



Moisture Content and Soluble Solids in *Apis Mellifera* L. Honeys from Family Beekeeping in the Semiarid Region of Pernambuco

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ARTICLE INFO	ABSTRACT
Published Online: 31 January 2026	In a context marked by edaphoclimatic constraints and high socioeconomic and environmental vulnerability, beekeeping has consolidated as an economically viable, socially inclusive, and environmentally sustainable productive alternative in the semiarid region of Pernambuco, particularly within family farming systems embedded in the Caatinga biome. This study aimed to evaluate the physicochemical quality of honey produced in the hinterland of Pernambuco by analyzing moisture content (%) and total soluble solids (°Bx) in <i>Apis mellifera</i> L. honeys from different municipalities of the semi-arid region. A total of 20 honey samples (HS) were analyzed using a digital refractometer, based on the parameters established by the Brazilian Ministry of Agriculture Normative Instruction MAPA No. 11/2000 and reference values reported in the scientific literature. The results indicated that most samples exhibited moisture contents within the legal limits, while °Bx values revealed a high concentration of soluble sugars, a characteristic associated with mature honeys and good physicochemical stability. The observed variability was related to climatic conditions, beekeeping management practices, comb capping time, and the floral origin of the regional apicultural pasture. The study highlights the feasibility of using digital refractometers as an accessible and effective tool for honey quality monitoring, enabling early detection of deviations, adoption of corrective management practices, and reduction of fermentation losses. Thus, the use of this technology contributes to strengthening family beekeeping in the semi-arid region by promoting the supply of honey with higher quality and food safety.
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I. INTRODUCTION

Beekeeping has assumed a prominent role in the semi-arid region of Pernambuco, Brazil, particularly within the context of family farming systems embedded in the Caatinga biome. In a region characterized by irregular rainfall, high temperatures, and structural limitations to conventional agriculture (Alves, 2013; Beserra, 2025), the rational management of honeybees of the species *Apis mellifera* L., 1758, shows high adaptability to local edaphoclimatic conditions, representing a viable alternative

for income generation and sustainable rural development (Beserra, 2025; Christ, 2023). Despite the relevance of regional beekeeping, studies evaluating the applicability of accessible tools for honey quality control directly within the context of family farming in the semi-arid region remain scarce.

Beyond its economic relevance, beekeeping plays a strategic ecological role, as bees act as key pollinators of the native flora of the Caatinga. Pollination enhances plant reproduction, contributes to vegetation regeneration, and

strengthens the resilience of semi-arid ecosystems, thereby extending the role of beekeeping beyond the productive dimension, with direct impacts on environmental conservation and the sustainability of rural territories.

For honey produced in the Caatinga of Pernambuco to achieve greater competitiveness and added value in regional and national markets, compliance with identity and quality standards established by Brazilian legislation is essential. In this regard, Normative Instruction (NI) No. 11 of October 20, 2000, issued by the Ministry of Agriculture and Livestock (MAPA) (Brazil, 2000), establishes physicochemical parameters that ensure the quality, safety, and authenticity of honey intended for human consumption.

Among these parameters, moisture content (%) and total soluble solids, expressed as degrees Brix (°Bx), stand out due to their direct association with honey maturity, stability, and shelf life (Arruda et al., 2005; Alves, 2013; Beserra, 2025; Christ, 2023). High moisture levels favor undesirable fermentation processes, whereas °Bx reflects the concentration of soluble sugars, influencing sensory attributes and commercial quality valued by the market (Silva et al., 2004; Arruda et al., 2005).

Although these analyses are traditionally performed in specialized laboratories, access to such infrastructure remains limited for small-scale beekeepers in the semi-arid region, hindering systematic quality monitoring at the production site. In this context, there is a clear gap in the dissemination and validation of accessible, low-cost, and field-applicable tools capable of supporting technical decision-making in beekeeping management within family farming systems.

Given this scenario, the question arises as to whether the use of digital refractometers constitutes a technically viable and accessible alternative for monitoring the quality of honey produced by family beekeepers in the semi-arid region of Pernambuco. Therefore, this study aimed to analyze the moisture content (%) and total soluble solids (°Bx) of *Apis mellifera* honeys produced in different municipalities of the semi-arid region of Pernambuco, within the Caatinga biome, and to discuss the use of digital refractometers as a strategic tool for honey quality control in the context of family farming.

