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Technical note

Color, moisture, and pollen content of honeys from the mangrove ecosystem of the coast of Tabasco, Mexico

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Abstract:

The physical characteristics of honeys are important attributes for consumers when choosing one honey over another; because of this, knowing these parameters and their botanical origin are essential to determine their quality and price. The present study determined the color, moisture, and pollen content of honeys collected in the mangrove area on the coast of the state of Tabasco, Mexico. Seventeen (17) samples were collected and their color and moisture content were determined, and a sample from each locality was selected to perform a melissopalynological analysis. Five honey colors were found with values from 12 to 120 mm Pfund, with extra light and white amber being the predominant colors. In relation to moisture content, there were samples with values of 18 to 23 %, of which 53 % of them comply with the limit (20 %) established in the regulations; finally, all the samples were multifloral, with the Fabaceae, Poaceae, and Asteraceae being the most important botanical families. In conclusion, in the mangroves of the coast of Tabasco, Mexico, multifloral honeys of light shades are produced, where those of extra light amber and white colors predominate, with a moisture content between 18 and 23 %; therefore, these honeys could be suitable for entering more specialized markets if a maximum moisture of 20 % is ensured.

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Honey is a natural product that bees produce from the nectar of flowers, secretions of living parts of plants, or from excretions of plant-sucking insects that remain on them and that bees collect, combine with their own specific substances, deposit, dehydrate, and store in the honeycomb so that it matures and ages(1). This process gives honey unique properties that define its physicochemical, sensory, and microbiological characteristics(2).

The study of the organoleptic properties and botanical origin of honeys has been important in recent years since their analysis provides commercial added value and allows to know the interaction of *Apis mellifera* with plants(3), facilitating their characterization since these parameters are decisive for consumers when choosing a honey(4). The color of honey is determined by its botanical origin, the composition of the nectar of the flower of origin, the extraction process, temperature, time, and storage conditions(2). Nonetheless, geographical origin, climatic conditions, soil conditions of the plant of origin, exposure to light, heat treatment, and crystallization processes, as well as the content of minerals, antioxidants, and sugars, also influence this attribute(5,6).

In recent years, there has been an increase in reports linking honey color with the presence of phytochemicals, such as ascorbic acid, phenolic compounds, amino acids, enzymes, tocopherols, carotenoids, and flavonoids, with dark-colored honeys having the highest content of pigments with greater antioxidant potential(7,8). In color determination, the Pfund technique is one of the most widely used due to its fast, economical, and simple characterization; it classifies honeys into seven shades of amber (water white, extra white, white, extra light amber, light amber, amber, and dark)(6,9). In Mexico, the study of the color of honeys has revealed that this attribute varies from month to month, demonstrating the change in floral resources throughout the year, with the lightest honeys coming from the months with the highest flow of nectar (October-November)(10). Likewise, a strong correlation has been found between antioxidant activity and color, with dark honeys having the highest capacity[11]; this is similar to what has been reported in honeys from Tabasco[12], where they show extra-light amber and light amber colors[13]. Another fundamental factor in the physicochemical characteristics of honeys is the pollen content[2] since, as it is distinguished by its high content of proteins, vitamins, minerals, carotenes, xanthophylls, phenols, and antioxidants, among others, its analysis is decisive to evaluate the quality of the honey and botanical origin[14].

The state of Tabasco has several geographical areas that offer an important beekeeping potential, where the mangrove is one of the ecosystems that can be exploited since it is possible to obtain sweet and perfumed honey, even with a salty and bitter touch[15]. According to CONABIO[16], Tabasco has 49,225 ha of mangrove, where red mangrove (*Rhizophora mangle* L.), black mangrove (*Avicennia germinans* L.), and white mangrove (*Laguncularia racemosa* L.) are the species with the greatest presence, developing on Solonchak soils and histosols generally rich in organic matter and nutrients[17]. These mangroves are distributed in the municipalities of Huimanguillo, Cárdenas, Comalcalco, Jalpa de Méndez, Paraíso, and Centla, where they offer important environmental and socioeconomic benefits, developing as important productive systems[18]. Due to the fact that there are gaps in information in research that documents and characterizes the honeys produced in these ecosystems, the color, moisture, and pollen content in honeys from the mangrove area on the coast of the state of Tabasco were determined and their characteristics are described in order to classify them according to these parameters.

