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Melipona honey: Scientific visibility and research opportunities

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*Elisana Julek**[1], Suelen Ávila[2], Julia Arantes Galvão[1]*

[1]*PostGraduation Program In Veterinary Sciences, Federal University of Parana (UFPR), Agrarian Sciences Sector, Rua dos Funcionários, 1540, Curitiba, Parana 80035-050, Brazil, https://orcid.org/0000-0003-4306-3629, https://orcid.org/0000-0002-1076-7286*
[2]*Program In Food and Nutrition, Federal University of Parana (UFPR), Health Science Sector, Avenida Prefeito Lothario Meissner, Curitiba, Parana 80210-170, Brazil, https://orcid.org/0000-0002-3776-1968*

*Author for correspondence: Elisana Julek – elisana@ufpr.br

Abstract: Bibliometric analysis is a technique that applies mathematical and statistical tools to assess the interrelations and impacts of publications, authors, institutions, and countries in a specific research area. Several studies have been summarizing the publication trends of bibliometric analysis in research specialties; however, no study has been carried out specifically on Melipona honey. Accordingly, this study aimed to establish the scientometric panorama of Melipona honey over time. Accordingly, the Scopus database was chosen, considering the high impact of the papers. Articles from 2012 to 2022, written in English, covering the terms "*Melipona*" and "Honey" were taken. Three hundred fourteen papers were retrieved (final selection of 38 articles), with Brazil as the primary source of authorship, followed by Mexico and the United States. The keywords were honey, Brazil, food products, bee, pollen, and Meliponinae. The spotlight was on the physicochemical, microbiological, and biological properties. of *M. subnitida*, *M. scutellaris*, and *M. quadrifasciata* honey. The most researched topics were honey, food products, antioxidants, and antibacterial agents. The emergent themes were *Melipona*, honey samples, physicochemical properties, and arid regions. The basic and recurring themes weren't uncovered. The five biomes (Amazon, Caatinga, Cerrado, Atlantic Forest, and Pampa) were studied. Approximately 90 species were explored (20% of the estimated number of Neotropical stingless bee species). These findings underscore the limited scientific attention to the *Melipona* genus and highlight a significant opportunity for further research.
Keywords: Stingless bees; Meliponini; Physicochemical; Microbiological; Official regulation.

1. Introduction

Brazil, renowned for its extensive biological diversity and numerous distinct biomes, is home to the Amazon in the north, which represents approximately 40% of the world's remaining rainforest. This biome, essential for carbon storage, global climate regulation, and industrial and agricultural activities, is facing one of the highest rates of forest destruction (Laurance et al., 2001; Garrett et al., 2021).

Native bees serve as bioindicators of environmental conditions and play a crucial role in restoring and preserving tropical forests, as well as maintaining the balance between natural and agricultural ecosystems. Nevertheless, they are facing a rapid decline primarily caused by the deforestation of their preferred habitats, the native forests (Duarte et al., 2012; Biluca et al., 2014; Ávila, Beux et al., 2018; Macedo et al., 2020).

The native bees belong to the Apidae family and the Meliponini tribe, and they are commonly referred to as stingless bees (SB) due to their atrophied sting (Biluca et al., 2016; Braghini et al., 2021). They are native to tropical and subtropical regions. They can be found in Australia, Brazil, Malaysia, and Mexico. It is estimated that more than 500 species of SB worldwide, with over 300 species in Brazil, are categorized into two main groups: *Melipona* and *Trigona* (dos Santos et al., 2022). These insects have garnered significant attention from small farmers and scientific researchers due to their nutritional and biological potential, as well as the high added value of their products.

Moreover, several factors, including the type of flowering, the bee species involved in production, the honey maturation phase, geographic region, and processing methods, have been correlated with honey's physicochemical and microbiological composition. Furthermore, SB production is relatively lower compared to *Apis mellifera* honey; this product from meliponiculture stands out for its distinctive characteristics, such as a more liquid appearance, a bittersweet flavor, diverse aromas, high acidity, and a high moisture content (Santos et al., 2021; Biluca et al., 2021).