II. THEORETICAL FRAMEWORK

The Caatinga is an exclusively Brazilian biome, characterized by high biological diversity and a significant degree of endemism (Silva et al., 2004), despite the adverse climatic conditions that define it. In this context, beekeeping stands out as an environmentally compatible productive activity, as it depends directly on the conservation of native vegetation and the maintenance of floristic diversity, establishing a direct relationship between economic production and environmental preservation.

Studies by Beserra (2025), Alves (2013), and Silva et al. (2024) demonstrate that the rearing of *Apis mellifera* L., 1758, in the Caatinga is intrinsically associated with the use of native apicultural pasture, composed of species such as velame (*Croton heliotropiifolius*), marmeleiro (*Croton blanchetianus*), algaroba (*Prosopis juliflora*), and jurema-preta (*Mimosa tenuiflora*), which are intensely visited by bees. This floristic assemblage is further enriched by species such as mastruz (*Alternanthera ficoidea*), ervinha-de-porco (*Amaranthus* sp.), faveleira (*Cnidocolus quercifolius*), and aroeira (*Myracrodruon urundeuva*), highlighting the remarkable botanical diversity of the biome.

This diversity confers unique physicochemical and sensory characteristics to honeys from the Northeastern Semi-arid region, reinforcing their territorial identity and adding socioeconomic value to beekeeping activities. Bees are considered keystone species in Caatinga ecosystems, playing a fundamental role in the pollination of native and cultivated plants and contributing to biodiversity conservation, agricultural production, and the sustainability of family-based farming systems (Beserra, 2025; Christ, 2023). Furthermore, bees act as bioindicators of environmental quality, being sensitive to degradation processes resulting from improper agrochemical use, deforestation, and habitat fragmentation.

Honey quality is defined by physicochemical parameters established by the Brazilian Technical Regulation of Identity and Quality of Honey (RTIQ), as set forth in Normative Instruction MAPA No. 11/2000, which include moisture content, reducing sugars, pH, free acidity, hydroxymethylfurfural (HMF), diastase activity, and ash content (Brazil, 2000). According to Beserra (2025), the systematic performance of these analyses enables verification of product compliance with MAPA requirements, ensuring its safety for human consumption (Schlabitz et al., 2010).

Among these parameters, moisture content plays a central role, as values above 20% favor fermentative processes and compromise the microbiological stability of honey. Total soluble solids (°Bx), in turn, are directly related to honey maturity and sensory attributes (Alves, 2013; Silva et al., 2023).

The adoption of appropriate, low-cost technologies, such as digital refractometers, is considered strategic for strengthening family farming in the Semi-arid region. This tool enables beekeepers themselves to perform rapid and reliable monitoring of moisture content, reducing losses, ensuring sanitary compliance, and enhancing honey competitiveness in the market (Beserra, 2025; Christ, 2023).

In this sense, beekeeping developed within the Caatinga biome shows strong convergence with the United Nations Sustainable Development Goals (SDGs) of the 2030 Agenda (UN, 2015), particularly SDGs 2, 8, 12, and 15. SDG 2 (Zero Hunger and Sustainable Agriculture) is

addressed through productive diversification, the provision of high nutritional value food, and pollination services that strengthen food security and agroecosystem resilience. SDG 8 (Decent Work and Economic Growth) is reflected in the generation of employment and income in rural areas, with potential for productive inclusion of family farmers, youth, and women, thereby strengthening local, territorially based economies (Beserra et al., 2022).

SDG 12 (Responsible Consumption and Production) is supported by the adoption of good beekeeping practices, quality control of honey, and the valorization of products with identified territorial origin, fostering environmentally responsible production systems and conscious consumption. Finally, SDG 15 (Life on Land) finds in beekeeping an activity that induces Caatinga conservation, as the maintenance of native apicultural pasture is essential for hive productivity, contributing to biodiversity preservation and sustainable ecosystem use.

Thus, beekeeping in the Caatinga is configured not only as a productive activity but as a territorial strategy for sustainable development, articulating environmental conservation, job and income generation, food security, and the valorization of natural resources in the Brazilian Semi-arid region.

III. METHODOLOGY

The research adopted a qualitative–quantitative approach, with an exploratory, descriptive, and analytical nature, grounded in the methodological assumptions proposed by Lakatos (2021), Minayo (2017), and Marconi and Lakatos (2003).