The honeys were collected from July to September 2022 through random sampling, considering, for this purpose, the beekeepers of the Beekeepers Registry registered in the Office of the Secretariat of Agriculture and Rural Development of the state of Tabasco, who are located in the mangrove areas, as well as their availability to collaborate in this study. The mangrove on the coast of the state is located approximately between the coordinates 18° 00' 31” and 18° 38' 53” N and 92° 25' 26” and 94° 07' 40” W; it is bordered to the north by the Gulf of Mexico, to the south by Plan Chontalpa, to the east by the San Pedro and San Pablo Rivers, and to the west by the Tonalá River.

The samples were stored in 500 ml translucent plastic containers, labeled according to their geographical origin, and transferred to the Food Laboratory of the College of Postgraduates, Tabasco Campus, for analysis. The color was determined using a Hanna colorimeter, model C 221, with direct readings in mm Pfund. The equipment was calibrated using glycerin as a reference target and the readings were taken in triplicate. The honeys were classified according to NOM-004[19], which classifies them according to the values of mm Pfund as water white (0-8), extra white (9-16), white (17-34), extra light amber (35-50), light amber (51-84), amber (85-114), and dark (115-140). Moisture percentage was measured in triplicate using an ATAGO PAL-22S digital refractometer, Honey Moisture (12~30 %). The data obtained were used to perform a descriptive analysis of the qualitative variables of interest (color and moisture) through the statistical software of R Core Team[20].

To characterize the pollen, a sample was chosen from each locality (10 in total), of which 50 g of each one was taken and analyzed using the melissopalynological method described by NOM-004[19]. The identification of pollen grains was carried out by comparison with the help of the pollen keys from the Reference Collection of the Palynology Laboratory of CIATEJ (Center for Research and Assistance in Technology and Design of the State of Jalisco, A.C.) and specialized scientific papers[21-29]. Honeys were characterized as monofloral when their composition presented a pollen species with a percentage ≥ 45 % or multifloral with several pollen species present, sub-classified into: (a) oligofloral, dominated by two or more taxa of a plant family with 16 to 44 %, (b) bifloral, with two relevant taxa from different botanical families present from 16 to 44 %, and (c) strictly multifloral, with three or more taxa from different families with percentages ≥ 10 %. Finally, the most important pollen families were identified based on their dominance in each sample.

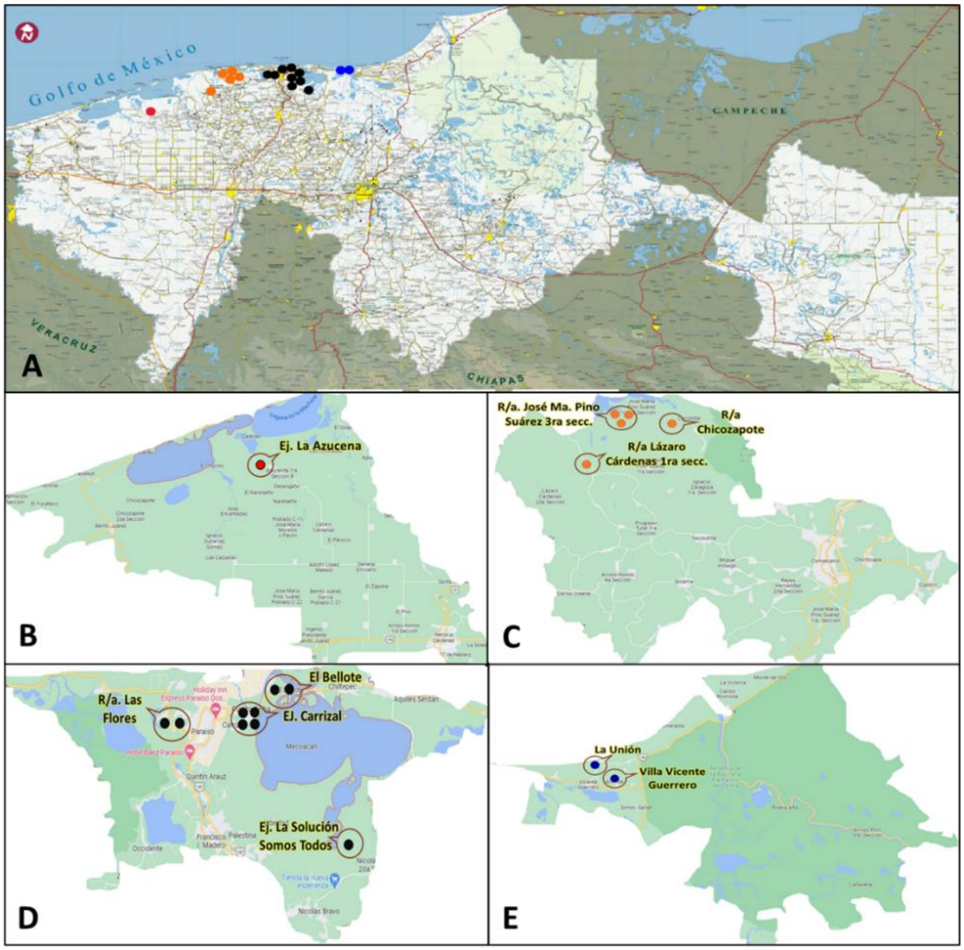
To determine color and moisture, 17 samples were collected in the municipalities of Paraíso, Comalcalco, Centla, and Cárdenas; the localities of origin and the percentage of samples by municipality is reported in Table 1.