Conversely, regulatory and supervisory bodies establish methodologies and official and international standards to control food quality, prevent adulteration, ensure food safety for consumer health, and assist in marketing. However, there is still no established standard for SB honey in national legislation; only *A. mellifera* honey is regulated (Brasil, 2000). The same lack of standardization exists at the international level (Codex Alimentarius 2001). The reference standards for SB honey available in the country are applied to the sale of products in specific states (Bahia, 2014; Amazonas, 2016; Paraná, 2017; São Paulo, 2017; Santos, 2019; SAR 2020), and do not consider the diversity between SB species, biomes, climates, and botanical variability (Santos et al., 2021).

Additionally, studies investigating the physical-chemical and microbiological parameters of *Melipona* bees are still scarce in the literature. Therefore, it is crucial to utilize exploratory search tools in reviews to comprehensively analyze the species based on the available data in the literature. Bibliometric analysis is the most suitable tool for this purpose. It enables the evaluation of a large volume of information, providing insights into trends, study subjects, and perspectives, as well as identifying prolific academics and institutions, and presenting the current research landscape.

Based on this, the article aims to analyze the scientific production of stingless bees of the genus *Melipona* in Brazil through a bibliometric analysis to evaluate the available literature. The analysis considers the geographical and chronological distribution of the research, the areas of study, and the journals involved, providing a comprehensive overview of current trends and the state of the art in this field.

The article is structured into four sections. The first section discusses the importance of native bees. The second presents the bibliometric analysis methodology applied. The third examines the results of the analysis of scientific publications. The final section offers conclusions and recommendations.

2. Methods

2.1. Data sources and search strategies

A literature review was conducted in the Scopus database to assess the information's high impact. In the first phase, the following criteria were applied: the period from 2012 to 2022, language: English, and title words, abstract, and keywords containing the terms "*Melipona*" and "Honey" as binary operators.

Three hundred fourteen publications (314) were obtained and exported in *BibTeX* format for further analysis using the *Bibliometrix* tool (Aria and Cuccurullo, 2017) in the *RStudio* version 4.2.1 software. The process involved installing the "*bibliometrix*" package with the command "*install. packages*("*bibliometrix*")," followed by loading the package using the command "*library* (*bibliometrix*)" and accessing the tool through the command "*biblioshiny*". Next, the exported *BibTeX* file was uploaded to the *Bibliometrix website* to determine the country with the highest scientific production worldwide, using the terms "*Melipona*" and "Honey."

2.2. Data cleaning

In the second phase, the same selection criteria from the previous phase were applied, along with additional descriptors: samples from Brazil and physicochemical and microbiological analyses. The results were carefully evaluated to eliminate duplicate and out-of-scope work, resulting in a final selection of 38 articles.

2.3. Bibliometric analysis and visualization

For the third phase, 38 articles were downloaded from the *Scopus* platform in *BibTeX* format. Content analysis was conducted using the *Bibliometrix* tool (Aria and Cuccurullo, 2017) to systematize the research findings and generate thematic maps, enabling a comprehensive bibliometric analysis. Through these analyses and discussions, new knowledge about the characteristics of honey from stingless bees of the genus *Melipona* was established.

3. Results

The study reported that Brazil is the most influential country in publications related to "*Melipona*" and "Honey." Among the 314 articles analyzed, Brazil had the highest number of authors (506), followed by Mexico (12) and the United States (10) (Figure 1). The data show a steady increase in publications related to honey from *Melipona* bees. In 2012, the proportion of publications was 5%, rising to 18% in 2013 and stabilizing around 12% from 2018 to 2022, with an average of 3 publications per year.