A total of 20 honey samples (HS) produced by *Apis mellifera* L., 1758, were analyzed. The samples were collected between January and July 2025 from registered apiaries belonging to family farmers located in municipalities of the Pernambuco Semi-arid region, within the Caatinga biome.

The samples were obtained from the municipalities of Santa Filomena, Carnaíba, Mirandiba, Parnamirim, Serra Talhada, Bodocó, São José do Belmonte, Dormentes, Floresta, and Petrolina (Figure 1). In order to adequately represent the floral diversity of microregions within different mesoregions of the Pernambuco Semi-arid, sampling was carried out during both the rainy season and the dry season, covering areas with distinct floristic compositions. The observed floral sources are typical of the Caatinga biome, consisting of native species adapted to the semi-arid edaphoclimatic conditions.

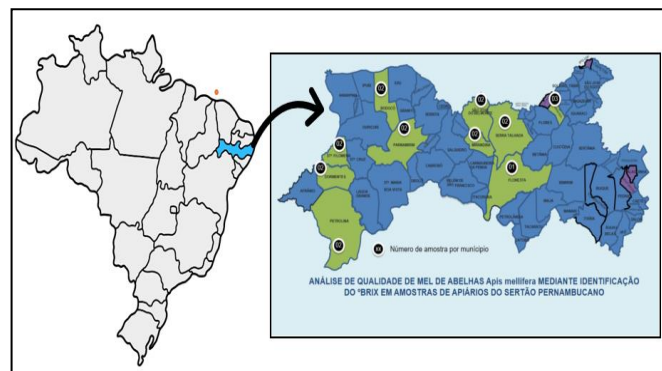


Figure 1. Location of honey sample collection sites.

Source: Author (2025).

Honey samples were collected directly from the apiaries, following good beekeeping and sampling practices. After collection, the samples were stored in appropriate, previously sterilized containers and properly labeled according to origin, collection date, and predominant flora during the production period.

The determination of total soluble solids (°Bx) was performed using a portable digital electronic refractometer, Milwaukee brand, model MA871, previously calibrated according to the manufacturer's recommendations. The equipment, manufactured in China, operates in a measurement range of 0 to 85 °Bx, with an accuracy of ± 0.2 °Bx at 20 °C, and had valid calibration until August 2025.

Analyses were conducted at ambient temperature, in shaded conditions, with thermal variation between 29 °C and 32 °C. For each determination, an aliquot of honey was applied directly onto the prism of the instrument, and readings were taken directly from the digital display. Temperature variations were automatically corrected by the refractometer's automatic temperature compensation (ATC) system.

The moisture content (%) of the samples was determined at the Laboratory of Entomology, Beekeeping and Meliponiculture (LEAPMEL) of the Federal University of the São Francisco Valley (UNIVASF), using the Chataway refractometric method. According to Cano et al. (2007), this method establishes a relationship between refractive index measurements and moisture percentage within a range of 13 to 25%, being considered an indirect method for determining moisture content. Based on the refractive index values obtained in °Bx, moisture content (%) was determined using the Chataway table.

The methodological procedures adopted are widely employed in physicochemical analyses of honey and followed the official standards of the Instituto Adolfo Lutz (2005). The results were subsequently compared with the parameters established by Normative Instruction MAPA No. 11/2000, which regulates the Technical Regulation of Identity and Quality of Honey (Brazil, 2000).

IV. RESULTS AND DISCUSSION

The analysis of moisture content (%) and total soluble solids (°Bx) of *Apis mellifera* honey samples produced in the Caatinga biome of Pernambuco revealed relevant variations among the evaluated municipalities, reflecting both local environmental conditions and beekeeping management practices. Regarding moisture content, most samples exhibited values below 20%, complying with the limits established by Normative Instruction MAPA No. 11/2000, which indicates adequate honey maturation prior to harvesting (Table 1).

Table 1. Identification of honey samples collected during the study.

