REVIEW
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Honey from stingless bees in Brazil: bibliometric analysis and systematic review

Mel de abelhas sem ferrão no Brasil: análise bibliométrica e revisão sistemática

Elisana Julek[I,*]
Vitor Luis Fagundes[II]
Juliana Chiesse da Silva Zatta[III]
Suelen Ávila Berthier[IV]
Julia Arantes Galvão[I]

[I] Programa de Pós-Graduação em Ciências Veterinárias, Universidade Federal do Paraná (UFPR), Curitiba, PR, Brasil

[II] Curso de Farmácia, Universidade Federal do Paraná (UFPR), Curitiba, PR, Brasil

[III] Laboratório de Controle de Qualidade e Segurança de Alimentos (LACQSA), Universidade Federal do Paraná (UFPR), Curitiba, PR, Brasil

[IV] Programa de Pós-Graduação em Alimentação e Nutrição, Universidade Federal do Paraná (UFPR), Curitiba, PR, Brasil

*** E-mail:** elisana@ufpr.br

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ABSTRACT

Introduction: The honey from stingless bees (SB) is distinguished from honey from *Apis mellifera* bees, by unique sensory attribute, characteristics such as sweet-sour flavor and fluid viscosity, arousing increased consumer interest. Nevertheless, in recent years the number of scientific productions related to the subject has increased, it is necessary that the published articles are replicable. **Objective:** To fill important gaps about SB honey in Brazil, considering the structuring and possibility of replication of available studies, as well as the observation of physicochemical and microbiological characteristics of the product in order to base a national legislation. **Method:** The nine steps described in *Methodi Ordinatio* were followed. The search for articles was made in SciELO, ScienceDirect, Scopus and Web of Science platforms, using the keywords: "honey from stingless bees", "meliponiculture", "physicochemical characteristics" and "microbiological properties". The content of 18 articles was analyzed. **Results:** Based on this literature survey, Brazilian SB honey from less than 31 of the species was evaluated. Therefore, there is a large number of species to be explored for their physicochemical, microbiological characteristics as well as antioxidant/microbial potential of their honeys from many Brazilian regions. Besides, it was observed that very large variations in the physicochemical characteristics of the products came from different species and productive regions. **Conclusions:** The standardization of a national legislation destined to the Stingless Bees (*SBs)* honey can only be established from deep studies, performed with each Brazilian species, providing more safety to the consumer.

KEYWORDS: Food Safety; Food Composition; Quality

RESUMO

Introdução: O mel das abelhas sem ferrão (ASF) se distingue do mel das abelhas *Apis mellifera*, por características sensoriais singulares como sabor agridoce e viscosidade fluida, despertando o aumento do interesse do consumidor. Embora nos últimos anos o número de produções científicas relativas ao tema tenha aumentado, é necessário que os artigos publicados sejam passíveis de replicação. **Objetivo:** Sanar importantes lacunas quanto ao mel de ASF no Brasil considerando a estruturação e a possibilidade de replicação dos estudos disponíveis, bem como a observação das características físico-químicas e microbiológicas do produto em vias de fundamentar uma legislação nacional. **Método:** Os nove passos descritos na *Methodi Ordinatio* foram seguidos. A busca de artigos foi feita nas plataformas SciELO, *ScienceDirect*, Scopus *e Web of Science*, utilizando as palavras-chave: "mel de abelhas sem ferrão", "meliponicultura", "características físico-químicas" e "propriedades microbiológicas". **Resultados:** Os conteúdos de 18 artigos foram analisados. Com base neste levantamento bibliográfico, o mel de ASF brasileiro de pelo menos 31 espécies foram avaliados. Portanto, há um grande número de espécies a serem exploradas quanto às suas características físico-químicas, microbiológicas, bem como potencial antioxidante/microbiano de seus méis de muitas regiões brasileiras. Além disso, foram observadas variações muito grandes nas características físico-químicas dos

produtos oriundos de diferentes espécies e regiões produtivas. **Conclusões:** A padronização de uma legislação nacional destinada ao mel de ASF só pode ser estabelecida a partir de estudos aprofundados, realizados com cada uma das espécies brasileiras, proporcionando mais segurança ao consumidor.

PALAVRAS-CHAVE: Inocuidade dos Alimentos; Composição de Alimentos; Qualidade

INTRODUCTION

Native bees (tribe *Meliponini* and family *Apinae*), also known as stingless bees (SB) due to their atrophied stinger, make short flights and are the largest group of eusocial bees in the world[1,2]. They are found in South and Central America, Africa, Southwest Asia, and Australia. There are more than 600 described species, of which Brazil has the greatest diversity, with more than 300 species.[1,3,4,5]

For a long time, meliponiculture was only practiced by local communities as a source of food and sustenance. The pollination process of these bees is fundamental for maintaining the biodiversity of forests, and in Brazil, more than 90% of trees depend on the pollination of these insects. Even so, they are in the process of disappearing as a result of environmental degradation[6,7,8].

