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Typological characterization of beekeepers in Campeche state, Mexico

Caracterización tipológica de apicultores del estado de Campeche, México

Caracterização tipológica dos apicultores do estado de Campeche, México

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Abstract

Background: Beekeeping is a livestock activity that provides multiple benefits to humanity, in addition to its cultural value. Therefore, it requires targeted intervention within the framework of rural extension projects to optimize economic resources and capacities. **Objective:** To characterize the typology of the beekeepers that make up the honey production chain in the municipalities of Campeche, Calkiní, and Hopelchén in the State of Campeche. **Methods:** Surveys were applied to 220 beneficiary producers, stratified into two groups: subsistence beekeepers without market linkage (E1) and subsistence beekeepers with market access (E2). Twenty social, economic, and technological variables were studied using principal components and cluster analyses. **Results:** Five variables explained 65.81% of the variance: schooling, production experience, number of hives, yield per hive, and annual production. Four beekeeper profiles were identified. *Type I*: Beekeepers with 10 years of experience, producing 107.80 kg of honey per year, with a yield of 6.7 kg per hive. *Type II*: Beekeepers with a higher technological index, ten additional years of productive experience, and completed basic education. *Type III*: Young beekeepers with high school education, achieving the highest honey production and yield, with the same technological index as Type II. *Type IV*: Elderly beekeepers operating within a social and solidarity economy framework, all of whom speak the Mayan language and follow traditional organization schemes. They achieve better yields per hive and higher honey production than Type I and II. **Conclusions:** This typology can be used to classify producers from other regions in the context of Rural Extension Programs with a targeted and differentiated approach, where specific development strategies are required. Type III beekeepers should be prioritized in Rural Extension Projects.

Keywords: *beekeeping; hives; honeybee; rural extension; smallholder beekeepers; technological level; typology.*

Resumen

Antecedentes: La apicultura es una actividad pecuaria que aporta múltiples beneficios a la humanidad, además de su valor cultural. Por ello, requiere una intervención focalizada en el marco de proyectos de extensionismo rural para optimizar los recursos económicos y las capacidades productivas. **Objetivo:** Caracterizar la tipología de los apicultores que conforman la cadena productiva de miel en los municipios de Campeche, Calkiní y Hopelchén, en el estado de Campeche, México. **Metodología:** Se aplicaron encuestas a 220 productores beneficiarios, estratificados en términos de subsistencia con y sin acceso al mercado. Se evaluaron 20 variables sociales, económicas y tecnológicas mediante análisis de componentes principales y de conglomerados (Clúster). **Resultados:** Cinco variables explicaron el 65.81% de la varianza: escolaridad, experiencia productiva, número de colmenas, rendimiento por colmena y producción anual. Se identificaron cuatro perfiles de apicultores: *Tipo I*: Apicultores con 10 años de experiencia, producción de 107.80 kg de miel por año y rendimiento de 6.7 kg por colmena. *Tipo II*: Apicultores con un mayor índice tecnológico, diez años más de experiencia productiva y educación básica concluida. *Tipo III*: Apicultores jóvenes con preparatoria terminada, mayor producción de miel y rendimiento, e igual índice tecnológico que el Tipo II. *Tipo IV*: Apicultores de la tercera edad con una lógica de trabajo más vinculada a la economía social y solidaria, todos hablantes de lengua maya que siguen esquemas de organización tradicional, logrando mejores rendimientos por colmena y mayor producción de miel que los Tipos I y II. **Conclusiones:** Esta propuesta puede utilizarse para tipificar a productores de otras regiones en el contexto de Programas de Extensionismo Rural, con una visión focalizada y diferenciada que permita establecer rutas de desarrollo específicas. Los apicultores Tipo III podrían ser el foco principal de los Proyectos de Extensionismo Rural.

