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Technical note

Classification of beekeepers in Chihuahua, Mexico

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Abstract:

Beekeeping is socioeconomically and ecologically important as it generates income and jobs while benefiting agriculture and the environment. A classification and description of beekeepers in the state of Chihuahua, Mexico, was done by analyzing the results of a beekeeper survey. Sixty beekeepers from twelve municipalities in the state were surveyed from November 2021 to May 2022. Principal component factor analysis (PCA), hierarchical and K-means cluster analysis (CA), and discriminant analysis (DA) were applied to the results using eight descriptive variables and five indices. Three groups of beekeepers were identified with the CA: small beekeepers (47 % of total), medium beekeepers (42 %), and large beekeepers (11 %). These were distinguished mainly by the number of apiaries and hives owned by producers. No significant differences were observed in a technical management index, but values in indices representing basic and specialized management, and genetic and nutrition were higher than those in other honey-producing regions in Mexico. The proposed beekeeper classification is potentially useful in designing strategies and actions to strengthen and promote beekeeping in Chihuahua.

Key words: Beekeeping, *Apis mellifera*, Technological index, Productive Capacity, Technical management.

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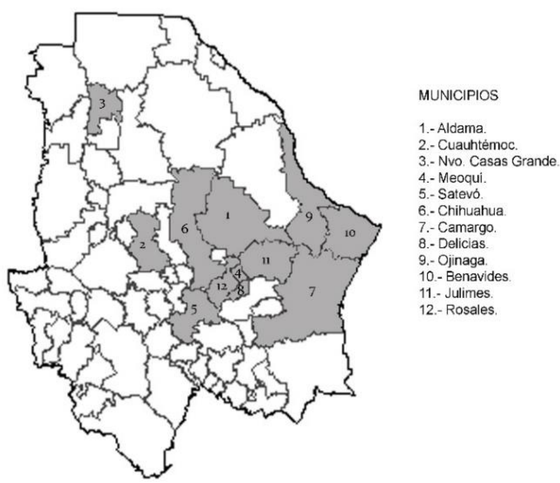
Beekeeping contributes to biodiversity preservation and can effectively improve income in rural areas[1]. In 2020, Mexico was the tenth largest honey-exporting country in the world, with more than sixty thousand tons harvested annually[2], in five regions: Altiplano, Pacific, Gulf, North and Yucatan Peninsula[3]. The state of Chihuahua is part of the Mexican Altiplano region[4], and in 2021 it was nationally ranked nineteenth in honey production. In addition to honey, beekeeping generates an economic impact through other derived products; for example, Chihuahua produces 15,000 reproductive queen bees sold throughout Mexico, which contribute to controlling Africanization and increasing production[5]. The state is also the main national producer of crops (e.g. alfalfa, cottonseed and apple) pollinated by bees and other pollinators[6].

Beekeeping practices vary throughout Mexico in response to regional biological variation and ecosystem diversity. This, in turn, influences economic and productive organization in the country's beekeeping regions. Minimal data is available on beekeeping in Chihuahua and the physical, socioeconomic and technical differences among its beekeepers and their production units. Research describing and classifying producers aids in optimizing public resource allocation, as well as proposing strategies to improve beekeeping. Multivariate techniques are most often used to classify producers[7]. This is because they provide the advantage of classification based on production unit similarities and differences *versus* a set of classification criteria[8]. Some classifications of beekeepers and their production systems consider the diversity of physical, socioeconomic and technical factors that cause beekeepers in different regions to have specific characteristics and challenges[8,9,10].

Beekeeping in Mexico, and particularly in Chihuahua, faces the challenge of an increasingly competitive and demanding market[11], specifically in terms of food safety and traceability. This is why having data on the beekeeping systems in a given area, and the production processes and factors that influence them, is vital for proposing intervention policies or recommendations. The present study objective was to classify and characterize beekeepers in the state of Chihuahua, Mexico, to increase information on this productive activity.