N°	Municipality (PE)	Location (UTM)		Date	Refractometer	
		Longitude (m E)	Latitude (m S)		Brix (°Bx)	Water (%)
1	Santa Filomena	331799.73	9106434.53	22/03/2025	81,00	19,70
2	Santa Filomena	318976.52	9096518.09	22/03/2025	80,90	19,80
3	Carnaíba	633192.10	9134062,23	29/03/2025	81,10	19,70
4	Carnaíba	637057.04	9143311.31	29/03/2025	79,90	19,60
5	Carnaíba	634604.50	9141959.20	29/03/2025	80,60	19,80
6	Mirandiba	531110.73	9100490.43	11/02/2025	80,80	19,70
7	Mirandiba	529206.70	9099691.03	11/02/2025	79,60	19,40
8	Parnamirim	380194.29	9094623.30	18/04/2025	77,40	23,90
9	Parnamirim	428993.68	9109724.09	19/04/2025	80,40	19,10
10	Serra Talhada	567058.53	9114408.87	21/06/2025	79,10	22,20
11	Serra Talhada	587567.77	9126925.11	21/06/2025	80,40	19,10
12	Bodocó	397393.08	9143506.00	12/07/2025	81,40	19,00
13	Bodocó	391530.36	9150185.97	12/07/2025	78,10	22,70
14	São José do Belmonte	561862.67	9167788.26	13/02/2025	81,50	19,00
15	São José do Belmonte	558245.36	9169344.67	13/02/2025	80,70	19,10
16	Dormentes	304135.15	9064937.61	09/05/2025	79,50	21,00
17	Dormentes	303596.68	9066492.85	09/05/2025	79,40	22,10
18	Floresta	564657.00	9078764.00	19/02/2025	80,10	19,20
19	Petrolina	307915.99	9027772.71	26/01/2025	78,60	21,30
20	Petrolina	333124.32	9007683.08	19/01/2025	78,90	22,00

Source: Author (2025).

Municipalities such as Santa Filomena, Carnaíba, Mirandiba, São José do Belmonte, and Floresta presented predominantly satisfactory moisture values, ranging from 19.0% to 19.8%. These results suggest appropriate harvesting conditions, possibly associated with predominant floral sources, local climatic conditions, and respect for comb capping time, as described by Silva et al. (2004), Arruda et al. (2005), and Beserra (2025).

In contrast, samples from Parnamirim, Bodocó, Serra Talhada, and Dormentes exhibited moisture values above the legal limit, reaching up to 23.9%. These results may be related to higher relative air humidity during specific periods, premature harvesting of honey from incompletely capped combs (Silva et al., 2004; Arruda et al., 2005; Beserra, 2025), or the influence of specific floral sources with higher nectar water content. Such findings reinforce the importance of continuous moisture monitoring as a preventive strategy against fermentation processes.

Statistical analysis of the 20 samples showed a mean moisture content of 20.37%, median of 19.70%, and standard deviation of 1.48, indicating moderate variability. Although the mean slightly exceeded the legal limit, the median below 20% demonstrates that more than half of the samples complied with regulatory standards. Seven samples exceeded the 20% threshold, one of which reached 23.9%, representing a potential risk of fermentation.

Sample No. 8 exerted a significant influence on the mean value, characterizing a possible outlier. In statistical series, extreme values tend to distort the arithmetic mean, making the median a more representative measure. This outlier may be associated with specific collection conditions, management practices, or honey maturation stage. Despite these occurrences, the overall results indicate that most honey samples met the requirements established by MAPA Normative Instruction No. 11/2000. The moisture content graph (Figure 2) shows that deviations were concentrated in a limited number of samples.

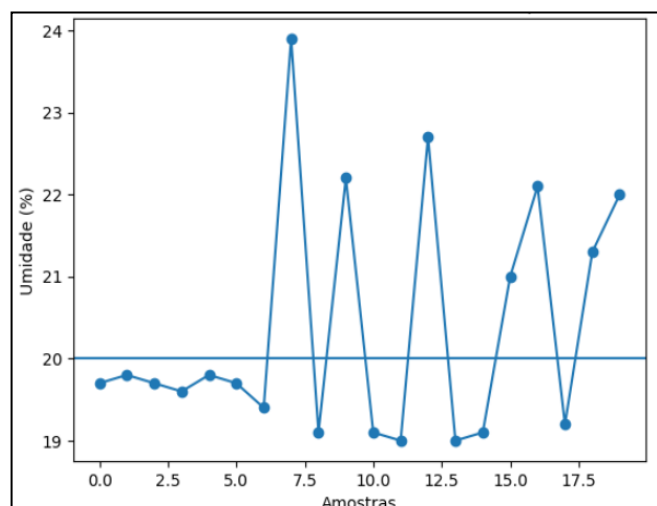


Figure 2. % of water in the samples analyzed.

Source: Author (2025).