Table 1: Number of honey samples collected, percentage by municipality, and localities of origin

Municipality	No. of samples	Percentage	Localities
Paraíso	9	53	R/a. Las Flores 1st section, Ejido Carrizal Puerto Ceiba, El Bellote, Ejido La Solución Somos Todos.
Comalcalco	5	29	R/a. Lázaro Cárdenas 1st section, R/a. José Ma. Pino Suárez 3rd section R/a. Chicozapote.
Centla	2	12	La Unión, Villa Vicente Guerrero.
Cárdenas	1	6	Ejido la Azucena 2nd section.

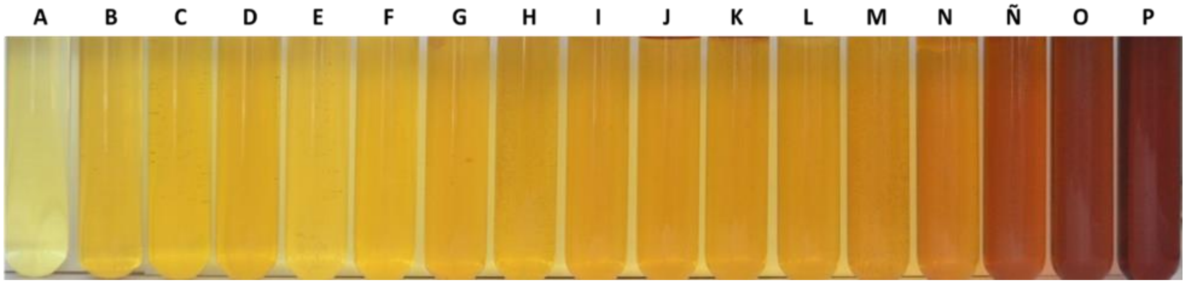
Figure 1 shows the location of the localities where the honey samples were collected, as well as the municipalities of origin.

Figure 1: A) Location of the localities where the honey samples were collected on the coast of the state of Tabasco (Modified from SOTOP, 2019), B) Cárdenas, C) Comalcalco, D) Paraíso, E) Centla.



According to the values of mm Pfund in the honeys analyzed, the following colors were found: extra light amber (47 % of the samples), white (29 %), light amber (12 %), amber (6 %), and dark (6 %); this is similar to what was reported for multifloral honeys from Guerrero, Mexico, where the variety of shades is attributed to the diversity of nectar-polliniferous plants and the metabolites they contain[11], originating from the floristic composition of the ecosystem that changes throughout the year[10]. Figure 2 shows the shades of the honeys collected: white (A, B, C, D, E), extra light amber (F, G, H, I, J, K, L, M), light amber (N, Ñ), amber (O), and dark (P).