Honey is a natural food produced by the species *Apis mellifera* and SB from flower nectar. Its physicochemical properties can vary depending on the species of bees involved, the geographical region, the available source of production, collection, and storage conditions. SB honey is produced in small volumes compared to *A. mellifera*, which makes it a rare product with a higher commercial value[9,10,2,11]. SB honey differs from honey from *A. mellifera* bees in its unique sensory characteristics, such as its bittersweet taste and fluid viscosity, arousing increased consumer interest. It also has valuable nutritional qualities, with specific physico-chemical properties, such as a higher acidity and moisture content, a low proportion of sugars and the presence of phenolic compounds.[12,13]

The *Codex Alimentarius* recommendations[14] and the quality standards required by the Ministry of Agriculture, Livestock and Food Supply (MAPA)[15] only cover *A. mellifera* honey and do not include the SB product, making it difficult to guarantee its safety[16,11]. However, some state inspection bodies for animal products in Brazil[17,18,19,20,21] have their own regulations for the product. Given that Brazil is a country of continental proportions with diverse environmental conditions, there is still a lack of in-depth studies to better contextualize the composition and quality characteristics of this product, to ensure clear, complete, and enlightening labelling in order to provide assertive information to consumers[22,23,24].

Although the number of scientific publications on the subject has increased in recent years, it is necessary for the articles published to be replicable[25]. Many studies lack fundamental information to enable this[26]. In this context, the *Methodi Ordinatio* methodology is the result of the demand to classify articles for a systematized literature review consisting of nine stages. The papers obtained are qualified by three criteria: number of citations, impact factor, and year of publication[25].

The aim of this research is to review scientific publications on SB honey in Brazil, considering their structure and the possibility of replication, as well as to observe the physicochemical and microbiological characteristics of SB honey from different species to help support national legislation for the product.

METHOD

This work was carried out following the nine-step protocol described in the *Methodi Ordinatio*[25]. Firstly, SB honey in Brazil was established as the topic to be analyzed, then the keywords "honey from stingless bees", "meliponiculture", "physicochemical characteristics" and "microbiological properties" were determined. In the second step, research was carried out using these keywords on the Scopus platform. The definition of the Scientific Electronic Library Online (SciELO), ScienceDirect, Scopus, and Web of Science databases made up the third stage of this research. Next, the time of publication, from July 2009 to July 2021, and the combinations of words searched were established.

The final search in the fourth stage was carried out in two stages. The first stage was carried out using combinations of ("stingless bee honey" OR "meliponiculture" OR "meliponines") AND ("physicochemical characteristics" OR "physicochemical properties" OR "physicochemical analysis") AND ("Brazil*" OR "brazilian"). The second stage was done using ("stingless bee honey" OR "meliponiculture" OR "meliponines") AND ("microbiological" OR "microbiological standard" OR "microbiological evaluation" OR "microbiological properties") AND ("Brazil*" OR "brazilian").

The data obtained was saved in *.RIS* format and, in the fifth step, imported into the Mendeley reference manager. At this point, duplicates and papers with keywords or abstracts inappropriate to the research topic were excluded from the platform. The sixth stage consisted of downloading the list of articles from Mendeley to a personal file on the computer and importing these materials into the *JabRef* application, making it possible to export the data in *HTML table*.

JabRef data was exported using the *CTRL+V* command in a blank Excel spreadsheet. Next, the volume, page, and blank line data was removed, and the Impact Factor (FI) and Number of Citations (CI) columns were inserted. The search for the former took place in the A5 spreadsheet database, provided by the Technology Transfer Management Group at the Federal Technological University of Paraná, using the Journal Citation Reports (JCR) for 2020 as the first choice; when this value for an article was not found, the CiteScore 2020 was used. For the second, only Google Scholar was used.

Sorting the articles was the seventh stage, in which the InOrdinatio equation (InOrdinatio = (Fi / 1000) + (α* (10 - (YearPesq - YearPub)) + (Ci)) was used to achieve the data sorting index. A new column was inserted into the spreadsheet with the title *InOrdinatio*, the equation was inserted into all the rows and the spreadsheet was sorted by the results obtained. The α is a metric ranging from 1 to 10, defined by the researcher according to the importance of the novelty of the topic, i.e., the more recent the topic, the higher the α. The articles resulting from this methodology were located and downloaded in phase eight and in the ninth stage the systematic reading and analysis was carried out.

RESULTS AND DISCUSSION

Bibliometric analysis

The final search for this review resulted in 89 articles. The first stage of searches resulted in 31 papers in ScienceDirect, 13 in Web of Science, nine in Scopus, and four in SciELO, totaling 57 searches. In the next phase, ScienceDirect resulted in 19 papers, SciELO five, Scopus and Web of Science four papers each, totaling 32 articles. The papers were then filtered, in which 31 were removed because they were not in line with the topic, 27 because they were duplicates, 12 because they were not scientific articles, and three because they were outside the established time range. In the end, the content of 18 articles was analyzed.