Unlike moisture content, Brazilian legislation does not establish a specific limit for total soluble solids (°Bx) in honey. Therefore, the interpretation of °Bx values is based on reference ranges reported in the scientific literature. Studies by Silva et al. (2003) Silva et al. (2004), Cândido et al. (2013), and Sales (2025) indicate that high-quality honeys generally present °Bx values between 77 and 83 °Bx, a range associated with high sugar concentration and reduced susceptibility to fermentation due to the inverse relationship between soluble solids and moisture.

In this study, the 20 honey samples showed °Bx values ranging from 77.4 to 81.5 °Bx, indicating a high concentration of soluble sugars and characteristics consistent with mature honeys (Arruda et al., 2005). The data showed a mean of 79.97 °Bx, median of 80.25 °Bx, and standard deviation of 1.13 °Bx, suggesting homogeneous distribution and high consistency. The proximity between

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mean and median indicates the absence of significant asymmetry, while the low standard deviation reflects uniformity in soluble solids concentration, associated with adequate honey maturation and lower susceptibility to fermentation.

The variation in °Bx values is directly related to the floral origin of the honeys, as the floristic diversity of the Caatinga influences nectar composition. Floral sources such as marmeleiro (*Croton blanchetianus*), jurema (*Mimosa tenuiflora*), algaroba (*Prosopis juliflora*), faveleira (*Cnidocolus quercifolius*), and ingazeira were associated with higher °Bx values, reinforcing the potential of native apicultural pasture as a competitive differential for honey produced in the Caatinga biome (Alves, 2013; Christ, 2023; Beserra, 2025).

The use of digital refractometers proved essential for the immediate identification of deviations in honey quality parameters (Figures 3). The possibility of performing measurements directly at the apiary allows safer technical decisions, such as delaying harvest, segregating batches, and adopting corrective management practices. For family beekeepers, particularly in socioeconomically vulnerable contexts, access to this technology represents a significant advance in production control.



Figure 3. Analysis of °Bx in a honey sample in the present study.

Source: Author (2025).

Integrated analysis of moisture content and total soluble solids highlights the close relationship between the edaphoclimatic conditions of the Pernambuco semi-arid region and the floristic composition of the regional apicultural pasture. While °Bx values ranged from 77.4 to 81.5 °Bx, moisture content varied between 19.0% and 23.9%, indicating, overall, honeys with high sugar concentration and adequate maturation. Most samples complied with the limits established by MAPA Normative Instruction No. 11/2000 for honey intended for human consumption.

The scatter plot analysis (Figure 4) revealed an inverse relationship between °Bx and moisture content, with

samples showing higher soluble solids presenting lower water percentages. This trend was statistically confirmed by the Pearson correlation coefficient, which indicated a strong negative correlation ($r = -0.884$; $p < 0.001$). This behavior is consistent with the Codex Alimentarius, which identifies moisture content as one of the main indicators of honey maturation and stability, directly influencing its conservation and microbiological quality (Codex Alimentarius, 2001).

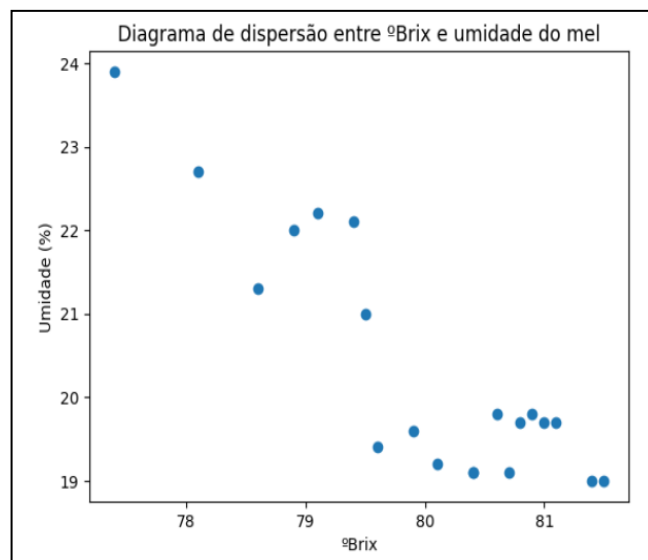


Figure 4. Relationship between moisture content and °Bx in honey samples.

Source: Author (2025).

From a biological perspective, this inverse relationship results from the natural honey maturation process, in which bees progressively dehydrate nectar through hive ventilation and enzymatic activity, concentrating sugars before comb capping. As highlighted by Wiese (2005), honey should only be harvested when it reaches an adequate maturation degree, characterized by low moisture content and high sugar concentration, conditions essential for ensuring stability and quality of the final product.

