Typological characterization of beekeepers in Campeche state, Mexico

Caracterización tipológica de apicultores del estado de Campeche, México

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Abstract

Background: Beekeeping is a livestock activity that brings multiple benefits to humanity, in addition to its cultural value; therefore, it requires focused 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 in terms of subsistence without market linkage (E1) and subsistence with market access (E2). Twenty social, economic, and technological variables were studied by main component and cluster analyses. **Results:** Five variables explain 65.81% of the variance: schooling, production experience, number of hives, yield/hive, and production per year. Four beekeeper profiles were identified. Type I includes beekeepers with 10 years of experience, production of 107.80 kg per year, and yield of 6.7 kg. Type II beekeepers have higher technological index, ten more years of productive experience, and completed basic education. Type III includes young beekeepers with completed high school and with the highest production of honey and yield and the same technological index as Type II. Type IV, elderly beekeepers with work logic more linked to the social and solidarity economy, all speaker of Mayan language with traditional organization schemes that obtain better yields per hive and honey production than Type I and II. **Conclusions:** This proposal can be used to typify producers from other regions in the context of Rural Extension Programs with a focused and differentiated vision in which development routes are required. Type III beekeepers could be the focus of 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 de una intervención focalizada en el marco de proyectos de extensionismo rural para optimizar recursos económicos y capacidades. **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. **Metodología.** Se aplicaron encuestas a 220 productores beneficiados, estratificados en términos de subsistencia. Veinte variables sociales, económicas y tecnológicas fueron estudiadas por análisis de componentes principales y Clúster. **Resultados.** Cinco variables explican el 65,81% de la varianza: escolaridad, experiencia productiva, número de colmenas, rendimiento/colmena y producción por año. Se identificaron cuatro perfiles de apicultores. Tipo I, apicultores con 10 años de experiencia, producción de 107,80 kg por año y rendimiento 6,7 kg. Tipo II, apicultores con mayor índice tecnológico, 10 años más de experiencia productiva y educación básica concluida. Tipo III, apicultores jóvenes con preparatoria concluida y con la mayor producción de miel y rendimiento e igual índice tecnológico que el Tipo II. Tipo IV, apicultores de la tercera edad con lógica de trabajo más ligada a la economía social y solidaria, hablantes todos de lengua maya con esquemas de organización tradicional que obtienen mejores rendimientos por colmena y producción de miel que los Tipo I y II. **Conclusiones.** Esta propuesta puede ser utilizada para tipificar a los productores de otras regiones en el contexto de Programas de Extensionismo Rural con una visión focalizada y diferenciada en los que se requieran rutas de desarrollo particulares. Los apicultores Tipo III, pudieran ser foco de atención de 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 e capacidades econômicas. **Objetivo.** Caracterizar a tipologia dos apicultores que compõem a cadeia produtiva do mel nos municípios de Campeche, Calkiní e Hopelchén no Estado de Campeche. **Metodologia.** Foram aplicados inquéritos a 220 produtores beneficiados, estratificados em termos de subsistência. 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 with undeniable cultural and economic importance in Mexico. This importance lies in the products produced by bees and their pollinating activity (SIAP, 2019). In Mexico, the North, Center, Altiplano, Gulf, and Yucatan Peninsula (YP) are the main honey-producing regions; the latter being responsible for 36.49% of the national production (23,445 tons). Campeche, second place in production nationwide, has 7,670 beekeepers and 480,342 hives. These producers are distributed in 10 of the 11 municipalities (Canepa and Pérez, 2017, Martínez-Puc *et al.*, 2018). In the YP, beekeeping uses native and cultivated floral resources (Martínez-Perez *et al.*, 2017), which makes it a secondary activity associated with agricultural activities and subject to support within the framework of rural extension projects (Martínez-Puc *et al.*, 2018). The rural extension project consists of a set of actions aimed to support smallholder producers by generating knowledge and applying it to their production systems to achieve self-sufficiency (FAO, 2016). The extension project provides the information and support necessary to develop the technical, organizational, and management capacities required by the producers (James, 2023). Therefore, this project boosts the use of technology in beekeeping production units via training and the participation of technical advisors and extension agents. However, economic, social, and technical conditions result in great variability in the characteristics and particular problems of the producers and their production units, complicating targeted intervention (Espinosa-García *et al.*, 2010). Few studies have focused on the characterization and typology of beekeeping production systems, which would allow targeting resources and capacities. This is due to problems in the production chain, the importance of the cultural context surrounding beekeeping in the YP (Magaña-Magaña *et al.*, 2012, Vélez-Izquierdo *et al.*, 2016), and the fact that the subsistence logic of this activity in the YP is, in most cases, complementary income (Güemes-Ricalde *et al.*, 2003). These aspects are closely related to the Mayan origin of the producers and family production tradition (Parra-Canto *et al.*, 2013). Therefore, this study aimed 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.