The study area included twelve municipalities in the state of Chihuahua (Figure 1). Located in northwest Mexico, Chihuahua is bordered to the north by the state of New Mexico and to the east by the state of Texas, both in the United States; in Mexico, it is bordered to the southeast by the state of Coahuila, to the south by the state of Durango, to the southwest by the state of Sinaloa and to the west by the state of Sonora. Chihuahua is the largest state in the country, representing 12.6 % of its area. Its population is 3.74 million inhabitants, 87 % of whom live in urban areas and 13 % in rural areas[12].

Figure 1: Municipalities in the state of Chihuahua where beekeeper surveys were applied



Data was collected through surveys applied to beekeepers from November 2021 to May 2022. The questionnaire included open and closed questions about beekeepers, apiary activities, sales and the market, organization and production costs.

The sample size (n= 60) was calculated by simple random sampling without replacement, considering maximum variance[13,14]. The population (N) was 187 beekeepers (a figure from Chihuahua state government reports)[15,16], the confidence level was 90 % and maximum permissible error was 9 %.

$$n = \frac{Z^2 Npq}{(N-1)e^2 + Z^2 pq}$$

Eight original variables were included in the multivariate analysis: beekeeper age, years of beekeeping experience, and education level; number of hives, number of apiaries, number of honey-producing hives, annual hive maintenance costs, and market shares. Five synthetic variables were also included in the analysis. These were technological indices[17], with values estimated based on field data:

1) Basic management index. Encompasses hive space management practices, frame and hive repair, area cleaning, changing wax in frames, queen replacement, hive inspection, and producer participation in the national beekeeping system.

2) Specialized management index. Includes hive identification activities, production and financial records, colony division, hive replacement, production of byproducts (pollen, propolis, royal jelly and wax), weighing honey, frame casting and painting hives.

3) Genetic index. Includes queen replacement from producer hives, queen replacement with queens produced in-state, queen replacement with queens from Ministry of Agriculture-certified producers, and application of a genetic improvement program.

4) Nutrition index. Based on whether beekeepers provide maintenance feed and stimulation feed.

5) Health index. Includes pest, varroa, and disease control activities, and producer participation in anti-varroa campaign.

In estimating the indices, each practice and technology was assigned a value of 1 or 0, where (1) indicated that the beekeeper did it and (0) that they did not[10,17]. The mathematical formula was:

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

Where I_{ij} is the technological index *i* for beekeeper *j*; δ_{in} is the real sum the beekeeper attains based on the number of practices and technologies implemented; and $\delta i \ldots n$ is the maximum sum of *n* practices or technologies that beekeeper *j* can undertake per index *i*. Index values were within a $0 \geq I_{ij} \leq 1$ interval. An estimate was also generated for a total technological index IT_j, with a value interval of $0 \geq IT_j \leq 5$, using the formula[10]:

$$IT_j = \sum_{i=1}^{5} I_{ij}$$

The first step in the statistical analysis was a principal component analysis (PCA) using a varimax rotation to reduce the variables to components explaining the greatest variance. Analysis feasibility was corroborated with the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's sphericity test, which tests the hypothesis that the correlation matrix is an identity matrix. As a second step, a hierarchical cluster analysis (CA) was run based on Ward's algorithm to graphically identify the number of groups; the beekeeper groups were then identified using the K-means cluster analysis. A discriminant analysis (DA) was used to evaluate classification and assignment of each individual to a group[18]. Within the DA, stepwise variable selection was used to identify the independent variables that most distinguished the groups, and verify that group formation was robust. An ANOVA was run to identify differences and compare between groups. Statistical analyses were done using the SPSS 27.0 software[19].

Five components were identified in the PCA, explaining a total of 71.7 % of total variance: the first contributed 20.7 %, the second 17.9 %, the third 13.0 %, the fourth 10.1 % and the fifth 10.0 %. Both the KMO (0.62) and Bartlett sphericity test (*P*<0.000), confirmed PCA feasibility. The first component included variables related to the number of colonies in a production unit and was labelled "productive capacity". The second encompassed the basic management, nutrition, specialized management and genetic indices and was labelled "technical management". The third, consisting of producer age and years of experience, was labelled "producer capabilities". The fourth included annual hive maintenance costs and the health index, and was labelled "health status". The fifth grouped education and market participation variables and was labelled "management potential".