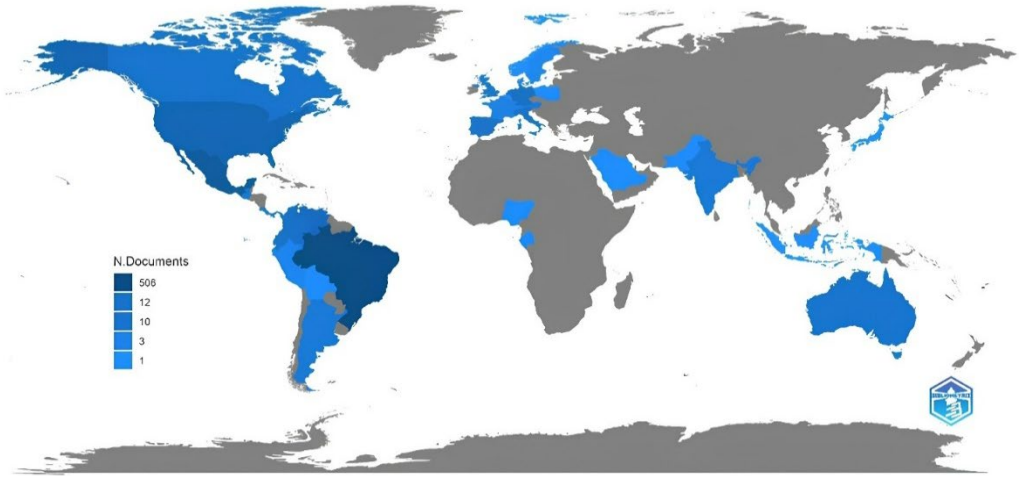

Figure 1 – The concentration of researchers worldwide studying "*Melipona*" and "Honey" from 2012 to 2022 in Scopus database.

The *Journal of Apicultural Research* was the most frequently published in the field, with six articles highlighting the significance of *Melipona* bees in honey research. Other notable journals include *Food Science and Technology* (3 publications), *Journal of the Science of Food and Agriculture* (3 publications), *LWT (Lebensmittel-Wissenschaft & Technologie) - Food Science and Technology* (3 publications), *Food Chemistry* (2 publications), and *Ciência Rural* (2 publications). The diversity of journals reflects an interdisciplinary approach to *Melipona* honey research, highlighting the growing scientific interest in its unique properties.

The most cited keywords in article titles included "honey," "Brazil," "food products," "bee," "pollen," and "meliponinae" (Figure 2). Research mainly focused on the physical, chemical, microbiological, and biological properties of *Melipona* honey. Among the species studied, *M. subnitida*, *M. scutellaris*, and *M. quadrifasciata* were the most analyzed. Furthermore, some studies examined the correlation between *Melipona* bees and *A. mellifera* as well as the relationship between honey, pollen, and phenolic

compounds. These detailed investigations aim to understand the unique characteristics of honey and its interactions with other components, thereby improving the quality control measures.

Figure 2 – The 50 most cited words in article titles about "Melipona" and "Honey" from 2012 to 2022 in Scopus database.

The thematic map (Figure 3) revealed the distribution of themes in four distinct quadrants based on density and centrality. In the upper right quadrant are the Driving Themes, such as "antioxidants," "phenols," "antibacterial agents," "honey," "food products," and "animals," which are highly developed and of great relevance to the area of study. In the lower left quadrant, Emerging or Declining Themes, such as "arid regions," show low density and centrality, suggesting that they are emerging or losing relevance. Other themes, such as "*Melipona*," "honey samples," and "physicochemical properties," located in the lower quadrants, indicate that they are developing but do not yet have high relevance or density.

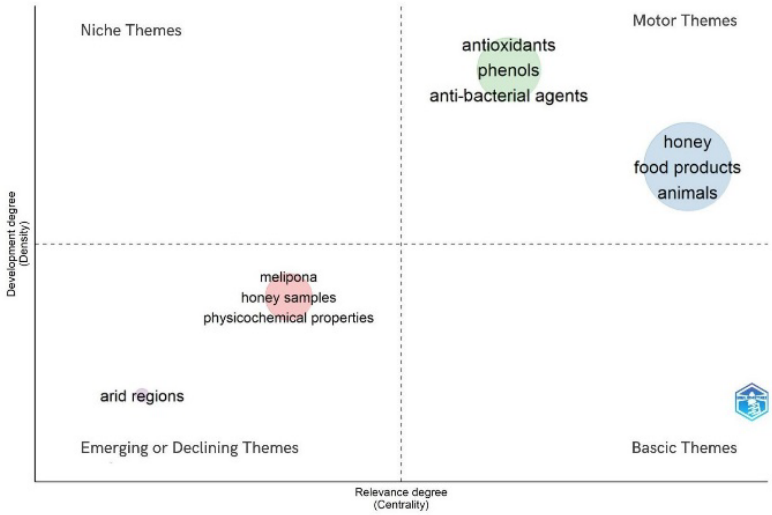

Figure 3 – The keywords used in the studies in article titles about "*Melipona*" and "Honey" from 2012 to 2022 in Scopus database.