The journals that returned the most papers were: *Food Chemistry* and *LWT - Food Science and Technology* (Chart 1). The authors who had the most articles published in this evaluation were: Ávila, S.; Beta, T.; Beux, M.R.; Biluca, F.C.; Costa, A.C.O.; Fett, R.; Gonzaga, L.V.; Hornung, P.S.; Ribani, R.H.; Teixeira, G.L. (Figure 1), who make up two distinct research groups from the Southern Region of Brazil, according to the articles' affiliation data. The most used keywords were "Honey" and "*Melipona*" with n = 4 each, indicating a trend in research into honey of the *Melipona* genus, in agreement with Dos Santos et al.[5] who described Brazil as the country where most research is carried out into honey from native bees, especially the *Melipona* genus.

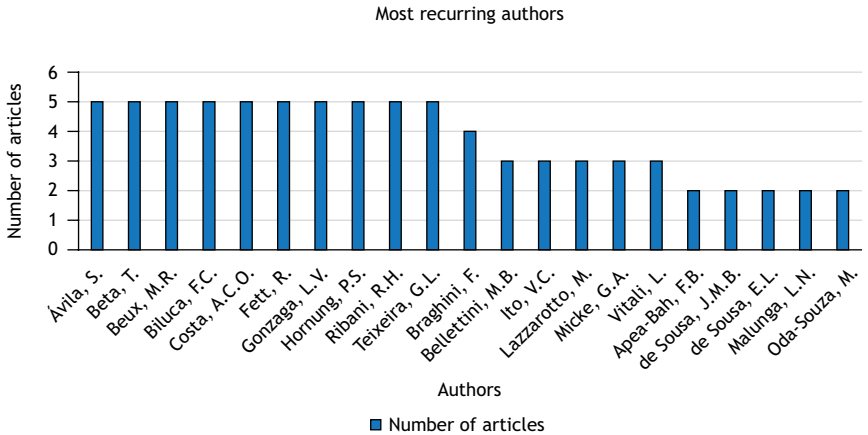
The Brazilian states with the highest number of studies were: Santa Catarina[6,27,3,12], Paraíba[16,9,28], Rio Grande do Norte[29,9,28], Paraná[29,30], and Rio Grande do Sul[4,11] (Figure 2). A total of 15 states plus the Federal District had no research selected for this article. This is a very important point, given that to establish federal standards studies are needed on the country's various climatic conditions, and there is still a large area of environmental biodiversity to be explored in Brazil. As for georeferencing coordinates, only seven (39.00%) studies[29,8,3,11,4,10,32] described this information.

Regarding the perimeter, whether urban or rural, rural samples were collected by Lage et al.[33], Damasceno Do Vale et al.[32], and Echeverrigaray et al.[4] and from urban areas by de Almeida-Muradian et al.[29] and Braghini et al.[3]. Both perimeters were evaluated by Duarte et al.[8] and Marcolin et al.[11]. The other 11 articles (61.11%) do not specify this information,

Chart 1. P Journals of selected works.

Journal	ISSN	Number of works
Food Chemistry	0308-8146	3
LWT - Food Science and Technology	1096-1127	3
Food Research International	0963-9969	2
Journal of Food Composition and Analysis	0889-1575	2
Journal of Food Processing and Preservation	1745-4549	2
Acta agronómica	0120-2812	1
Anais da Academia Brasileira de Ciências	1678-2690	1
Food Science and Technology	1678-457X	1
International Journal of Food Microbiology	0168-1605	1
International Journal of Food Science and Technology	1365-2621	1
Journal of food science and technology	0022-1155	1

Source: Prepared by the authors, 2023.



Source: Prepared by the authors, 2023.

Figure 1. Most frequent authors in selected articles.

and the georeferencing informed by Ribeiro et al.[10], was not located by Google Maps. De Sousa et al.[9] and De Melo et al.[28] did not specify the cities where the samples were collected.

