple handling that requires little labor and low production costs. This means that the striped catfish may be produced easily in several conditions present in Veracruz. Nevertheless, low water temperatures present naturally are to be considered upon the arrival of cold fronts. Juveniles, the most sensitive stages, may be kept in controlled temperature conditions within small greenhouses. Likewise, breeders are to be kept at the same temperature conditions. Under this handling and feeding system, with previously mentioned market prices, the striped catfish in Mexico turns out to be highly profitable, with production costs of MX$22.00 kg^{-1} (self-estimation based on the cost of inputs for 2018).

During the winter period, fish considerably decreased food consumption (observed indirectly as it showed more non-consumed food residues during the periodic pond draining); also, it was observed that its abdominal area was flattened (with no food). The above suggests that growth decrease was due to a decrease in food consumption, brought by the decrease of metabolic activity at low temperatures. Despite its low growth during winter, 87.8% survived, which allowed a total production of 2.2 t. This amount is considered to be adequate for a pond of 12 m in diameter and represents an outstanding alternative both for backward aquaculture and commercial aquaculture. It also represents a great potential for tropical regions in Mexico, mainly where there is no electric power available. Several rapidly growing individuals reached 2 kg or more during this study, which does not discard the possibility of obtaining even greater yields with better handling of feeding, temperature and water quality.

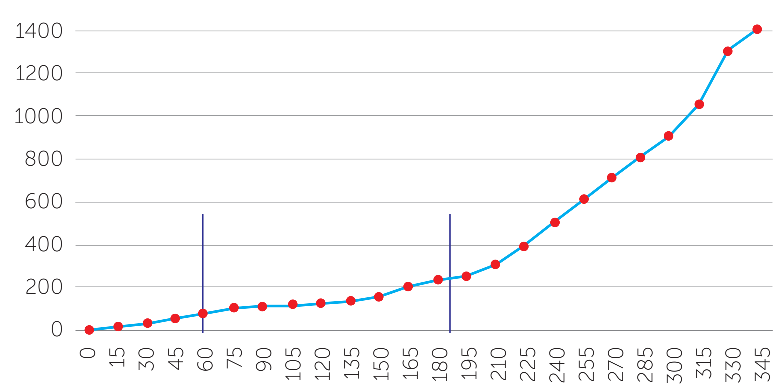

Figure 7. *Pangasius hypophthalmus* wet weight (g) growth curve on a rural farm in Veracruz State, Mexico. Short vertical lines delimit the winter period with temperatures below 26 °C.

Temperature influence in growth has important implications for the development of aquaculture farming handling for this species. Hence, when spring begins, stripe catfish juveniles could be farmed to seize the entire period of temperatures greater than 26 °C without going through the winter period. In order to attain this, a controlled breeding program is required during the winter in order to supply juveniles upon the occurrence of adequate temperatures. Another option is to breed when winter begins in order for the offspring to grow under greenhouse conditions and farming juveniles of an advanced size in uncovered ponds when spring begins. Each of both forms requires a controlled breeding program. Despite the limitations for this preliminary essay, results offer a clear feasibility insight for the farming thereof and show the importance of keeping temperatures above 26 °C during their growth period. This information also shows the need of research on this species in order to adapt the farming of this species consumed widely in Mexico to local rural conditions. Mexico has approximately 30 million hectares of tropical lands that allow producing *Pangasius* in the south-southeast region of the country and has an unsatisfied demand in the market. This simple production system may create hundreds of thousands of rural jobs, as well as supply high-quality protein rich in omega 3 and 6 for mass consumption by the population with low income.

CONCLUSIONS

Pangasius production is an aquaculture alternative that may be adapted successfully to the conditions of rural farms in tropical zones of Mexico, with water temperatures greater than 26 °C, both for rural backyard aquaculture and commercial aquaculture with potential to generate a great amount of jobs and quality protein at low cost.

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