Author interaction based on co-citations of works was employed to identify research communities, as illustrated in Figure 4. Seven isolated clusters were observed. Among the three clusters consisting of only two authors, the brown cluster focused on international methods of analysis and honey standards (Codex Alimentarius, 2001; Bogdanov, 2009). The pink cluster revolved around two books on *A. mellifera* breeding (beekeeping) (Crane, 1980) and stingless bees (stingless bees) (Nogueira-Neto, 1997). The yellow cluster comprised works in entomology related to identifying stingless bees and their importance in pollination (Heard, 1999; Silveira et al., 2002).

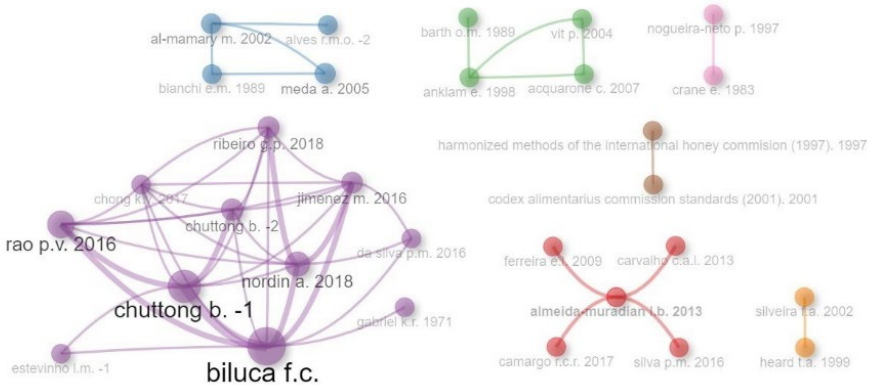

Figure 4 – The author network is constructed via co-citations using data from 38 selected articles about "*Melipona*" and "Honey" from 2012 to 2022 in Scopus database.

Among the two clusters with four authors, the blue cluster encompassed documents on the characteristics and composition of stingless bee honey (Fattori 2004; Souza et al. 2004) and bioactive compounds (Al-Mamary et al. 2002; Meda et al. 2005). The green cluster focused on articles correlating pollen origin in honey (Monika et al. 2016), its geographic origin (Anklam 1998; Acquarone et al. 2007), and the use of this product in medical treatments (Anklam 1998; Vit et al. 2004).

The red group consisted of five authors who were interconnected by the physicochemical and palynological analysis of stingless bee honey and *A. mellifera* (De Almeida-Muradian et al. 2013). Topics included the acceptance of SB honey (Ferreira et al. 2009), its composition, stability, authenticity (da Silva et al. 2016), and discussions about regulating this product (Carvalho et al. 2013; Camargo et al. 2017).

The purple cluster exhibited the most significant interaction, with 11 studies focusing on physicochemical properties, bioactive compounds, stability (Biluca et al. 2014; Chuttong et al. 2016; Jimenez et al. 2016), therapeutic effects (Rao et al. 2016), and thermal processing of honey from stingless bees (Chuttong et al. 2016; Chong et al. 2017; Ribeiro et al. 2018).

The cluster analysis highlights the diversity of research into SB honey and the importance of an integrated approach. Collaboration between groups is recommended to evaluate all the characteristics of the samples and improve quality control and regulatory practices comprehensively and effectively.

Table 1 presents the top 10 most cited works globally on the genus *Melipona* and honey, ranked based on their total citations (TC). Total citations represent the number of times each article has been referenced in documents indexed within a bibliographic database. This valuable information sheds light on the impact and significance of these works in the *Melipona* and honey research field, providing valuable insights for researchers and scholars.

Relevant publications	TC[1] per year	TCT
Silva[b] et al. (2013)	12,91	142
Silva[d] et al. (2013)	12,55	138
de Sousa et al. (2016)	15,50	124
de Almeida-Muradian et al. (2013)	8,36	92
Pimentel et al. (2013)	5,18	57
Barbosa et al. (2018)	8,67	52
Lage et al. (2012)	2,42	29
Duarte et al. (2012)	2,33	28
Duarte et al. (2018)	3,67	22
de Oliveira et al. (2017)	3,00	21

Table 1 – The 10 most relevant publications, according to the Total Citations, among the 38 selected papers.
[1] TC - total citations; TCT - overall total citations.