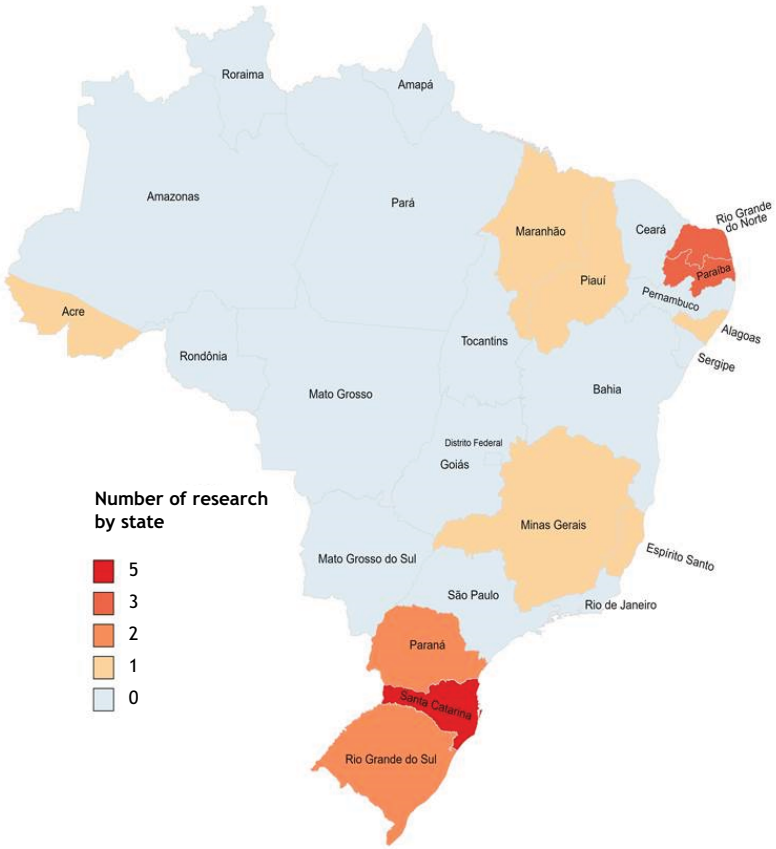
Brazil has an area of around 8,515,767.0 km^2 and six main biomes: the Amazon, the Caatinga, the Cerrado, the Atlantic Forest, the Pantanal, and the Pampa, which are distributed unevenly across several states[34,35]. Therefore, the lack of georeferencing makes it impossible to assertively determine the honey coming from Brazilian biomes. Despite the growing amount of research into the properties of SB honeys, studies into this product in urban areas are still scarce. However, they are relevant, since the breeding of SB is facilitated by their characteristic atrophied sting and stands out as a growing practice, but one that still needs more studies[36,37].

The years with the most samples collected were 2014[1,3,11,32] and 2015[1,10,38,11] (Figure 3A) but the authors of three studies did not mention this data[29,6,27]. The months with the highest number of samples were January[10,30,31,3], May[33,4], and March[16,3,38] (Figure 3B). However, eight studies did not provide this information[1,6,8,9,12,27,28,29].

Collections during the rainy and dry seasons were carried out and cited by De Sousa et al.[9] and De Melo et al.[28]. Duarte et al.[8] described that their collections were made only in the rainy season, and Marcolin et al.[11] reported that they collected in winter and summer. Regarding the number of collections made per year, the authors of one study cited only one collection[6], two other studies cited three collections[1,4], the authors of three studies cited two collections[11,29,33], while the authors of the other 12 studies did not include this information.

Regarding sample collection methods, Silva et al.[16] and Lage et al.[33] described them as directly from the colonies, Braghini et al.[3] used commercial honey and samples directly from the colonies. Echeverrigaray et al.[4] used sterile micropipettes; Marcolin et al.[11] and Damasceno Do Vale et al.[32] used disposable syringes; and Duarte et al.[8] reported using sterile syringes. The maintenance of the collected samples was not specified in three studies[33,10,27]. Freezing was used by Braghini et al.[3] and Biluca et al.[6] and at room temperature by De Almeida-Muradian et al.[29] and Biluca et al.[12]. Braghini et al.[27], Lage et al.[33], and Ribeiro et al.[10] did not describe the handling method and refrigeration was used by the other 11 studies.

The average number of honey samples per study was 23.44 ± 15.99 (mode 32). The average number of species evaluated per study was 4.41 ± 4.09 (mode 2). The most researched genus of SB was *Melipona* (n = 50), and the most studied species was *M. bicolor* (n = 8). Biluca et al.[6], Marcolin et al.[11], and



Source: Prepared by the authors, 2023.

Figure 2. Number of research carried out in Brazilian states based on selected articles.