Materials and methods

Description of the study site

This study was conducted in Campeche, in the municipalities of Campeche, Calkiní, and Hopelchén, which are located between 17°49’ and 20°51’ N and 89°06’ and 92°27’ W. The average altitude of these municipalities is 48.45 masl, with maximum elevations of 340 masl. The study site had an area of 908.23 km², which corresponds to 2.95% of the country's surface. The predominant climate is tropical subhumid with an annual mean temperature of 25 °C and annual rain precipitation between 1,200 and 2,000 mm. Five communities in the three municipalities were considered: Uayamón (Campeche), Tankunché and Santa Cruz ExHacienda (Calkiní), and Bolonchén and Sacabchén (Hopelchén).

Subjects of study

The interviewed beekeepers are smallholders that fall within the Strata I and II defined by the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (in English: Ministry of Agriculture, Livestock, and Rural Development) (González-Cambero, 2014). These strata group producers with economic disadvantages that do not produce surpluses that allow foray into large markets, and where the participation of collection centers and intermediaries is essential.

Typology

This methodology included: (i) characterizing the profile of the producer from a social, technical, productive, and commercial point of view, (ii) information systematization and analysis, and (iii) classifying the type of producers. A non-probability sampling (Otzen and Manterola, 2017) was carried out due to the accessibility and proximity of the producers, with a sample size of 220 beekeepers, to whom previously elaborated surveys were applied. The information was systematized into two sections: socioeconomic and technology adoption. The analysis included constructing a database in Microsoft Office Excel 2019 and data processing using the R Development Core Team (2017) version 3.4.3. Twenty variables were selected to identify the types of 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, receives training, 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 (δin) by the sum of the total practices that the beekeeper can perform (δi...n).

$$I_{ij} = \sum_{ij} \frac{\delta_{in}}{\delta_{i\ldots n}}$$

The data on practices susceptible to technological adoption were *registration of hives*, *previous training*, *division of hives*, *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 used to select the 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 used to differentiate the groups of producers (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 number 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
Technological level	Information directly obtained from the producer. This variable is independent of the others and important in the structure of beekeeping.

With the selected variables, a k-means clustering analysis was carried out to identify the groups or beekeepers (Mair *et al.*, 2012) using Manhattan distances (the partitioning around medoids represents greater robustness). Each cluster is represented by a group (or object) that can be considered as a type or representative individual of the group that it belongs to (Brock *et al.*, 2008).

In other words, these analyses define and combine variables to construct the 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

Importantly, due to the characteristics of the region and the access to the beekeeping production units, it was considered appropriate to use general attributes that can function as operatives for the extensionist (De Martinelli, 2011).

To eliminate the systematic error that could bias the results (Badii-Zabeh *et al.*, 2008), the variation of the technological index was determined, which represents the adoption of technology of the subjects of study based on the categories of producers obtained from the cluster analysis, which depends on the explicative or independent variables using the 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 on average 49 years of age, 14 years of experience, and three years of education. Additionally, 70.9% speak Mayan and have a collective interest in improving the productivity of their hives (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 have an unfinished primary education (six years of school instruction). A few of them have at most nine and 12 years of education (middle and high school, 8.3%). As for beekeeping experience, in Bolonchén and Tankunché, producers had at least 16 years of experience, which favors work settlement. In Uayamón, their experience was less than eight years. Regarding the average age of this community, beekeepers in Uayamón are younger compared to other regions (Table 3).