The first work, “Phenolic profile, antioxidant activity, and palynological analysis of stingless bee honey from Amazonas, Northern Brazil,” received 142 citations in the Scopus database. The study emphasizes that samples with higher concentrations of phenolic compounds exhibited higher antioxidant activity. Additionally, it reports the detection of flavonoids, including taxifolin and catechol, in honey from stingless bees in Brazil, marking the first documentation of their presence.

The second paper, "Phenolic compounds, melissopalynological, physicochemical analysis, and antioxidant activity of jandaíra (*M. subnitida*) honey," established a positive correlation between antioxidant activity and phenolic content in the samples. The study identified the presence of flavonoids naringenin, quercetin, and isorhamnetin, as well as gallic, vanillic, 3,4-dihydroxybenzoic, and coumaric acids in eight honey samples.

The third article, titled "Sugar profile, physicochemical, and sensory aspects of monofloral honey produced by different stingless bee species in the Brazilian semi-arid region," examined the influence of floral sources on color, acidity, sugar profile, ash, and proline content of stingless bee honey. The authors found that these characteristics were influenced by the floral source but not by different bee species (*M. subnitida* Duke and *M. scutellaris* Latrelle) from the same floral source.

Regarding the origin of the honey samples analyzed in the manuscripts, a significant proportion came from the states of Maranhão (18.50%), Alagoas (10.23%), and Paraná (9.84%), as depicted in Figure 5. The color scale in the figure indicates the frequency of surveys by state, showing the number of evaluated samples across Brazil. The states of Amazonas, Pará, and Paraná each had an equal number of studies, accounting for 7% of the total.