Figure 2: Colors of honey collected in the mangrove area of the state of Tabasco



The lightest shade was found in a white honey (12±0.6 mm Pfund), whereas the darkest shade was for a dark-colored honey (120±1.2 mm Pfund) from Paraíso, as shown in Table 2. These values are similar to those reported in honeys from Peru, where it was found that the color of the honeys varied from extra light amber (44 mm Pfund) to dark amber (107 mm Pfund), attributing this variation to melanoidins (pigments generated in the Maillard reaction), which were also found in light, light amber, and dark honeys from Poland, these being the ones that establish the differences between a light and a dark honey(30,31).

The light shades are characteristic of black mangrove (*A. germinans*) honeys(32), accompanied by sweet and bitter flavors, even a little salty(33). In Tabasco, extra-light amber and light amber honeys (46 to 68 mm Pfund) from different geographical areas have been reported(13). These light shades have been linked to low mineral content, mild flavors, and subtle aromas, whereas dark shades are associated with strong flavors and aromas, and high content of pigments, antioxidants, and minerals(10). Therefore, the color of honey can be used as an indicator of certain phytochemical compounds(11,33,34).

Table 2: Color and moisture of honey samples collected in the mangrove area of the state of Tabasco

Sample	mm Pfund (Mean ± SD)	Color[16]	Moisture, % (Mean ± SD)
A	12 ± 0.6	White	19.8 ± 0.2
B	21 ± 0.0	White	19.6 ± 0.1
C	28 ± 0.0	White	20.4 ± 0.2
D	32 ± 0.0	White	19.3 ± 0.2
E	32 ± 1.2	White	21.3 ± 0.3
F	38 ± 0.0	Extra light amber	21.9 ± 0.2
G	40 ± 0.6	Extra light amber	20.2 ± 0.5
H	42 ± 5.2	Extra light amber	22.8 ± 0.1
I	45 ± 0.0	Extra light amber	18.6 ± 0.1
J	45 ± 1.0	Extra light amber	19.3 ± 0.2
K	46 ± 6.4	Extra light amber	20.5 ± 0.3
L	48 ± 5.5	Extra light amber	20.5 ± 0.1
M	49 ± 3.1	Extra light amber	20.8 ± 0.1
N	57 ± 9.8	Light amber	19.1 ± 0.5
Ñ	76 ± 9.0	Light amber	19.6 ± 0.1
O	114 ± 0.6	Amber	18.9 ± 0.1
P	120 ± 1.2	Dark	18.9 ± 0.2

The honeys analyzed had an average moisture of 20.1 %; however, 47.1 % of these (Table 2) do not comply with the provisions of NOM-004[19] and the Codex Alimentarius[1] (20 % maximum for *Apis mellifera* honeys). The highest values were for samples H, F, and E (22.8 ± 0.1, 21.9 ± 0.2, and 21.3 ± 0.3 %, respectively), which could indicate that they were harvested from uncapped honeycombs[30], causing a short shelf life due to fermentation problems[35]. The variability in the moisture content (18.6 ± 0.1 to 22.8 ± 0.1) of the samples could be influenced by the moisture of the nectar of the floral source and the conditions of the environment since, in addition to the fact that the honeys are bifloral and multifloral (Table 3), they come from the 2022 spring harvest, so the increase in temperatures and the onset of rains in June[36] increase the relative humidity of the environment and therefore that of the nectar of the floral source[2].

In relation to the light shades of the honeys produced by beekeepers in this area, 59 % of them mention that this characteristic generates distrust in local consumers, so they have resorted to mixing them with darker honeys from other apiaries, areas, or seasons; nevertheless, it is important to preserve their original characteristics since each type of honey has its market and price, so these honeys could be suitable for markets such as the United

States, where they are preferred[37]. Therefore, even though it represents more work for beekeepers, it is important to keep honey from different apiaries, hives, and microregions separate, allowing a wide variety of shades and physical, chemical, and microbiological properties, targeting more specialized and demanding markets[10,38]. In addition to this, good beekeeping practices must be guaranteed to avoid dark tones generated by bad beekeeping practices, such as heating[5,14].