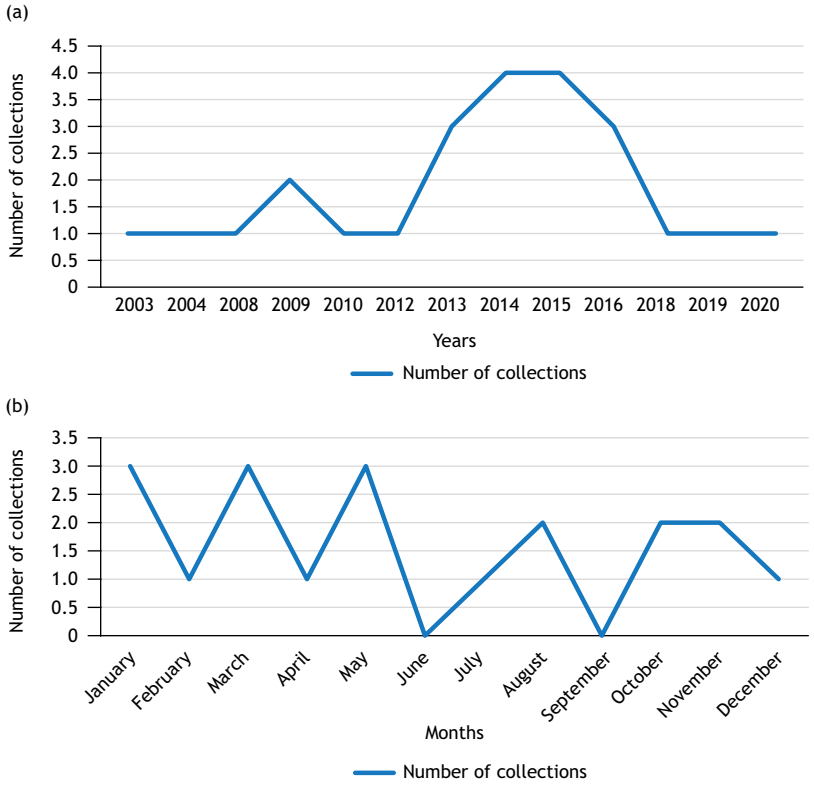


Figure 3. Number of collections carried out annually (A) and monthly (B).

De Almeida-Muradian et al.[29] researched honey from SB and *A. mellifera*; the other studies did not include the latter bee (Chart 2). Considering that there are more than 300 species of SB in Brazil[5], the honey of only 31 of them was evaluated based on this bibliographical survey. Therefore, there are a large number of species to be explored in terms of their physicochemical and microbiological characteristics, as well as the antioxidant/microbial potential of their honeys from many Brazilian regions. Furthermore, given that the composition of the product varies according to the seasons[33,38,11], new studies should cover more collections throughout the year, considering the diversity of the soil and climate and the variations in humidity between the months of the year throughout the country.

Characteristics of honeys

The sensory characteristics evaluated were color (n = 8), taste (n = 2), and viscosity (n = 2). The most analyzed physicochemical characteristics were pH (n = 14), hydroxymethylfurfural (HMF) (n = 13), and humidity (n = 13). The most commonly assessed microbiological criteria were yeast count (n = 3), *Salmonella* spp. test (n = 2), mould count (n = 2), physiological characterization of yeast isolates (n = 2) (Chart 3).

Ávila et al.[30] indicated that the chemical and biological properties of SB honey are directly associated with the origin of the pollen. The result of the melissopalynological analysis by De Almeida-Muradian et al.[29] revealed differences between the honey of *A. mellifera* and *M. subnitida*, indicating that these species do not travel through the same plants. Duarte et al.[8] observed symmetry in most of the pollen samples, suggesting a similar floral origin among the SB species analyzed. Silva et al.[16] evaluated only the pollen of *M. subnitida* and found 19 pollen types from nine families.

The SB honey from southern Brazil evaluated by Ávila et al.[31] indicated its origin as floral and from nectars with low conductivity (> 0.8μS.cm^{-1}) and ash content (0.60%). De Sousa et al.[9] reported in their results that honeys from the juazeiro tree (*Ziziphus joazeiro*) varied in terms of their intense color (95.4 to 103.4 mm Pfund) and high proline content (17.4 to 20.5 mg.kg^{-1}), glucose content (37.7 to 38.1%), and ash content (0.41 to 0.52%), while honeys from the malícia plant (*Mimosa pudica)* had higher acidity (66.1 to 86.8mEq.kg^{-1}). More specifically, the honey from the jandaíra species (*M. subnitida)*, whose floral source is the juazeiro, had the highest pH (5.3) and fructose content (59.2%).

In another study, Ávila et al.[31] pointed out that, in general, different genera of bees have a direct impact on the properties of honey. The *Melipona* group had higher levels of moisture (29.38 to 40.07%), water activity, color (0.30 to 152.57 mm Pfund), electrical conductivity (0.15 to 0.66 μS.cm^{-1}), total acidity (18.59 to 140.36 mEq.kg^{-1}), and total mineral content. The *Scaptotrigona* group had higher levels of Brix (66.50 to 71.17), pH (3.58 to 4.81) and ash (0.08 to 0.55%).

When studying samples of honeys from six species of SB from the same region, season and meliponary, Duarte et al.[8] found

Chart 2. Bee species researched (sorted by total citations).

