MAPPING SIX DECADES OF STINGLESS BEE HONEY RESEARCH: CHEMICAL QUALITY AND BIBLIOMETRICS

PATRICIA VIT, TEMITOPE CYRUS EKUNDAYO AND ZHENGWEI WANG

SUMMARY

Stingless bees (Apidae: Apinae: Meliponini) process honey in cerumen pots, thus it is called pot-honey. Almost 600 species of stingless bees produce tropical pot-honey. Despite the Codex Alimentarius Commission neglecting the international regulation of this relevant meliponine product, local and national regulations are growing since 2014. Besides the higher water content and free acidity, a recent discovery of the sugar trehalulose in pot-honey is one more distinctive trait. The great entomological biodiversity has an impact on chemical composition and bioactivity of the honey, as well as the botanical origin which has been less studied due to the vast number of stingless bee species compared to the unique Apis mellifera. *A bibliometric review (1962-2022) was conducted to analyze the evolution of stingless bee honey scientific literature, prolific authors, most active institutions, most productive countries, major journals used to disseminate pot-honey research, to identify theme maps and their connections to scientific disciplines using the Scopus database and the* bibliometrix *software. The taxonomic structure for this bibliometric review was described. In these six decades, a Venezuelan author stood out, Universidad de Los Andes was the third institution with the highest number of publications, and Venezuela ranked as the sixth most productive country after Brazil, Malaysia, Mexico, the United States, and Indonesia. A word cloud, tree map, dendrogram, and conceptual map were visualized. The network of sources and the evolution of authors' keywords were mapped with VOSviewer. This review was the first comprehensive science mapping analysis of stingless bee honey.*

Introduction

Honey is a unique natural product with chemical fingerprints from plant, animal and microbial origins. Honey making is a process of sociobiology in the bee nest (Vit P, personal observation). Chemical transformations take place via enzymes from the plants, the bees and the microbes. Microbial natural reservoirs are selected and vectored by the bees from floral nectar to their nests (Starmer and Lachance, 2011). The manufacture of honey from the sweet substances originated in nature, such as nectar and honeydew, occurs in beeswax combs of *Apis* spp. and cerumen pots of Bombini and Meliponini (Michener, 2007). Thus, the honey produced by stingless bees was named pot-honey because stingless bees produce honey in cerumen pots (Vit *et al*., 2013). This processing container is used for fermentation inside the nest, both for honey and pollen, which was also named pot-pollen (Vit *et al*., 2018).

The first document on stingless bee biology was a British paper (Bassindale and Harrison Matthews, 1955) retrieved before the exclusion of brood in the bibliometric search, and the first chemical composition to contrast *Apis mellifera* and *Melipona* was a French-Brazilian article by Gonnet *et al*. (1964). Stingless bee honey is present in the Eva Crane´s book (1975) considered a Bible of honey, with chapters from American, Australian, Canadian, English, Kenyan, and Swiss experts. However, these

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Patricia Vit. Ph.D. in Biology, Cardiff University, United Kingdom. Professor, Universidad de Los Andes (ULA), Mérida, Venezuela. Address: Apitherapy and Bioactivity, Food Science Department, Faculty of Pharmacy and Bioanalysis, Universidad de Los Andes, Mérida, Venezuela. e-mail: vitolivier@gmail.com

Temitope Cyrus Ekundayo. PhD in Microbiology, University of Fort Hare, South Africa. Research Fellow, Department of Biotechnology and Food Science, Durban University of Technology, Steve Biko Campus, Durban, South Africa. Lecturer, Department of Microbiology, University of Medical Sciences Ondo, Nigeria.

Zhengwei Wang. Ph.D. in Bee Biology, Yunnan Agricultural University, China. Associate Professor, CAS. Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Kunming, China.