Production profile

The average number of hives was 30, with an average production of 11.47 kg of honey. Bolonchén and Uayamón were the communities with the lowest yields per hive (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 corroborated that the technological index is inversely related to the age of the beekeeper ($R^2 = -0.005$), likewise, the yield/hive *versus* the years of experience. The other variables showed lower correlation values ($p \leq 0.6$).

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 in this study (Figure 1).

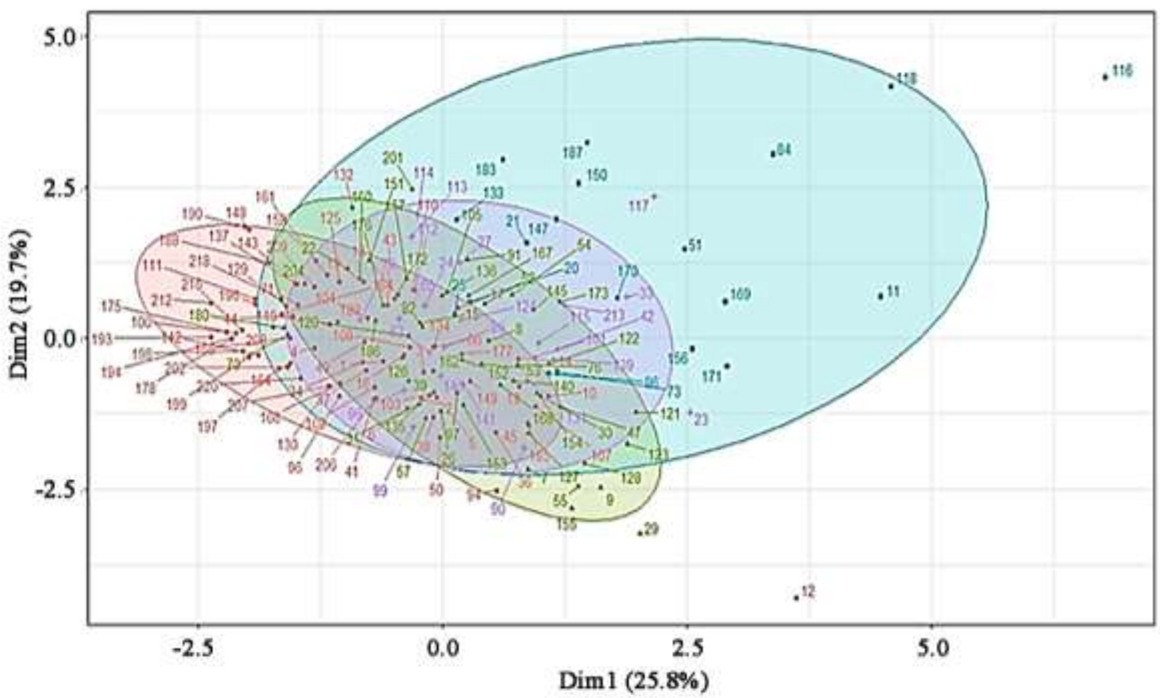

Figure 1. Projection of the beekeeper groups.

Type I includes beekeepers with 10 years of experience and lower production and yield, 107.8 kg/year and 6.7 kg/year, 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), and there was a positive correlation between the technological index and years of experience (coefficient=0.39 ± 0.002). That is, greater experience was related to greater adoption of technology. The interaction between the Mayan language and technological index was ruled out because education level and years of experience are expected to be significant (p=0.03 and p=0.0008, respectively). To identify at what education level there were marked differences in the means, the Bonferroni paired test was used, where it was determined that there are differences in the adoption of technology between the years of education (p=0.0447). It was confirmed that the beekeepers with nine years of education (complete basic education) were the ones with 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 activities with greater governmental support in Campeche. However, despite previous efforts with rural extension projects, honey production and technology have not increased. Results indicate low technology adoption and highly variable honey production in Campeche. These findings are like those reported by Parra (2009), who mentioned that beekeepers in rural areas and those without basic education base their beekeeping on culturally transmitted empiric knowledge. This could explain the low adoption of new technology or knowledge (Güemes-Ricalde *et al*., 2003; Magaña-Magaña *et al*., 2012; Contreras *et al*., 2013; Martínez-Pérez *et al.,* 2017). In this scenario, the years of experience variable is an important factor in the productivity of the hives and, therefore, in the economic benefit of beekeeping. Magaña-Magaña *et al.* (2016) discussed that the similarity in production observed between beekeepers with high and low education levels could be explained by the nature of this activity and its relationship with environmental factors. In addition to the fact that the handling practices of hives do not require high education levels, but are influenced by productivity and social factors, such as years of experience and age. As observed in Bolonchén and Uayamón, the communities with the lowest yields/hive that had few years of experience and a lower education level.