The CA identified three groups, and the DA correctly classified 98.3 % of the respondents. The Wilks' Lambda statistic (0.132) indicated that the groups were statistically different. Both the Wilks' Lambda ($P<0.05$) and F statistic values (>3.84) for each factor confirmed that the factors that most contributed to group definition were productive capacity, producer capabilities, health status and management capacity; technical management did not contribute to group definition (P= 0.408, F= 0.912). This was corroborated with a completely random ANOVA of the technical management variables. In other words, no differences were identified between beekeeper groups in the indices for basic management (F= 2.093; gl= 2, 57; P= 0.133), specialized management (F= 2.583; gl= 2, 57; P= 0.084), nutrition (F= 0.887; gl= 2, 57; P= 0.417) and genetics (F= 1.484; gl= 2, 57; P= 0.235). It is therefore probable that the producers applied similar technical management practices.

The first group, "small beekeepers," consisted of 28 beekeepers and accounted for 47 % of respondents. This group included the youngest and least experienced beekeepers, with a high school or university education level. In terms of productive capacity, they had an average of three apiaries and 62 colonies, and a honey yield of 18.4 kg per hive per year (Table 1). Annual maintenance costs were low compared to the other two groups. Sales were focused on local, state and national markets, although 18 % had exported honey. Their relatively lower production capacity allowed them to be self-employed, and their income from beekeeping represented less than 50 % of family income.

Table 1: Mean and standard deviation of descriptive variables

Factor	Variable	Beekeepers		
		Small	Medium	Large
1. Production capacity	Number of hives	62±38	98±76	465±162
	Number of honey-producing hives	51±37	76±61	379±217
	Number of apiaries	3±2	8±7	16±7
2. Technical management	Basic management index	0.81±0.21	0.89±0.07	0.89±0.09
	Nutrition index	0.89±0.28	0.94±0.22	0.79±0.39
	Specialized management index	0.51±0.22	0.58±0.24	0.71±0.13
	Genetic index	0.42±0.19	0.44±0.24	0.57±0.28
3. Producer capabilities	Age	43±15	57±13	45±9
	Years' experience	11±8	23±16	28±16
4. Health condition	Annual hive maintenance costs	879±449	1,382±1,042	1,418±871
	Health index	0.88±0.32	0.67±0.31	0.96±0.09
5. Management capacity	Education level	12±3	14±3	10±3
	Market share	0.28±0.22	0.17±0.08	0.29±0.16
	Kilos honey per hive	18.4±11.2	14.8±8.4	23.15±15.3
	Total technological index	3.49.0±0.86	3.49±0.68	3.9±0.75
	Family jobs	1±1	1±1	2±2
	Contribution to household income	<50 %	< 50 %	> 75 %

The second group, "medium beekeepers" consisted of 25 beekeepers, representing 42 % of the sample. It included older beekeepers with more experience in beekeeping, and a high school or university education level (Table 1). They had an average of 98 colonies distributed in eight apiaries, and an average production of 14.8 kg honey per hive. Their total technological index was 3.49, with particular emphasis on nutrition practices such as maintenance and stimulation feeding, as well as basic management activities such as colony inspection, area management and cleaning, frame and hive repair, changing of old combs and queen replacement. Most of those in this group applied control measures for varroa (84 %), pests (wax moth) (68 %), and other diseases (nosemosis and European foulbrood) (56 %). These producers were self-employed and generated less than 50 % of their household income from beekeeping. Their market share was local and statewide.

The third group, "large beekeepers", included seven producers and represented 11 % of respondents. These were the most experienced in honey production, with 45 yr average age and a secondary or high school education level. On average, they had 379 colonies for honey production, and average production per hive was 23.15 kg. They generated an average of two-family jobs and had a slightly higher technological index than the other groups, since they used more genetic and specialized management activities; annual hive maintenance costs were consequently higher. These producers generally kept financial and production records, replaced hives, divided colonies, and produced honey and wax. They also rented hives for pollination of crops such as apple, watermelon, melon, cotton, cucumber and green tomato. Their market share was local, state and national, and more than 75 % of their household income came from beekeeping.