seminal contributions were not retrieved in the current Scopus bibliometric search. The need of regulatory standards for the chemical quality of honey produced by stingless bees (*Melipona*, *Scaptotrigona*, and *Trigona*) was published in 2004 with suggested standards for contents of water, reducing sugars, sucrose, acidity, ash, hydroxymethylfurfural, and diastase activity (Vit *et al*., 2004), confirmed in 2006 by Souza *et al*., and the inclusion of the recently discovered trehalulose was proposed for the international standards (Zawawi *et al*., 2022). The first Brazilian standard was created for *Melipona* honey in the State of Bahia (ADAB, 2014), further State standards were established in Amazonas (ADAF, 2016), Paraná (ADAPAR, 2017), Espírito Santo (IDAF, 2019), and Santa Catarina (SAR, 2020). The first National standard was created for Kelulut –Malaysian name given to all stingless bees– honey in Malaysia (Department of Standards Malaysia, 2017), and the second was for the Argentine stingless bee *Tetragonisca fiebrigi* known with the ethnic name Yateí (Secretaría de Regulación y Gestión Sanitaria y Secretaría de Alimentos y Bioeconomía, 2019). All these standards are sustained by scientific research. Venezuela undervalued the creation of pot-honey standards at the Venezuelan normative agency COVENIN, supported by pioneering multifactorial analysis of honey quality factors for stingless bee taxa (Vit *et al*., 1998).

The aim of the current study was to appraise scholar activities and outputs related to chemical quality of pot-honey produced by stingless bees. It is hoped that it would provide crucial insights to regional research activities.

Previous Bibliometric Analysis and Current Approach of Pot-Honey or Stingless Bee Honey Research

A previous bibliometric analysis on honey produced by *Apis mellifera* (Zakaria *et al*., 2021) did not include honey produced by Meliponini. Our study aimed to investigate scientific literature published on honey produced by stingless bees –or pot-honey because it is bio-processed, chemically transformed, and stored in cerumen pots of the nests– in terms of growth of annual publications, prolific authors, most active institutions, most productive countries, citation trend, top subject areas, top journals, and most supportive financial agencies to date. For that purpose, we used the Scopus database. Further co-authors networks and a collaborative map were visualized, author's keyword co-ocurence, a word cloud, and theme maps were processed with the bibliometric software Bibliometrix on study trends and patterns of the conceptual, intellectual and social structure of a research topic (Tay, 2022). Biblioemtrix was developed by Aria and Cuccurullo (2017), and covers a wider menu of visualizations than VOSviewer (Van Eck and Waltman, 2021), which was launched in 2009 and is also available online.

The two major scientific databases are not free. Web of Science (WoS) and Scopus are the Titans in science (Pranckute, 2021) expanding their use for bibliometric reviews. Scopus is more recent than WoS but is amplifying its presence in academic literature (Zhu and Liu, 2020). Compared to WoS, Scopus coverage of literature is higher (Falagas *et al*., 2008). Free access of the biomedical database and the academic Google Scholar Citations are iconic search tools. A literature search was conducted using the Scopus database because it covers a larger number of publications, has more citations than others (Aria and Cuccurullo, 2017; Tay, 2022), and it was available.

The search on pot-honey or stingless bee honey including year 2022 retrieved an absolute number on 919 publications. The query string consisted in both terms linked with the OR operator. The CSV (comma separated values) files were exported from the retrieved dataset of the "TITLE-ABS-KEY" field, done on October 23rd 2022. These results were filtered for a dataset based on the selected inclusion and exclusion criteria (Table SI, see Supplementary Tables), including articles, reviews, and chapters published in journals or books in any language, in their final publication stage. After limiting the search to articles, chapters and reviews, final publication stage, journal and book source type, in any language, 546 documents were retrieved for pot-honey or stingless bee honey.

Bibliometric Indicators on Research of Pot-Honey and Stingless Bee Honey Since 1962 to 2022

General information of the retrieved documents

This bibliometric study was conducted the 23rd October 2022 using all years available in the Scopus database. All documents for pot-honey or stingless bee honeys were retrieved with two search strings for the absolute number of publications summarized in Table I. The total (919) was limited to (546) to date, with the selection criteria of Table I and excluding words in the query string below with the AND NOT operator (brood, caste*, gene, pollinat*, and recruitment) to select research on chemical quality. Since the first document is from year 1962, this review covers six decades of research on honey produced by stingless bees. In the query string, melipon* was inserted to test if meliponine and meliponini would increase the number of documents but none of them increased the retrieval, thus melipon* was discarded.

Query string for all documents

TITLE-ABS-KEY (pot-honey* OR ("stingless bee*" AND honey)) AND PUBYEAR < 2023 **919 doc**.