Palabras clave: *apicultores minifundistas; apicultura; colmenas; extensión rural; miel de abejas; nivel tecnológico; tipología.*

Resumo

Antecedentes: A apicultura é uma atividade pecuária que traz múltiplos benefícios para a humanidade, além de seu valor cultural; por esta razão, requer uma intervenção focada no âmbito de projetos de extensão rural para otimizar recursos econômicos e capacidades produtivas. **Objetivo:** Caracterizar a tipologia dos apicultores que compõem a cadeia produtiva do mel nos municípios de Campeche, Calkiní e Hopelchén no Estado de Campeche. **Metodología:** Foram aplicados inquéritos a 220 produtores beneficiários, estratificados em termos de subsistencia com e sem acesso ao mercado. Vinte variáveis sociais, econômicas e tecnológicas foram estudadas e analisadas por componentes principais e Cluster. Cinco variáveis explicam 65,81% da variância: escolaridade, experiência produtiva, número de colmeias, rendimento/colmeia e produção por ano. **Resultados:** Foram identificados quatro perfis de apicultores. *Tipo I,* apicultores com 10 anos de experiência, produção de 107,80 kg por ano e rendimento de 6,7 kg. *Tipo II,* apicultores com maior índice tecnológico, mais 10 anos de experiência produtiva e ensino fundamental completo. *Tipo III,* apicultores jovens com ensino médio completo e com maior produção e rendimento de mel e o mesmo índice tecnológico do Tipo II. *Tipo IV,* apicultores idosos com lógica de trabalho mais ligada à economia social e solidária, todos falantes da língua maia com esquemas de organização tradicionais que obtêm melhores rendimentos por colmeia e produção de mel do que os tipos I e II. **Conclusões:** Esta proposta pode ser utilizada para tipificar produtores de outras regiões no contexto de Programas de Extensão Rural com uma visão focada e diferenciada em que são requeridas rotas particulares de desenvolvimento. Apicultores tipo III poderiam ser foco de Projetos de Extensão Rural.

Palavras-chave: *apicultura; colmeias; extensão rural; mel de abelhas; nível tecnológico; pequenos apicultores; tipologia.*

Introduction

Beekeeping is an agricultural activity of significant cultural and economic importance in Mexico. This relevance is attributed to both the products derived from bees and their crucial role in pollination (SIAP, 2019). In Mexico, the North, Center, Altiplano, Gulf, and Yucatán Peninsula (YP) are the primary honey-producing regions, with the YP contributing 36.49% of national production (23,445 tons). Campeche, the second-largest honey-producing state, accounts for 7,670 beekeepers and 480,342 hives, distributed across 10 of its 11 municipalities (Canepa and Pérez, 2017; Martínez-Puc et al., 2018).

In the YP, beekeeping relies on both native and cultivated floral resources (Martínez-Pérez et al., 2017), making it a secondary activity closely linked to agricultural practices. Consequently, it is frequently included in rural extension projects aimed at supporting smallholder producers by generating and applying knowledge to enhance their production systems and promote self-sufficiency (FAO, 2016).

Rural extension projects provide beekeepers with essential technical, organizational, and managerial skills (James, 2023). These initiatives enhance the use of technology in beekeeping production units through training, technical advisors, and extension agents. However, the diversity of economic, social, and technical conditions among producers leads to significant variability in their characteristics and challenges, making targeted intervention more complex (Espinosa-García et al., 2010).

Despite its economic and cultural importance, few studies have focused on the characterization and typology of beekeeping production systems, which are crucial for effectively directing resources and capabilities. This gap is partly due to challenges within the production chain and the deep cultural context of beekeeping in the YP (Magaña-Magaña et al., 2012; Vélez-Izquierdo et al., 2016). Additionally, beekeeping in the YP is often a complementary source of income (Güemes-Ricalde et al., 2003), strongly linked to the Mayan heritage of the producers and family-based production traditions (Parra-Canto et al., 2013).

Therefore, this study aimed to characterize the typology of beekeepers participating in the honey production chain in the municipalities of Campeche, Calkiní, and Hopelchén in the state of Campeche.

Materials and Methods

Description of the study site

This study was conducted in the state of Campeche, specifically in the municipalities of Campeche, Calkiní, and Hopelchén, located between 17°49' and 20°51' N latitude and 89°06' and 92°27' W longitude. These municipalities have an average altitude of 48.45 meters above sea level (masl), with maximum elevations of 340 masl. The study area covers 908.23 km^2, representing 2.95% of the country's total land area. The predominant climate is tropical subhumid, with an annual mean temperature of 25 °C and annual rainfall ranging from 1,200 to 2,000 mm. Five communities were selected across the three municipalities: Uayamón (Campeche), Tankunché and Santa Cruz Ex-Hacienda (Calkiní), and Bolonchén and Sacabchén (Hopelchén).