The melissopalynological analysis allowed to identify 34 pollen types, belonging to 7 plant families; none of the samples was considered monofloral (with some dominant taxon ≥ 45 %), so all the samples were multifloral (Table 3), of which samples H and M were subclassified as bifloral, where Fabaceae, Poaceae, and Asteraceae were the most important botanical families (16 to 44 %); finally, sample P was subclassified as strict multifloral with three taxa from different botanical families, where Myrtaceae, Fabaceae, and Sapindaceae presented percentages ≥ 10 %.

Table 3: Pollen classification of honey harvested in the mangrove area of the state of Tabasco

Municipality	**Sample**	**Locality**	**Pollen classification**	**Pollen families**
Paraíso	A	El Bellote	Multifloral	-
	E	Ejido Carrizal Puerto Ceiba	Multifloral	-
	H	R/a. Las Flores 1st section	Bifloral	Fabaceae, Poaceae
	P	Ejido La Solución Somos Todos	Strict multifloral	Myrtaceae, Fabaceae, and Sapindaceae
Comalcalco	I	R/a. Lázaro Cárdenas 1st section	Multifloral	-
	K	R/a. José Ma. Pino Suárez 3rd section	N/ID	-
	N	R/a. Chicozapote	Multifloral	-
Centla	M	La Unión	Bifloral	Poaceae and Asteraceae
	O	Villa Vicente Guerrero	Multifloral	-
Cárdenas	C	Ejido la Azucena 2nd section	N/ID	-

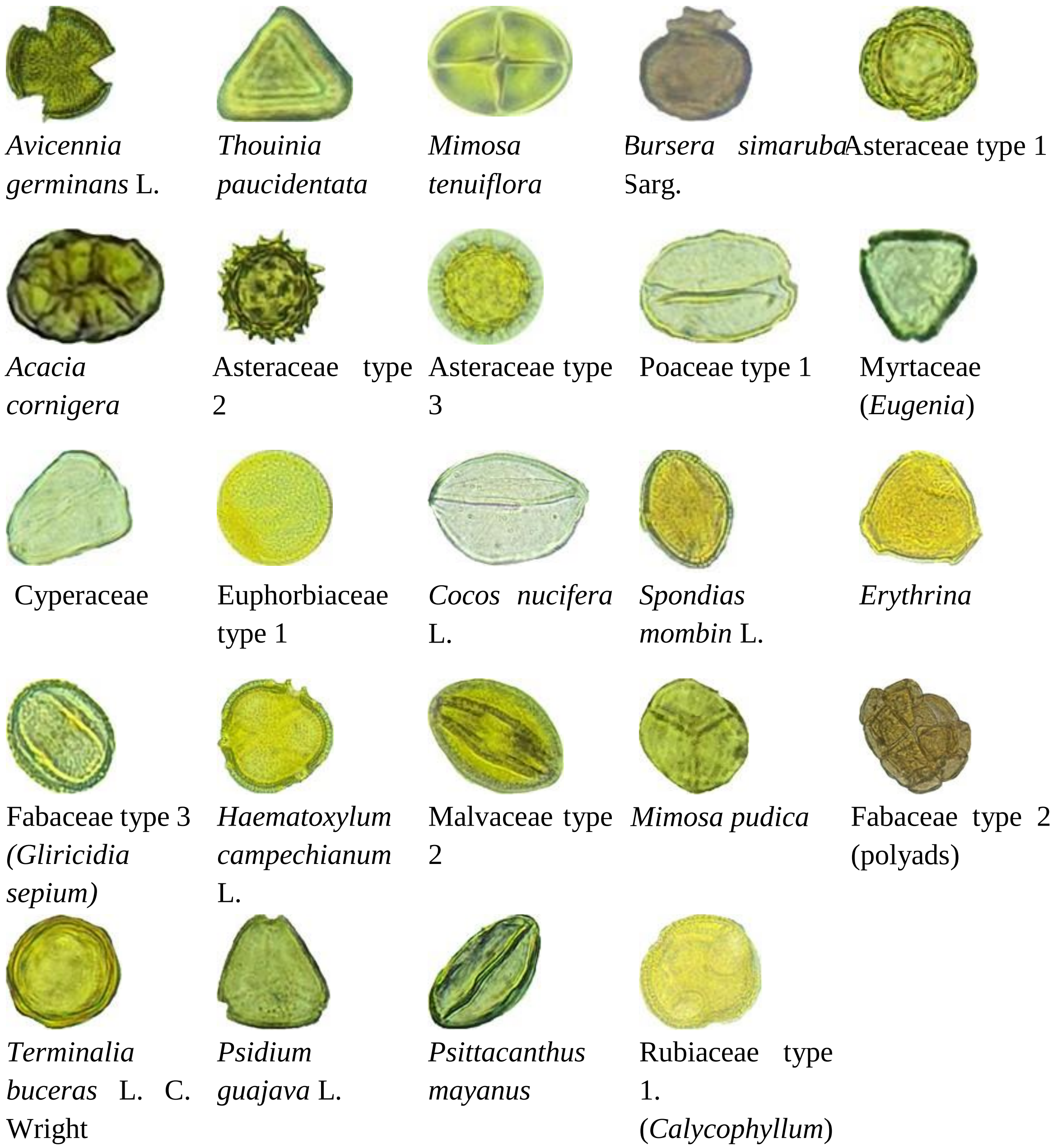
N/ID= not identified due to low pollen content.