Query string for selected documents on chemical quality

TITLE-ABS-KEY ((pot-honey* OR "stingless bee*" AND honey AND NOT brood AND NOT caste* AND NOT gene AND NOT pollinat* AND NOT recruitment)) AND PUBYEAR < 2023 AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "b")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "re")) **546 doc**.

The selected documents (articles, reviews, and chapters) were published in six languages: English (518), Portuguese (19), Spanish (10), French (2), Chinese (1), and German (1). The documents in different languages in the Scopus database do not frequently match with the number of publications. Additionally, the all-documents retrieval included 146 conference papers, reviews, and proceedings, and 27 notes, books, letters, data papers, editorials, and book series, with 21 documents in press.

Research on chemical quality of pot-honey or stingless bee honey was represented by 546 documents in six decades of scientific publications (Table I). Bibliometrix Main menu assessed 262 source types used to disseminate findings on chemical quality of pot-honey or stingless bee honey. A total of 1,878 authors contributed to that research with 28 single-authored documents citing 23,534 references. Average of co-author´s number in multi-authored publications was 4.71. International co-authorship was less than 50%.

A note on the presentation of lists from Bibliometrix. This R based package provides its own format of authors, authors' keywords, source titles, and other attributes of documents retrieved in the dataset after the biometric

TABLE I
MAIN INFORMATION ON BIBLIOMETRIC DESCRIPTORS FOR ALL DOCUMENTS OF POT-HONEY OR STINGLESS BEE HONEY RESEARCH (1962-2022) AND SELECTED DOCUMENTS FOR CHEMICAL QUALITY

Bibliometric descriptor	Counts	
	All documents	Selected documents
Time span	1962-2022	
Scopus database		
Number of documents	919	546
Number of articles	706	468
Number of reviews	59	39
Number of chapters	53	39
Conference papers (No.)	67	-
Conference reviews (No.)	13	-
Conference proceedings	66	-
Notes (No.)	6	-
Books (No.)	5	-
Letters (No.)	4	-
Data papers (No.)	2	-
Editorials (No.)	2	-
Final publication stage	898	-
In press publication stage	21	-
Book series	8	-
Number of languages	6	6
Bibliometrix		
Annual growth rate (%)	-	6.66
Sources (No. journals, books)	-	262
Author's Keywords DE (No.)	-	1,361
Keywords Plus ID (No.)	-	2,703
Average citations per document	-	18.4
Document average age (years)	-	6.74
Authors (No.)	-	1,878
Single-authored documents (No.)	-	28
Multi-authored documents (No.)	-	1850
International co-authorship (%)	-	27.72
Average co-authors per document (No.)	-	4.71
References (Total No.)	-	23,534

search in the database. For readers unfamiliar with Bibliometrix output, please do not be surprised to see species without Italics, and capital letter for the genus. For example tetragonisca.angustula, apis. mellifera, or microbes such as escherichia. coli. Similarly, authors surnames and initials are not capitalized in some plots like Co-authors collaborative network e.g. vit p, zawawi n, or all letters capitalized in others like Author local impact by H index e.g. VIT P, ZAWAWI N.

Growth of Annual Publications in Pot-Honey or Stingless Bee Honey

The option Analyze search results of Scopus displays useful analysis, tables and cards. In Figure S1 the temporal evolution on yearly growth of document number on chemical quality of pot-honey or stingless bee honey research has not been even, but it is steadily growing in linear No. documents. It raised from 8 in 1997 to 36 in 2013, with a drop to 17 in 2014, and further raise from 15 in 2015 up to 75 documents in 2021. A steep rise was observed in 2017 with 53 documents. Current counts of 48 documents in 2022 may predict a drop of productivity for this year.

Most Prolific Authors in Scientific Publications on Pot-Honey or Stingless Bee Honey