Subjects of study

The beekeepers interviewed in this study are smallholders who belong to Strata I and II, as defined by the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) (González-Cambero, 2014). These strata encompass producers with economic disadvantages who do not generate surpluses that allow them to access large markets, making the participation of collection centers and intermediaries essential.

Typology

The methodology consisted of:

1. Characterizing the profile of the producers from a social, technical, productive, and

commercial perspective.

2. Systematizing and analyzing the information.

3. Classifying producers into different types.

A non-probabilistic sampling approach was used (Otzen and Manterola, 2017) due to the accessibility and proximity of the producers. The sample consisted of 220 beekeepers, who were surveyed using a pre-designed questionnaire. The information collected was systematized into two main sections: Socioeconomic characteristics and Technology adoption.

The data were processed using Microsoft Office Excel 2019 and analyzed using R Development Core Team (2017), version 3.4.3.

A total of 20 variables were selected to classify the beekeepers: *gender, marital status, age, education level, income, years of experience as a beekeeper, number of children, number of family members that work in the beekeeping unit, number of family members that do not work in the unit, number of employees, number of beekeepers, number of hives, producer hives, honey production, yield per hive, income from the sale of honey, speaks only indigenous language, training received, is organized, and lastly, as a synthetic variable, technological index.*

The technological index (I_{ij}) was calculated for each beekeeper. Based on the work by Freitas-Barbosa and Pinheiro-de Sousa (2013), the I_{ij} was calculated by dividing the sum of the practices performed by the beekeeper (δ_{in}) by the sum of the total practices that the beekeeper could perform ($\delta_{i...n}$).

$$I_{ij} = \sum ij \frac{\delta_{in}}{\delta_{i...n}}$$

The data on practices considered for technological adoption included *hive registration, prior training, hive division, queen replacement, queen purchase, queen production, feeding implementation during shortages, and disease control.* These eight technologies were used to calculate the technological index.

A principal component analysis was conducted to select representative variables based on the coefficient of variation (CV > 0.50), suggested by Berdegué et al., (1990). The significant variables were determined from the standardized correlation matrix and were used to differentiate the producer groups (Table 1).

Table 1. Representative variables of beekeepers in Campeche.

Variable	Description
Age (years)	Information from the survey to the producer
Schooling (years)	Information from the survey to the producer
Experience (years)	Information from the survey to the producer
Number of hives	Determined by counting the amount of hives in the beekeeping production unit
Production (ton)	Determined directly from the beekeeping production unit
Yield (ton/hive)	Determined directly from the beekeeping production unit Information directly obtained from the producer.
Technological level	This variable is independent of the others and important in the structure of beekeeping.

Using the selected variables, a k-means clustering analysis was performed to identify beekeeping groups (Mair et al., 2012) using Manhattan distances (with partitioning around medoids for greater robustness). Each cluster was represented by a group (or object) that served as a representative of the respective cluster (Brock et al., 2008). In other words, these analyses defined and combined variables to construct typologies that order phenomena into similar groups (Mair et al., 2012).

Based on these analyses, eight variables were defined to construct the typology (Table 2).

Table 2. Variables used for the typology of beekeepers.

Variable type	
Qualitative	**Indigenous language (Mayan)**
Quantitative	Age
	Schooling
	Years of education
	Number of hives
	Honey production
	Yield per hive
	Technological index

Considering the regional characteristics and the accessibility of beekeeping production units, it was deemed appropriate to use general attributes that could serve as operational tools for extension agents (De Martinelli, 2011).

To eliminate the systematic errors that could bias the results (Badii-Zabeh et al., 2008), the variation in the technological index was analyzed. This index reflects the adoption of technology among the study subjects, based on the producer categories identified in the cluster analysis. The technological index depended on explanatory or independent variables, as expressed in the following equation:

$$Y = \mu + \text{age}_i + \text{education level}_i + \text{years of experience} + \text{Mayan language}_j + \varepsilon_{ij}$$

Where: Y= Technological index (dependent variable), μ = intercept, ε_{ij}= random error, covariables: age, education level, years of experience, Mayan language (1=Yes or 0=No).