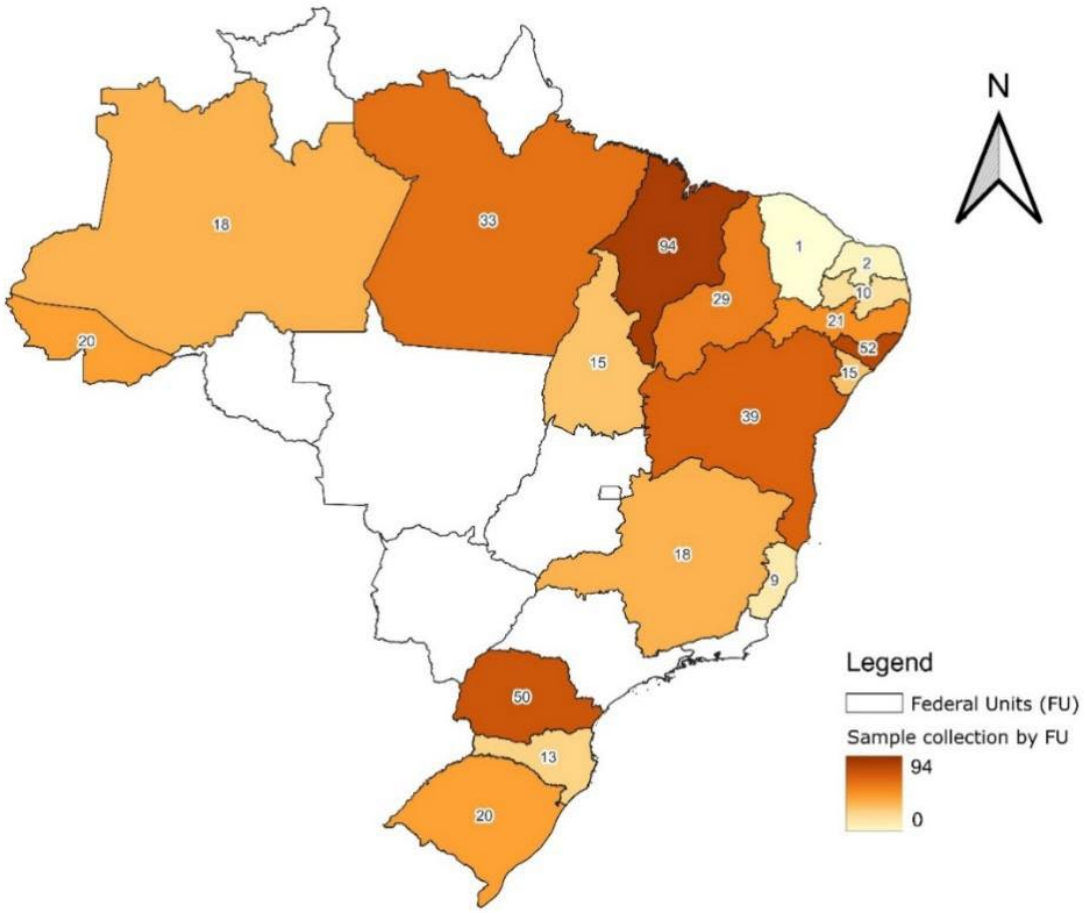

Figure 5 – Frequency of surveys with samples of *Melipona* honey by state, showing the number of evaluated samples across Brazil from 2012 to 2022.

Among the meliponine species recorded for Brazilian fauna, approximately 90 are endemic, corresponding to 20% of the estimated Neotropical stingless bee species. Fresh honey samples were assessed to evaluate honey quality parameters. Approximately 50% of the researchers refrigerated the samples until the analysis started. Among the analyzed kinds of *Melipona* honey, *M. fasciculata* Smith accounted for 26%, followed by *M. subnitida* Ducke (18.70%), *M. scutellaris* Latreille (17.71%), *M. quadrifasciata* Lepeletier (5.51%), *M. bicolor* Lepeletier (4.52%), and *M. marginata* Lepeletier (4.13%), as presented in Table 2.

Singless bee specie	Samples number	Reference
Melipona (*Melikerria*) *fasciculata* Smith, 1854	133	Silva[a] et al. 2013; Fernandes et al. 2018; Lemos et al. 2018; Fernandes et al. 2020; da Sant'ana et al. 2020; Echeverrigaray et al. 2021; Ribeiro et al. 2022; de Sousa et al. 2022
Melipona (*Melipona*) *subnitida* Ducke, 1910	95	Duarte et al. 2012; de Almeida-Muradian et al. 2013; Costa et al. 2013; Silva[d] et al. 2013; da Costa et al. 2018; Duarte et al. 2018; Pinheiro et al. 2018; Braga et al. 2020; da Sant'ana et al. 2020
Melipona (*Michmelia*) *scutellaris* Latreille, 1811	90	Duarte et al. 2012; Correia-Oliveira et al. 2016; de Sousa et al. 2016; de Oliveira et al. 2017; do Vale et al. 2017; Barbosa et al. 2018; da Costa et al. 2018; Duarte et al. 2018; Costa et al. 2019; Braghini et al. 2020; Echeverrigaray et al. 2021; da Silva Cruz et al. 2021; do Nascimento et al. 2022
Melipona quadrifasciata Lepeletier, 1836	28	Duarte et al. 2012; Ávila et al. 2018; Ávila et al. 2019; Braghini et al. 2020; Echeverrigaray et al. 2021; dos Santos et al. 2022; da Silva et al. 2022
Melipona bicolor Lepeletier, 1836	23	Ávila et al. 2018; Ávila et al. 2019; Braghini et al. 2020; Echeverrigaray et al. 2021; dos Santos et al. 2022
Melipona marginata Lepeletier, 1836	21	Ávila et al. 2018; Ávila et al. 2019; Braghini et al. 2020; dos Santos et al. 2022
Melipona sp.	16	da Silva et al. 2016; do Vale et al. 2017
Melipona (*Michmelia*) *mondury* Smith, 1863	15	Lage et al. 2012; Braghini et al. 2020; Echeverrigaray et al. 2021
Melipona (*Melikerria*) *interrupta* Latreille, 1811	13	Dourado et al. 2019
Melipona (*Michmelia*) *rufiventris* Lepeletier, 1836	13	Lage et al. 2012; Ribeiro et al. 2022
Melipona (*Michmelia*) *seminigra merrillae* Cockerell, 1920	12	Silva[b] et al. 2013; Silva[c] et al. 2013
Melipona (*Michmelia*) *flavolineata* Friese, 1900	11	Silva[a] et al. 2013; Lemos et al. 2018; Domingos et al. 2021
Melipona (*Melipona*) *quadrifasciata anthidioides* Lepeletier, 1836	10	de Oliveira et al. 2017; Duarte et al. 2018; Silva et al. 2021
Melipona (*Michmelia*) *capixaba* Moure & Camargo, 1994	9	Lage et al. 2012
Melipona compressipes Fabricius, 1804	7	Pimentel et al. 2013; de Oliveira et al. 2017
Melipona (*Eomelipona*) *asilvai* Moure, 1971	4	de Oliveira et al. 2017; Duarte et al. 2018
Melipona (*Michmelia*) *seminigra* Friese, 1903	3	Domingos et al. 2021; Echeverrigaray et al. 2021
Melipona (*Melipona*) *quadrifasciata* Lepeletier, 1836	2	de Oliveira et al. 2017; Rodrigues et al. 2018
Melipona (*Melikerria*) *grandis* Guérin, 1844	1	Domingos et al. 2021
Melipona (*Melipona*) *mandacaia* Smith, 1863	1	de Oliveira et al. 2017
Melipona (*Michmelia*) *eburnea* Friese, 1900	1	Domingos et al. 2021
Total samples tested	**508**	