The views about author details provided further academic data on metrics overview of each author. Table II shows the topmost prolific authors on research of pot-honey or stingless bee honey (1962-2022): 1. Patricia Vit (24 documents) from Universidad de Los Andes, Food Science Department, Mérida, Venezuela; 2. Roseane Fett (12 documents) from Universidade Federal de Santa Catarina, Department of Food Science and Technology, Florianopolis, Brazil; 3. Vera Lucia Imperatriz-Fonseca (11 documents) from Universidade de São Paulo, São Paulo, Brazil; 4. Ali Agus (10 documents) from Universitas Gadjah Mada, Yogyakarta, Indonesia; 5. Fabíola Carina Biluca (10 documents) from Universidade Federal de Santa Catarina, Florianopolis, Brazil; 6. Luciano Valdemiro Gonzaga (10 documents) from Universidade Federal de Santa Catarina, Florianopolis, Brazil; and 9 documents for each of the following authors 7. Ana Carolina Oliveira Costa from Universidade Federal de Santa Catarina, Florianopolis, Brazil; 8. Elizabeth Ortiz-Vázquez from Tecnológico Nacional de México, Mexico City, Mexico; 9. David Ward Roubik from the Smithsonian Tropical Research Institute, Ancon, Panama; and 10. Norhasnida Zawawi from Universiti Putra Malaysia, Serdang, Malaysia.

Their h-index varied from 8 to 45, corresponding to a number of citations from 285 to 5643. In the Scopus database the ranking of authors is given by the number of publications in the searched topic, in descending order, and by alphabetical order of surnames, not by the impact of their h-index or number of citations. The total number of citations is cumulative in the author's academic life, including other topics too. The citations on the topic were retrieved from the document ranking of each author, number of documents published by author matches your query in the topic search, select all (not select page), and CSV (comma separated values) export Excel file. With the Scopus database, the citations of the topic are not available, they need to be estimated with the corresponding CSV files of each author, summing up the citations of the publications retrieved in the search, in this case on pot-honey or stingless bee honey. Link Supplementary TEXT S1.

Word cloud of authors' keywords

Word clouds are effective graphic representations for visual impact of frequent author keywords in the Scopus database. They are clusters of words represented in different sizes and colors, and in different positions. The bigger and bolder the word appeared, the most frequent it was in the dataset. The frequency of keywords is proportional to the position, size and boldness of words in the clouds, additionally contrasted with different colors. See Figure S5 for the word cloud Bibliometrix built by default with the dataset of research documents (1962-2022) obtained with the

TABLE II
AUTHOR RANKING BY NUMBER OF DOCUMENTS, *H*-INDEX, NUMBER OF CITATIONS, AND COUNTRY OF AFFILIATION FOR RESEARCH ON CHEMICAL QUALITY OF POT-HONEY OR STINGLESS BEE HONEY RESEARCH IN THE PERIOD 1962 TO 2022

Ranking	Author	No. Document topic/total	h-index	No. Citations topic/total	Country	Institution
1	Vit, P.	24/56	19	792/1476	Venezuela	Universidad de Los Andes, Merida
2	Fett, R.	12/131	39	362/4509	Brazil	Universidade Federal de Santa Catarina, Florianopolis
3	Imperatriz-Fonseca, V.L.	11/169	36	291/5037	Brazil	Universidade de São Paulo, São Paulo
4	Agus, A.	10/72	10	36/300	Indonesia	Universitas Gadjah Mada, Yogyakarta
5	Biluca, F.C.	10/26	10	356/487	Brazil	Universidade Federal de Santa Catarina, Florianopolis
6	Gonzaga, L.V.	10/90	32	356/3375	Brazil	Universidade Federal de Santa Catarina, Florianopolis
7	Costa, A.C.O.	9/100	30	356/2673	Brazil	Universidade Federal de Santa Catarina, Florianopolis
8	Ortiz-Vázquez, E.	9/45	13	18/607	Mexico	Tecnológico Nacional de México, Mexico City, Mexico
9	Roubik, D.W.	9/132	45	305/5695	United States	Smithsonian Tropical Research Institute, Washington, D.C.Currently at STRI, Balboa, Ancon, Panama
10	Zawawi, N.	9/29	13	160/358	Malaysia	Universiti Putra Malaysia, Serdang

search query for chemical quality of pot-honey or stingless bee honey. The keyword honey was the central largest word, stingless bees, stingless bee and stingless bee honey followed by visual impact size.