The diverse ecosystems in the region, in terms of types and states of natural and modified vegetation, represent resources that influence honey production (Porter-Bolland, 2010). For example, Campeche production was too low (378. 57 kg of honey per year), compared to Jalisco production of 1,600 kg of honey per year (Contreras *et al.,* 2013). Notably, the number of hives was not related to the total honey yield (Table 4). Said parameter depends on various factors, such as the amount of flora available, the technology applied, the climatic conditions, and the genetics of the bees, among others. In the study by Magaña-Magaña *et al.* (2016), beekeepers from Campeche and Quintana Roo had on average 37.10% fewer hives than Yucatan. In addition, production of honey or hives may be affected by incidence of diseases or pests, but these factors were not included within the analyses of the present study.

Within the framework of agricultural chains, for Strata III and IV producers (González-Cambero, 2014), education level and age are closely related to productivity. The correlation analysis confirmed the negative association between age and technological index. The beekeepers in the regions included in this study are old and are not incorporating new practices. This could be due to resistance to change or the traditional production culture that prevails in Strata I and II producers (Contreras *et al.,* 2013; Rodríguez-Balam and Pinkus, 2015).

All profiles identified (Table 6) denote the social and productive heterogeneity in the study communities. In future studies, it would be interesting to determine the economic threshold referred to as the minimum number of hives necessary to make beekeeping more profitable. As for Type III beekeepers, it is important to highlight the economies of scale as tools that influence variables such as yield per hive and production. Furthermore, based on their adoption of technology (67%), Type II beekeepers would be the best to receive training by extensionists, considering traditional organization schemes and components of social and solidarity economy, which are deeply rooted in Mayan beekeepers (CEDRSSA, 2019; Kokwe *et al*., 2022; Rodríguez *et al*., 2009). The Linear model showed that the education level and years of experience influence the incorporation of new practices. Therefore, it is necessary to implement strategies that increase the technological index and its effect on production.

Castellanos-Potenciano *et al.* (2015) proposed that the social capital of a specific region influences the knowledge that a beekeeper learns and that it is the communication with the system. Analyses highlight the role of the extensionist as an agent of development, considering the interaction between beekeepers in a specific context, which enables the effectiveness of their intervention. In other words, rural extension is a process of practical feedback that is built from a micro-social logic in which dialogue and producer experience are recognized (Gómez-Martínez *et al.,* 2017; Ardila, 2010). Therefore, through rural extension, it will be possible to identify a defined path towards development with the participation of beekeepers, considering their assessments, attitudes, and motivations (Russo, 2009).

Although beekeepers are 47-53 years-old, they have low levels of education and limited incorporation of technology. This affects the effectiveness of extension programs beyond the capacities of the extensionists. Type III beekeepers, identified in Strata I and II, could be considered a dynamic group in the production chain due to their lower age and higher education and technological index. Obviously, this group could be the focus of extension initiatives if the purpose is to improve their competitiveness.

Our methodology approach can be used to typify producers from other regions in the context of Rural Extension Programs with a focused and differentiated vision in which development routes are required. Undoubtedly, profiles such as these could be useful in the framework of development initiatives and/or differentiated and focused projects in which, in addition to strengthening the chain, social-territorial development is a priority. It is possible to detect the importance of specific socioeconomic characteristics in the production chain and their impact on the framework of extension projects. Moreover, future studies should consider the economic threshold referred to as the minimum number of hives needed to make beekeeping profitable, especially for Type III and IV beekeepers. Likewise, consideration should be given to strengthening training programs in good production practices for beekeepers, with the aim of increasing their technological index which, in synergy with experience in the management of hives, give rise to greater competitiveness.

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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