Classification of beekeepers in Chihuahua was based on unit productive capacity, which is related to production unit size. This coincides with the small, medium and large classifications reported in a similar study done in the state of Morelos[10]. Production unit size in Chihuahua was smaller in terms of number of colonies and honey production than in regions such as Morelos and the Gulf[9,10]. In these regions, small or traditional beekeepers had an average of 80 colonies, medium beekeepers had 157 colonies, and large or commercial beekeepers 426 colonies. In Chihuahua, small beekeepers had 62 colonies, medium ones had 98, and large ones 379. This is a relevant metric because in beekeeping production systems colonies represent capital and are associated with a producer's economic dependence on beekeeping.

The nutrition, basic management, specialized management and genetic indices did not differ between the three groups. However, compared to these indices for beekeepers in Morelos[10], the index values in all three groups in Chihuahua were higher, especially in the genetic and nutrition indices, highlighting different management practices between the two regions. One notable difference is that 90 % of the surveyed beekeepers in Chihuahua employed maintenance feeding and stimulation practices in an effort to increase honey production and guarantee colony survival through the winter[20], a particular concern in the highlands where flowering occurs suddenly and is short-lived[21]. Another discrepancy is that producers in Morelos largely replaced queens from their own hives or from in-state producers, with only large beekeepers replacing them with queens from certified producers. In Chihuahua, by contrast, 85 % of large and 60 % of small producers replaced them with queens from certified suppliers, and 64 % of medium producers used queens from in state. Compared to the total technological index results in the Morelos study[10], the index value for the studied Chihuahua producers indicates they are at an intermediate technological level.

Productive capacities were another important component in classifying the beekeepers in Chihuahua. These were similar to those reported in the states of Jalisco[22] and Morelos[10], and in the Gulf region[9]. Average age in the groups ranged from 43 to 56 yr, with the middle-aged beekeepers being the most experienced.

Hive health status index values were high (0.7) in all three groups of beekeepers in Chihuahua, and higher than reported in Morelos[10]. Beekeepers in Chihuahua clearly valued hive health since 92.5 % engaged in activities related to this index. Even though it increases annual hive maintenance costs, they invested in hive health because it reduces the risk of losses both in bee populations and income.

In contrast to other honey-producing regions in Mexico[10,23], beekeepers in Chihuahua generally had a higher educational level, allowing them to access information and connect with markets. These are important aspects of the marketing process, since the market is dynamic, requiring sales strategies and clear definition of distribution channels[24]. For example, in the present results, 81.7 % of respondents sold honey in the local market, 8.3 % in the national market and 10% exported to countries such as the United States and Germany.

For the small and medium producers, beekeeping was a secondary economic activity representing less than 50 % of household income. They supplemented it with agricultural activities, another business or a job. This is similar to the type of beekeeping done in the state of Yucatan[25], where it is considered a complementary household income source, but still contributes to regional development and sustainability. The large beekeepers, for whom beekeeping generates most of their income, applied technological innovations in technical management, much like producers with more than 500 hives in the state of Jalisco[22]. Studies done in Mexico[26], Argentina[8], and Brazil[17], highlight the importance of beekeeping in generating jobs and household income, and emphasize its worldwide social and economic importance. It also has the added advantage of generating favorable environmental impacts[27].

The present analysis of beekeepers in the state of Chihuahua identified three types of beekeepers: small, medium and large. Production unit productive capacity (e.g. number of apiaries and colonies) was the main factor in effectively classifying them. The three types did not differ in terms of technical management practices, although, compared to other honey-producing regions in Mexico, the Chihuahua beekeepers implement management practices that place them in an intermediate technological index value. All three groups were concerned with maintaining hive health condition and exhibited management capacity when accessing different markets. For the small and medium beekeepers, it is a secondary activity, while for large producers it is a primary activity that generates jobs.

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