These results are closely linked to the characteristics of the Caatinga apicultural pasture, marked by the predominance of plant species adapted to water stress, such as *Croton* spp., *Cnidocolus quercifolius*, *Mimosa tenuiflora*, *Prosopis juliflora*, *Libidibia ferrea*, and *Poincianella pyramidalis*. According to Caporal (2009), production systems based on local biodiversity tend to generate products with strong territorial identity, with beekeeping being an emblematic example of an activity that transforms biological diversity into productive diversity without compromising ecosystem integrity.

In this context, melissopalynological analysis represents an essential tool for understanding the relationship between floral sources and the physicochemical parameters of honey. According to Louveaux, Maurizio, and Vorwohl (1978), pollen spectrum analysis allows the

identification of botanical origin and inference of chemical composition, seasonality, and production patterns. Barth (2004) emphasizes that the dominance of pollen from native species confers botanical and territorial identity to honey and contributes to the homogeneity of physicochemical parameters; however, such analyses are often financially inaccessible for small producers.

Nevertheless, the recurrence of typical Caatinga species in the analyzed samples suggests that the exploitation of native apicultural pasture favors the production of honeys with high °Bx values and low moisture content, particularly during periods of low rainfall. According to Barth (1989), honeys derived from well-defined floral sources tend to exhibit greater physicochemical stability, which may explain the strong negative correlation observed between °Bx and moisture in this study.

Samples with moisture contents above 21% were mostly associated with relatively lower °Bx values, possibly indicating premature harvesting, higher relative humidity, or the influence of secondary floral sources with more diluted nectar. In such cases, melissopalynological analysis becomes strategic by allowing the identification of predominant botanical species and providing technical support for improving beekeeping management and defining the optimal harvest time (Louveau; Maurizio; Vorwohl, 1978).

Thus, even in the absence of integrated physicochemical and melissopalynological analyses, the possibility of performing measurements directly at the apiary enables safer technical decisions, such as postponing harvest, batch segregation, and implementation of corrective management practices. In this way, the refractometer ceases to be merely a punctual measurement instrument and assumes a strategic role in quality management, contributing to legal compliance, loss reduction, and honey valorization in the market.

V. FINAL CONSIDERATIONS

The results of this study allow the recommendation, from a technical and operational perspective, of the use of degrees Brix (°Bx) as an indirect indicator of honey moisture content, particularly within the context of family-based beekeeping. The strong negative correlation observed between these variables ($r = -0.884$; $p < 0.001$) demonstrates that °Bx readings obtained using portable refractometers constitute a reliable method for inferring honey maturity and its compliance with the identity and quality standards established by current sanitary legislation.

Considering that the direct determination of moisture content requires specific equipment, higher levels of technical training, and laboratory infrastructure that are not always accessible to small-scale producers, it is recommended that refractometers with a °Bx scale be

incorporated as a priority quality control tool at the field level. This strategy supports decision-making regarding the optimal harvest time, reducing the occurrence of honeys with high moisture content and, consequently, minimizing the risks of fermentation and economic losses throughout the production process.

Within the scope of public policies aimed at sustainable rural development, the findings of this study indicate the need for technical assistance and rural extension programs to systematically incorporate the training of beekeepers in the use of refractometers and in the interpretation of °Bx values as an operational indicator of honey quality produced by family farmers in the Caatinga biome. The adoption of this simple and low-cost technology contributes to the democratization of access to sanitary quality control, strengthening productive autonomy and management capacity in family-based apicultural systems.

It is further recommended that public institutions, such as rural extension agencies, cooperatives, and government programs supporting beekeeping, promote the standardization of simplified quality control protocols, recognizing °Bx as a complementary operational parameter to direct moisture determination. This approach is particularly relevant in semi-arid regions, where native apicultural forage favors the production of naturally concentrated honeys, yet structural limitations to access conventional laboratory analyses persist.

Finally, the incorporation of °Bx as a field-based technical instrument aligns with the principles of agroecology and social technology by valuing solutions adapted to local realities and promoting integration between scientific knowledge, practical know-how, and inclusive public policies. This strategy contributes to strengthening honey quality, expanding opportunities for insertion into differentiated markets, and fostering sustainable territorial development pathways in the Brazilian semi-arid region.

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