This analysis was carried out in R version 3.4.3.

Results

Characterization and sociodemographic profile of beekeepers

The 220 surveyed beekeepers had an average age of 49 years, 14 years of experience, and three years of formal education. Additionally, 70.9% speak Mayan and share a collective interest in improving hive productivity (Table 3).

Table 3. Sociodemographic profile of the beekeepers.

Community	**Number of beekeepers surveyed**	**Age** (years)	**Number of children** (children/family)	**Beekeeping experience** (years)	**Schooling** (years)
Bolonchén	60	51.01±2.12a	3.62±0.23a	16.50±1.87a	5.41±0.37c
Sacabchén	40	53.15±2.78a	3.75±0.61a	12.62±2.28a	4.20±0.46d
Santa Cruz	40	47.74±2.52a	3.96±0.30a	14.71±1.92a	5.92±0.46a

Tankunché	40	51.86±2.59a	4.05±0.29a	16.50±1.87a	5.77±0.46b
Uayamón	40	41.15±2.78b	2.93±0.30a	7.92±1.08b	4.30±0.46e

Data: mean±standard deviation. Different letters indicate significant differences within columns (Tukey, p<0.05).

Most of the beekeepers had unfinished primary education (six years of schooling). Only 8.3% had completed middle or high school (9–12 years of education). As for beekeeping experience, it was highest in Bolonchén and Tankunché (at least 16 years), favoring work settlement. Uayamón beekeepers had significantly less experience (less than eight years) and were also younger compared to those in other regions (Table 3).

Production profile

The average amount of hives per beekeeper was 30, with an average honey yield of 11.47 kg per hive. The lowest yields per hive were recorded in Bolonchén and Uayamón (Table 4).

Table 4. Production profile of beekeepers.

Community	Number of hives	Number of producing hives (units/year)	Honey yield per hive (kg)	Honey production kg/year
Bolonchén	36.82±3.46a	25.55±3.46a	8.77±2.03a	318.88±60.89a
Sacabchén	24.03±4.40a	17.50±4.23a	14.26±2.48a	491.65±76.62a
Santa Cruz	27.88±4.23a	24.18±4.23a	13.42±2.48a	390.29±74.58a
Tankunché	34.55±4.23a	29.25±4.23a	13.49±2.48a	512.83±72.69a
Uayamón	23.59±4.29a	16.58±4.23a	8.80±2.48a	198.47±76.62b*

*Significantly different (Tukey, p<0.05).

Data analysis

The correlation coefficient analysis confirmed that the technological index is inversely related to the age of the beekeeper (R^2 = -0.005), and honey yield per hive was inversely related to years of experience. The other variables showed low correlation values (p > 0.6).

The principal component analysis determined that the three first dimensions explain 65.81% of the accumulated variation. The first factor was closely related to the productive capacity of the beekeeper (years of experience, number of hives, and honey production). The second factor included the education level and the third one the yield/hive, which is the variable that marked the difference in this group of beekeepers (Table 5).

Table 5. Principal component analysis for beekeeper characterization.

Variable	1	2	3
Eigenvalue	1.957	1.506	1.143
Accumulated variance (%)	27.962	49.478	65.813
Parameters			
Age	0.398	-0.736	0.039
Years of formal education	0.089	0.655*	-0.374

Years of experience	0.624*	-0.520	-0.185
Number of hives	0.725*	0.149	-0.348
Honey production kg/year	0.733*	0.313	0.194
Yield/ hive	0.241	0.168	0.898*
Technological index	0.531	0.341	0.052

*Values marked with an asterisk (*) indicate a greater contribution to the variation.

Beekeeper typology

Based on the k-means clustering analysis, four "Type" profiles were identified in the beekeeper population (Figure 1).