Table 2 – The species of Melipona stingless bees, the number of samples analyzed for each species, and their corresponding references.

4. Discussion

The predominance of Brazilian authors reflects the country's central role in the research and conservation of these species, favored by Brazil's ideal conditions for meliponiculture (Araújo et al., 2020). The concentration of studies in tropical and subtropical regions, where BS is more abundant, highlights the focus of research in countries with rich biodiversity and a tradition in meliponiculture. On the other hand, the presence of authors in countries where SB does not occur naturally is probably due to international collaborations. The increase in publications related to Melipona honey reflects a balance between recognition of the potential of this type of honey and consolidation of existing knowledge. In addition, regional regulations on SB honey in Brazil have been instrumental in supporting ecological and economic agriculture, stimulating growing interest in meliponiculture (dos Santos et al., 2024).

The thematic map offers a comprehensive overview of the predominant and emerging themes in research, highlighting well-established areas and potential opportunities for future research (Flórez-Martínez et al., 2021; Mishra et al., 2022). It is worth noting that the two most frequently cited global articles, Silva[b] et al., (2013) and Silva[d] et al., (2013), focus on the relationship between antioxidant activity and phenolic compounds. At the same time, the third article explores the product's characteristics, indicating that the current main line of research on stingless bee honey is related to its antioxidant properties. The third article (de Sousa et al. 2016), which explores the product's characteristics, complements this line of research, indicating a growing tendency to investigate the antioxidant properties of honey and their variations depending on the floral source and physicochemical characteristics.

The distribution of the species evaluated may be attributed to bees of the *Melipona* genus, which primarily inhabit humid forest regions, with a higher concentration in the Amazon basin, (Kerr, 1948) making them more accessible to Brazilian researchers. Physicochemical analysis was the most employed method, featured in 74% of the selected articles, followed by microbiological analysis in 32% of the studies.

Bees play a crucial role as the primary pollinators of tree species, thereby contributing to the maintenance of numerous native and cultivated plants in diverse ecosystems worldwide. This vital role benefits the environment and supports environmental conservation efforts (Barros et al., 2022). The studies encompassed the five Brazilian biomes: Amazon, Caatinga, Cerrado, Atlantic Forest, and Pampa. Among the Brazilian states, the highest research concentration on honey from stingless bees was observed in Bahia (12%) and Maranhão (10%). The concentration of samples in Figure 5 may reflect greater availability of honey or specific interest in these regions. The regional variation in the samples highlights the need to expand research to include more states and to consider geographical differences in honey analysis.

5. Conclusion

The results highlighted a significant gap in research on the honey of *Melipona*, disclosing a valuable opportunity to advance in the area. With Brazil owning a considerable diversity of stingless bees, further studies are urgently needed to provide robust evidence to support federal regulations and adequate protection measures for these bees. The bibliometric analysis shows that, despite growing interest and promising research, the visibility of investigations into *Melipona* honey is still limited. Further research will not only support the effective regulation of Melipona honey, but it will also improve the conservation of bees and the preservation of the ecosystems they support. This focus is crucial to ensuring sustainable meliponiculture practices and contributing to Brazil's biodiversity and environmental health.

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