From the 24 frequency sets automatically created by the word cloud function, 6 of them comprised keywords related with chemistry, with the following 14 keywords in each frequency set: 14 physicochemical properties, 7 chemometrics, 6 (adulteration, antioxidants, chemical composition, food composition, moisture), 5 (multivariate analysis, physicochemical characteristic, polyphenols), 4 (physicochemical parameters, phytochemical, total phenolic content, adulterated honey), and 3 fermentation. Note that only moisture, phenolics and polyphenols were the three chemical compounds selected as keywords by authors of stingless bee honey publications. Statistics was covered by two keywords, chemometrics and multivariate analysis. The unique process was fermentation. A group of chemical compounds were comprised in physicochemical properties, chemical composition, food composition, physicochemical composition, and physicochemical parameters. These keywords may refer to the analytical honey standards: ash, free acidity, hydroxymethylfurfural (HMF), moisture, reducing sugars, sucrose, and the diastase activity, which is a biochemical enzymatic assay generally not separated from chemical components. Two further very important keywords addressed to the adulteration issue. The keyword antioxidants was possibly related to the antioxidant activity of honey, because the complex matrix of honey antioxidants has not been elucidated to propose a routine analysis. Link Supplement Text S2 (Figure 1).

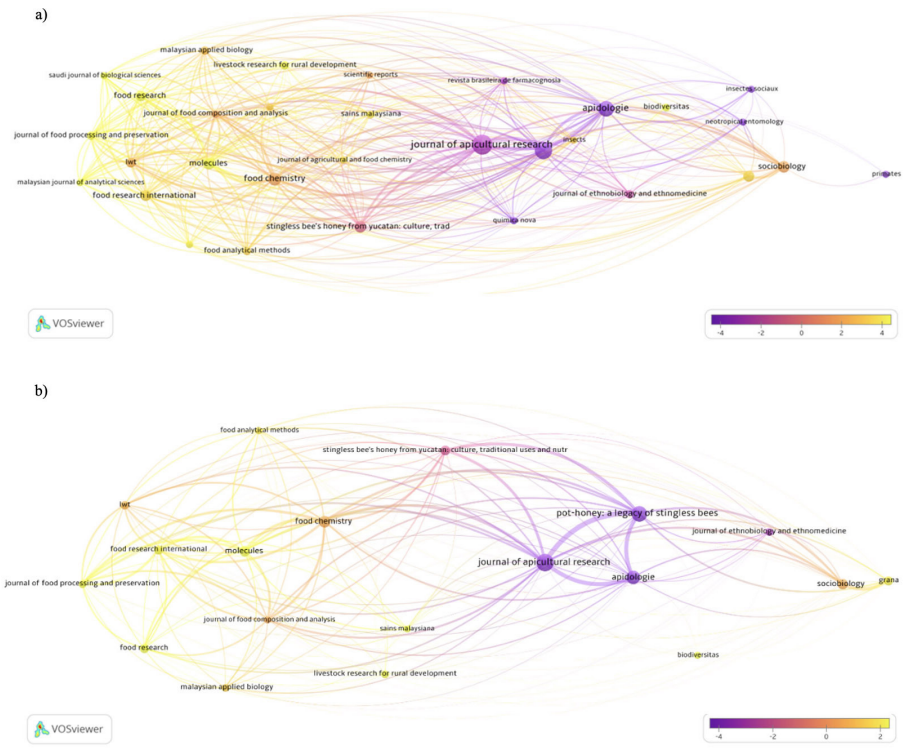

Figure 1. Network of sources used by authors to publish their research on chemical quality of pot-honey or stingless bee honey (1962-2022). (a) The upper diagram was mapped using cluster size 3, and the lower (b) was mapped using cluster size 4, increasing node resolution. Courtesy: Saúl Armendáriz.

Preliminary Proposal of Standards for the Neotropical Tetragonisca Honey and Paleotropical *Geotrigona thoracica*, *Heterotrigona itama*, *Tetragonula carbonaria*

The bibliometric scenario visualizing six decades of stingless bee honey research on chemical quality was a framework for progress. Therefore, expanded stingless bee honey standards were proposed to support further research for food regulatory applications, after the initial *Melipona*, *Scaptotrigona*, and *Trigona* by Vit *et al*. (2004). Four preliminary pot-honey standards of a Neotropical

and three Paleotropical stingless bee species were proposed in Table III.