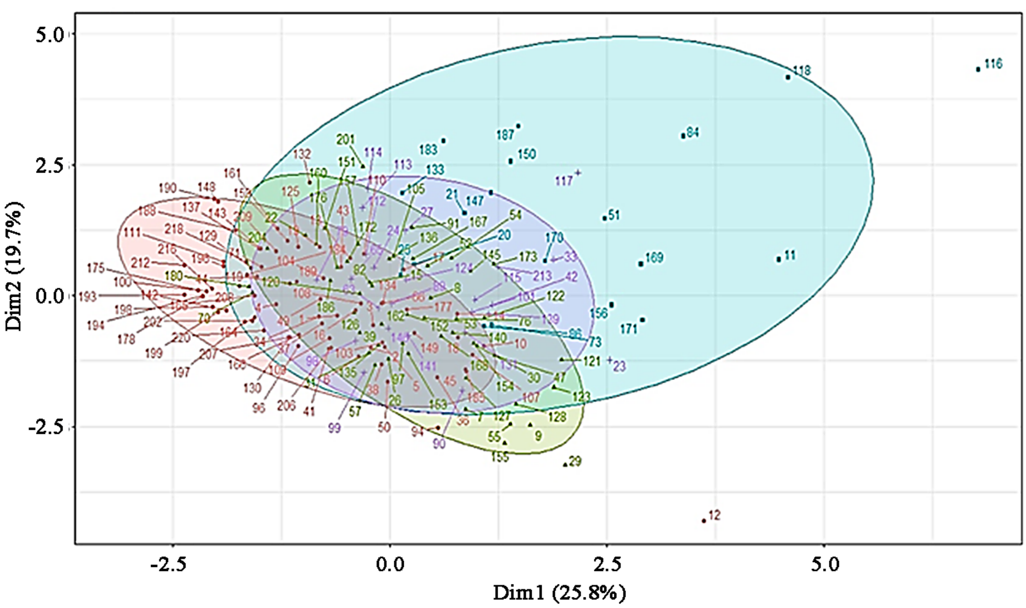

Figure 1. Projection of the beekeeper groups.

Type I includes beekeepers with 10 years of experience and lower production and yield (107.8 kg/year, 6.7 kg/hive, respectively). Type II beekeepers have a greater technological index compared to Type I, 10 more years of experience, and completed primary and middle school education. In Type III, beekeepers are younger (39 years on average), have 12 years of education, the highest honey production and yield, and a greater technological index compared to Type II producers. Type IV includes the beekeepers that, despite having the lowest technology level (22%), obtain better yields/hive and honey production than Type I and II producers. Additionally, beekeepers with low technology levels (Type IV) and approximately 30 hives are more productive than the beekeepers with greater technological index (Type I and II) (Table 6).

Table 6. Beekeeper profile in five communities.

Variables	Type I	Type II	Type III	Type IV
Age (years)	59	58	39	62
Years of education	6	9	12	3
Years of experience	10	20	15	15
Number of hives	16	33	50	30
Production (kg/year)	107.8	319.1	1,063.8	652.5
Hive yield (kg)	6.7	12.3	21.3	21.7
Technological index	56%	67%	67%	22%

Note: Each group is represented by a representative observation.

Beekeeping technological index

The ANCOVA linear model explained 7.8% of the variance ($R^2 = 0.078$), showing a positive correlation between the technological index and years of experience (coefficient = 0.39 ± 0.002). That is, greater experience was associated with higher adoption of technology. The interaction between the Mayan language and the technological index was ruled out, as education level and years of experience were expected to be significant ($p = 0.03$ and $p = 0.0008$, respectively). To identify the education level at which significant differences occurred, the Bonferroni paired test was applied, confirming differences in the adoption of technology across education levels ($p = 0.0447$). It was found that beekeepers with nine years of education (complete basic education) had the highest adoption of technology (Table 7).

Table 7. Adoption of technology in four education levels.