Species	Total of research
Melipona bicolor	8
Melipona marginata	7
Melipona quadrifasciata	7
Scaptotrigona bipunctata	6
Melipona mondury; Melipona scutellaris	5
Melipona subnitida	4
Melipona fasciculata; Tetragonisca angustula	3
Melipona scutellaris Latrelle; Melipona subnitida Ducke; Scaptotrigona depilis; Tetragona clavipes	2
A. mellifera; Frieseomelitta varia; Melipona asilvai; Melipona capixaba; Melipona quadrifasciata anthidioides; Melipona rufiventris; Melipona rufivestris mondory; Melipona seminigra; Melipona sp.*; Nannotrigona testaceicornis; Plebeia droryana; Plebeia emerina; Plebeia nigriceps; Plebeia remota; Plebeia saiqui; Plebeia* sp.*; Scaptotrigona tubiba; Tetragonisca fiebrigi; Trigona fuscipennis*	1
Not specified	1

Source: Prepared by the authors, 2023.

differences in the results of moisture (19.0% to 35.0%), pH (4.1 to 5.6), free acidity (17 to 125 mEq.kg^{-1}), total phenolics (32 to 136 mgGAE- q.100g^{-1}), total flavonoids (8 to 55 mgGAEq.100g^{-1}), reducing sugars (59.0% to 75.9%), and antioxidant activity (20 to 110.84 mgGAEq.100g^{-1}). In the study by Marcolin et al.[11], the honeys of six *Meliponini* species differed from *A. mellifera* honey in terms of moisture (*Meliponini*: 18.1% to 20.3% and *A. mellifera* 23.4 to 36.4%), acidity (*Meliponini* ranged from 9.6 to 66.7 mEq.kg^{-1} while *A. mellifera* 15.8 to 28.1 mEq.kg^{-1}), reducing sugars ranged from 45.3% to 58.3% in *Meliponini* honey and from 61.0% to 64.4% in *A. mellifera* honey and sucrose ranged from 4.0% to 25.4% and 5.3% to 10.0% in *Meliponini* and *A. mellifera* honey, respectively.

Similarities between the physicochemical characteristics were found in the analysis of samples of *M. subnitida* and *M. fasciculata* honeys from the Brazilian semi-arid region[38]. When comparing the parameters of *M. subnitida* honey with the legislation in force in Brazil[15] for *A. mellifera honey*, the moisture content (24.80%) and diastatic activity (nil) were disapproved[29]. In both studies by Ávila et al.[31] and Biluca et al.[1], potassium (K) was the most frequent mineral element, followed by calcium (Ca). The physicochemical analysis of jandaíra (*M. subnitida*) honeys in the study by Silva et al.16 showed a similar profile of their samples in terms of pH (2.9 to 3.7), acidity (24.5 to 93.5 mEq.kg^{-1}), HMF (10.80 to 15.76 mg.kg^{-1}), water activity (0.650 to 0.720), ash (0.01% to 0.27%), nitrogen (0.09 to 0.26 mg.100g^{-1}), sugars (50.5% to 72.5%), and moisture (22.2% to 24.4%). The latter is an important characteristic of this type of honey, as it influences its viscosity, fluidity, and preservation.

The results obtained by Biluca et al.[12] from *Meliponini* honeys were high in moisture content (24.28%-38.20%) and free acidity above 50 mEq.kg^{-1} for most of the samples, while the results for sugars (ranged from 58.79% to 73.01%) and diastatic activity (< 3 to 70.91 Göthe units) were lower, as was the absence of HMF. In the *in natura* samples evaluated by Biluca et al.[6], the fructose content (31.11 to 40.20%) was higher than glucose (8.20% to 30.98%) while sucrose and HMF were below the quantification limit.

De Almeida-Muradian et al.[29] suggested that the maximum moisture content should be 30%, higher than for *A. mellifera*. While diastatic activity serves as an indicator of freshness for the *A. mellifera* product, its presence was not detected in the SB honey studied. This may be influenced by its frequent acidic pH and high acidity, which also prevents the microbiota from multiplying and increases the product's shelf life[33,39]. On the other hand, high acidity is also an indicator of the presence of unfavorable fermentation. The higher water activity in this product can encourage microbial growth, especially yeasts, so proper handling and storage is necessary to avoid microbial contamination.[33, 2]

The short-term heat treatment used by Braghini et al.[27] did not cause significant changes in the physicochemical characteristics of SB honey, and HMF, a parameter often used as an indicator of overheating and storage conditions[39], was not detected. HMF was also not observed under the time and temperature conditions tested by Biluca et al.[6]. Ribeiro et al.[10], evaluating the influence of freezing, pasteurization, and maturation of tiúba honey, observed that freezing caused a reduction in viscosity (from 993 to 463) and humidity (from 24.50 to 23.70), maturation at 30°C for 180 days caused a decrease in pH (from 3.73 to 3.56), and pasteurization increased the pH (from 3.73 to 3.85) of *M. fasciculata* honey. The frozen and pasteurized unripened samples were described as having dark spots and a sweet taste and aroma, while the ripened ones had an acidic and fermented taste, viscous and grainy.

In the study by Braghini et al.[3], only storage at 40°C showed high levels of HMF (from 43 to 231 mg.kg^{-1}), suggesting that this condition should be avoided, based on the higher maximum limit values for this parameter under state legislation, which is 40 mg.kg^{-1} [18,19,21]. While in the study by Braghini et al.[27], the short-term heat treatment used significantly reduced thermotolerant resistance to coliforms, *Salmonella* spp., yeasts, and molds. Thus, the authors suggest using this treatment as an alternative

Chart 3. Classification of articles according to the Methodi Ordinatio, title of articles evaluated, analyzes carried out in each study, and authors.