In Paraíso, there were multifloral samples that were subclassified as bifloral and one strict multifloral (Table 3), which differs from what was reported in previous research for honeys in this municipality[26], where two monofloral samples of *Cocos nucifera* and *Mimosa albida* were identified, respectively; nonetheless, a bifloral sample was also found, with *C. nucifera* and *Psidium guajava* being the important pollen species. In Comalcalco and Cárdenas, there were honeys that were classified as multifloral, whereas for the municipality of Centla, a bifloral sample was found, where the Poaceae and Asteraceae were the important botanical families (16 to 45 %). In the case of samples K and C, they did not contain enough pollen particles to determine their frequency, so they could not be classified. Figure 3 shows some of the pollen types identified in the samples analyzed.

Black mangrove pollen was present in seven samples from the four municipalities, being found as secondary pollen in sample E (26.6 %), which is a white honey from Paraíso, as well as in sample N (17 %), which has a light amber coloration and is from Comalcalco. No pollen from other mangrove species was found, which could be attributed to the abundance of flowers from other plant species in the area and season since bees tend to discriminate and select flowers by color, smell, or by type of pollen. Because of this, it is necessary to carry out studies that allow the identification of these granules in the harvests of other seasons.

According to the total diversity of palynomorphs found in the honeys collected from the coastal mangroves, nine important taxa were found, considering their presence in the honeys in a percentage ≥10 %, the most representative being Poaceae type 1 (Poaceae), Asteraceae type 1 (Asteraceae), *Eugenia* (Myrtaceae), *Avicennia germinans* L. (Acanthaceae), *Mimosa tenuiflora* (Fabaceae), *Mimosa albida* Humb. & Bonpl. Ex Willd. (Fabaceae), *Bursera simaruba* Sarg. (Burseraceae), *Thouinia paucidentata* Radlk. (Sapindaceae), and *Lonchocarpus punctatus* Kunth (Fabaceae). Previous studies have identified important taxa in these areas, such as Acanthaceae, Poaceae, and Fabaceae, among others[26].

Figure 3: Pollen types found in honey samples collected in the mangrove area of the state of Tabasco



In conclusion, the honeys collected in the mangrove area of the coast of Tabasco and from the 2022 spring harvest are multifloral honeys with light shades, where those of extra-light amber and white colors predominate, with an average moisture content of 20.1 % (between 18 and 23 %), so these honeys could be suitable for entering into more specialized markets if the moisture content established by the regulations to guarantee their quality from production to consumption is complied with. Likewise, although they could not be considered as mangrove honeys in terms of pollen, black mangrove pollen grains were found in 70 % of the samples analyzed, and as secondary pollen in 2 of them, so the mangrove is an ecosystem that can be considered important for beekeeping production in the area.

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