Schooling	Technological index %
Unfinished primary education	39.9
Finished primary education	45.7
Middle school	48.5
High school	44.4

Discussion

Beekeeping is one of the most supported agricultural activities by the government in Campeche. However, despite previous efforts through rural extension projects, honey production and technological adoption have not significantly improved. The low technology adoption rate and high variability in honey production found in this study align with previous research by Parra (2009), who indicated that beekeepers in rural areas, particularly those with lower education levels, rely primarily on culturally transmitted empirical knowledge. This reliance could explain the low adoption of new technologies and best practices (Güemes-Ricalde et al., 2003; Magaña-Magaña et al., 2012; Contreras et al., 2013; Martínez-Pérez et al., 2017). In this context, years of experience is a critical factor in hive productivity and economic benefits. Magaña-Magaña et al. (2016) proposed that similar production levels among beekeepers with different education levels could be due to the nature of beekeeping, which depends more on environmental factors than on formal education. Hive management practices do not require high education levels, but productivity and social factors, such as years of experience and beekeeper age, play a significant role. This trend was evident in Bolonchén and Uayamón, where low hive yields were associated with fewer years of experience and lower education levels.

The diverse ecosystems in the region, characterized by natural and modified vegetation, directly affect honey production (Porter-Bolland, 2010). For example, honey production in Campeche was significantly lower (378.57 kg per year) compared to that in Jalisco (1,600 kg per year) (Contreras et al., 2013). Notably, the number of hives was not related to total honey yield (Table 4). This parameter depends on multiple factors, such as the availability of floral resources, applied technology, climatic conditions, and bee genetics, among others. In a study by Magaña-Magaña et al. (2016), beekeepers in Campeche and Quintana Roo had 37.10% fewer hives than those in Yucatán. Additionally, honey production may be affected by disease or pest incidence, which were not analyzed in this study.

Within the agricultural value chain, education level and age are closely related to productivity, particularly for Strata III and IV beekeepers (González-Cambero, 2014). The correlation analysis confirmed a negative association between age and technological adoption. The older beekeepers in the studied regions showed resistance to adopting new technologies, possibly due to cultural traditions and an unwillingness to change—a trend commonly observed in Strata I and II producers (Contreras et al., 2013; Rodríguez-Balam and Pinkus, 2015).

The four beekeeper profiles identified (Table 6) highlight the social and productive diversity in the study communities. Future studies should establish an economic threshold to determine the minimum number of hives required for profitability. Type III beekeepers stand out due to economies of scale, which positively affect yield per hive and overall honey production. Type II beekeepers, with 67% technological adoption, should be prioritized for extension training, considering their traditional organization models and their involvement in the social and solidarity economy (CEDRSSA, 2019; Kokwe et al., 2022; Rodríguez et al., 2009). The linear model demonstrated that education level and years of experience significantly influence the adoption of new practices. Thus, strategies should focus on increasing the technological index to improve productivity.

Castellanos-Potenciano et al. (2015) argued that social capital influences beekeepers' knowledge acquisition through communication within their production system. The success of extension programs depends on the interaction between beekeepers and extension agents, reinforcing the idea that extensionists are key facilitators of development. In other words, Rural extension should be viewed as a participatory process that builds upon dialogue and producer experience (Gómez-Martínez et al., 2017; Ardila, 2010). By integrating local knowledge with extensionist guidance, more effective interventions can be designed by considering beekeeper perceptions, attitudes, and motivations (Russo, 2009).

Beekeepers between 47 and 53 years of age have low levels of education and limited adoption of technology, affecting the effectiveness of extension programs beyond the capacities of the extension agents. Type III beekeepers, identified in Strata I and II and characterized by younger age, higher education, and greater technological adoption, could serve as a dynamic group within the production chain, potentially increasing competitiveness if targeted by extension programs.

This study's methodological approach can be applied to typify producers in other regions, particularly within the framework of Rural Extension Programs that require focused and differentiated development strategies. Beekeeper profiles can guide extension initiatives aimed at strengthening both the production chain and broader socio-territorial development. Future research should define the economic threshold for hive profitability -minimum number of hives-, especially for Type III and IV beekeepers. Finally, training programs in good production practices should be strengthened to increase technological adoption, which, when combined with experience, can enhance competitiveness and sustainability.

Declarations

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Conflicts of interest

The authors declare they have no conflicts of interest regarding the work presented in this report.

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Author contributions

Design or conception of the study: JCAM, JERB, JHCV; Administration of the project: JHCV, JERB; collection of the data: LPSB, JAZE; Article writing and edition: LPSB, LAME, JCAM, JAZE; Article Review: JCAM, JERB, LHCV

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

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