CI	Title	Analyzes carried out	Citation
1	Compostos fenólicos, melissopalinológicos, análises físico-químicas e atividade antioxidante do mel de jandaíra (*Melipona subnitida*)	Melissopalynological analysis, pH, free acidity, HMF, water activity (Aw), ash, nitrogen, reducing sugars, and moisture content, phenolic compound profile, and antioxidant activity	16
2	Perfil de açúcares, aspectos físico-químicos e sensoriais de méis monoflorais produzidos por diferentes espécies de abelhas sem ferrão no semiárido brasileiro	Moisture, protein, proline, HMF, color, electrical conductivity, pH, free acidity and sugar profile, color, viscosity and flavor	9
3	Perfis físico-químicos, minerais e compostos bioativos do mel de abelha sem ferrão (*Meliponinae*)	HMF, carbohydrates, minerals, total phenolic compounds, antioxidant activity, moisture, electrical conductivity, free acidity, pH, diastase activity, soluble solids	1
4	Estudo comparativo das características físico-químicas e palinológicas do mel de *Melipona subnitida* e *Apis mellifera*	Color, humidity, HMF, free acidity, water-insoluble solids, diastasis activity, ash, electrical conductivity, proteins, lipids, total carbohydrates, energy, and sugars. Fiehe test, Lugol reaction, Lund reaction, and melissopalynological analysis	29
5	Mel e pólen de abelha produzidos por *Meliponini* (*Apidae*) em Alagoas, Brasil: análise multivariada de perfis físico-químicos e antioxidantes	Moisture, pH free acidity, reducing sugar content; electrical conductivity, proline and HMF content; diastasis activity and color	8
6	Teor de 5-HMF e carboidratos em mel de abelha sem ferrão por EC antes e após tratamento térmico	HMF, carbohydrates (fructose, glucose, and sucrose)	6
7	Efeito de diferentes condições de armazenamento nas características físico-químicas e bioativas de méis de abelhas sem ferrão processados termicamente	Moisture, acidity, HMF, diastase activity, and bioactives (antioxidant potential and individual phenolic compounds)	3
8	Parâmetros físico-químicos, compostos bioativos e potencial antibacteriano do mel de abelha sem ferrão	Total phenolics, free radical scavenging activity, ferric reducing antioxidant power, quantification of phenolic compounds, antibacterial potential	12
9	Propriedades físico-químicas do mel de três espécies de *Melipona* brasileira	Aw, percentage of soluble solids, pH, acidity, and humidity	33
10	Caracterização do mel de abelhas sem ferrão do semiárido brasileiro	Moisture, reducing sugars, sucrose, total soluble solids, free acidity, pH, HMF, diastase activity, color, total phenolic compounds, total flavonoids, and carboxylic acids	38
11	Compostos bioativos e propriedades biológicas do mel de abelha sem ferrão brasileiro têm forte relação com a origem floral do pólen	Melissopalynology, ash, pH, electrical conductivity, with, phenolic compounds, total phenolic compounds, antioxidant capacity, microbial activity	30
12	Influência do congelamento, pasteurização e maturação na qualidade do mel de Tiúba	Content of reducing sugars, total acidity, alcohol, moisture, total soluble solids, pH, water activity, viscosity and HMF, descriptive and acceptance sensory analysis	10
13	Qualidade do mel de *Melipona* sp. abelhas no Acre, Brasil	Moisture, total sugars, reducing sugars, apparent sucrose, ash, crude protein, diastasis activity, Brix degrees, free acidity, lactonic acidity, total acidity, pH, HMF, electrical conductivity, color and Lugol, Lund, and Fiehe reactions	32
14	Influência do gênero de abelhas sem ferrão (*Scaptotrigona e Melipona*) no conteúdo mineral, propriedades físico-químicas e microbiológicas do mel	Moisture, soluble solids, electrical conductivity, color, pH, total acidity, ash content, HMF, reducing sugars, sucrose, aerobic mesophilic bacteria, total and thermotolerant coliforms, lactic acid bacteria, *Salmonella* spp.	31
15	Atividade prebiótica de méis monoflorais produzidos por abelhas sem ferrão no semiárido do nordeste brasileiro para *Lactobacillus acidophilus* LA-05 e *Bifidobacterium lactis* BB-12	Water, total soluble solids, pH, total acidity, glucose, fructose, sucrose, arabinose, prebiotic effect of honeys, and phenolic compounds	28
16	Mel de *Meliponinae* e *Apis mellifera* no sul do Brasil: caracterização físico-química e determinação de agrotóxicos	Free acidity, acidity, pH, ash content, electrical conductivity, soluble solids, humidity, HMF, sugar profile (glucose, fructose, maltose and sucrose), reducing sugars, and pesticide determination	11
17	Impacto do tratamento térmico de curta duração no mel de abelha sem ferrão (*Meliponinae*): Qualidade, compostos fenólicos e capacidade antioxidante	Moisture, free acidity, pH, HMF, diastasis activity, electrical conductivity, soluble solids (fructose, glucose and sucrose) content of phenolic compounds, antioxidant activity, microbial load (molds and yeasts, thermotolerant coliforms and *Salmonella* spp.)	27
18	Biodiversidade de leveduras em mel produzido por abelhas sem ferrão criadas no planalto do sul do Brasil	Density, total soluble compounds, pH, reducing sugars, total reducing sugars and water activity, isolation and counting of yeasts, molecular identification of yeasts, physiological characterization of yeast isolates	4

Source: Prepared by the authors, 2023.
aW: water activity; CI: *Inordination* classification; HMF: Hydroxymethylfurfural; EC: Capillary electrophoresis.

for post-harvest preservation of the honey analyzed, considering its practicality and low impact on product quality.

In the study by Echeverrigaray et al.[4], honey from the *Plebeia* genus showed higher water activity (0.71 to 0.86) and a 2 to 3 log higher yeast population size than honey samples from other *Meliponini* genera. Of all the samples, 16 yeast species were characterized, with the main ones categorized as *Starmerella* and *Zygosaccharomyces*, with a high incidence of *Starmerella* sp. and *S. apicola*. The occurrence of other yeasts was only identified in smaller groups or related to specific bee species. Osmotolerants capable of fermenting glucose and fructose were the most abundant and prevalent species.

The existence of certain yeasts in the honey of different bee species points to a close relationship between bees and the yeast microbiota. The existence of fungi in honey is related to the interaction of honey with the intestinal contents of bees, beehives, and grasses. Possibly associated with environmental conditions and being indicators of the quality of production management[41]. It is currently hypothesized that symbiotic microorganisms act by helping to obtain nutrients, while others act significantly on the immunity of bee colonies. Menezes et al.[42] pointed out in their research with *Scaptotrigona depilis* the possibility of a symbiotic link with the fungus of the genus *Monascus*, using it as protection for larval food from other microorganisms.

In the analysis of the antibacterial potential, the SB honey samples showed a reduction in the growth of *Escherichia coli* or *Staphylococcus aureus* strains, showing promising effects capable of stimulating further studies in the area[12]. Information on the total phenolic and flavonoid content and antioxidant activity of SB honey and pollen is still scarce[8]. However, Ávila et al.[31] found a positive correlation between total phenolic compounds and antioxidant activity.

The jandaíra honey (*M. subnitida)* researched by Silva et al.[16] showed a similar phenolic profile among the samples, with the flavonoids naringenin, quercetin, and isorhamnetin and gallic, vanillic, 3,4-dihydroxybenzoic, and coumaric acids being present in eight samples. The only sample with a different profile came from a different geographical location but in general all the samples showed high antioxidant activity. This study showed that the phenolic content of honey samples is partly responsible for their antioxidant activity and corroborates Biluca et al.[1] that honey is an important source of natural antioxidants.

Changes in phenolic compounds after short-term heat treatment are generally related to the increased antioxidant potential of honey studied by Braghini et al.[27]. Braghini et al.[3] suggest that this product, when processed and stored at low temperatures, can maintain its stability, helping to preserve its physicochemical and bioactive properties.

In the analysis by Damasceno Do Vale et al.[32], the SB honey samples did not meet all the criteria laid down by the legislation in force in Brazil for *A. mellifera*, with excess moisture being the main reason for rejection. While for Biluca et al.[1], the main differences were free acidity, reducing sugars, and humidity. The results obtained by Biluca et al.[2] showed that it is not yet possible to characterize specific groups of samples according to flowering time or bee species, and this may be one of the reasons why there is no national or worldwide law.

CONCLUSIONS

There is still a very limited amount of research on the subject and many of the studies cannot be replicated as they stand. There is a need to broaden the spectrum and depth of studies on the subject, enabling a better understanding of the object of study. In addition, very large variations were observed in the physicochemical characteristics of products from different species and production regions, so the standardization of national legislation for SB honey can only be established based on in-depth studies carried out with each of the Brazilian species, providing greater consumer safety.

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Authors' Contribution

Julek E - Conception, planning (study design), acquisition, analysis, and writing of the work. Fagundes VL - Analysis and writing of the work. Zatta JCS - Data interpretation and writing of the work. Berthier AS - Conception, planning (study design), and data interpretation. Galvão JA - Conception, planning (study design), analysis, and writing of the work. All the authors approved the final version of the work.

Conflict of Interest

The authors inform that there is no potential conflict of interest with peers and institutions, political or financial, in this study.

Elisana Julek, Vitor Luis Fagundes,
Juliana Chiesse da Silva Zatta, Suelen Ávila Berthier,
Julia Arantes Galvão

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