The Codex Alimentarius Commission (CAC), coordinates member countries to propose, develop, and endorse the official standards comprised in the international food code, with headquarters in Rome, Italy. Targeting the CAC for the inclusion of the neglected pot-honey processed by stingless bees in cerumen pots is an action to expand the international honey standards created for *Apis mellifera* Codex Stan (2019). They were endorsed by the CAC in 1981, later revised in 1987, 2001 (Vit, 2013), and amended in 2019. An outstanding Malaysian team with joint efforts from Thailand and Venezuela prepared the proposal of chemical standards for stingless bee honey by meta-data analysis of 23 countries (M.Z. Mustafa, personal communication). This fine effort shows the progress after the first proposal of honey standards for stingless bee honey from Guatemala, Mexico, and Venezuela (Vit *et al*., 2004), and the first national norm for Kelulut honey (Department of Standards Malaysia, 2017). The biodiversity of about 600 global stingless bee species will demand a wise and progressive standardization process initiated almost twenty years ago with the suggested chemical standards for the honey quality of three Neotropical genera of stingless bees (Meliponini) and the current *Tetragonisca* in Table III, based on a *Tetragonisca angustula* honey proposal (Vit, 2023a) and including *Tetragonisca fiebrigi* honey too (Vit, 2023b).

Constantly focusing first on the stingless bee species chosen by stingless bee keepers worldwide because they have an ethnobiological component for food chemistry laboratories. Thus, leading sound choices on what paramount meliponine species were available for pot-honey or stingless bee honey research, and their derived publications. Therefore, new columns for suggested stingless bee honey standards were inserted for the most widespread Neotropical stingless bee genus *Tetragonisca*, and for three Paleotropical stingless bee species: *Geniotrigona thoracica* and *Heterotrigona itama* from Malaysia (Zawawi *et al*., 2022), and *Tetragonula carbonaria* from Australia (Persano Oddo *et al*., 2008).

On the Reviewers of Bibliometrics Contributions

Peer review of scientific manuscripts coordinated by sources of scientific documents is of utmost importance in the publication process for all academics (Dhillon, 2021), and it needs to be conducted proficiently. Link Supplementary TEXT S3.

Final Remarks on Stingless Bee Honey and Future Bibliometric Proposals

A more broadly support of the bibliometric science will benefit with feedback between the experts in the two worlds: On the multidisciplinary topics and the librarians with instrumental skills for the analysis. In this review only the Scopus database was used, but next project will embrace other databases such as World of Science, Google Scholar Citations, and the specialized Pubmed, and others in Agriculture, Biology, and Zoology. The expanded Dataset could become a Data Paper, classified as such in the Scopus database. Additionally, the preliminary exploratory state-of-the-art of bee scientists in the scientometric field, motivated a new book project on *Bibliometrics for Bee Science*. Coverage by invited authors to develop tentative research themes on biodiversity of bees and plants visited by bees, ethnobiology (bee keepers and bee researchers), melissopalynology, pollination, stingless bee products (pot-honey, pot-pollen, geopropolis), bee health and diseases, social immunity, microbes associated with bees, analytical techniques used in bee research,

TABLE III
NEW SUGGESTED PRELIMINARY HONEY STANDARDS FOR THE NEOTROPICAL *Tetragonisca* HONEY [a] AND FOR THE PALEOTROPICAL INDO-MALAYAN *Geotrigona thoracica* AND *Hetreotrigoma itama* [b] AND AUSTRALASIAN *Tetragonula carbonaria* [c] AFTER THE SUGGESTED NEOTROPICAL STINGLESS BEE GENERA *Melipona*, *Scaptotrigona*, AND *Trigona* [d]

Chemical quality factors	*Apis mellifera*	Neotropical stingless bee genera				Paleotropical stingless bee genera		
						Indo-Malayan [b]		Australasian [c]
	Honey standards [e]	Suggested honey standards [d]			New suggested honey standards [a]	New suggested honey standards		
		Melipona	*Scaptotrigona*	*Trigona*	*Tetragonisca*	*Geniotrigona thoracica*	*Heterotrigona itama*	*Tetragonula carbonaria*
Water (g/100g honey)	Maximum 20.0	Maximum 30.0	Maximum 30.0	Maximum 30.0	Maximum 30.0	Maximum 30.0	Maximum 30.0	Maximum 30.0
Reducing sugars (g/100g honey)	Minimum 65.0	Minimum 50.0	Minimum 50.0	Minimum 50.0	Minimum 50.0	Minimum 50.0	Minimum 50.0	Minimum 50.0
Sucrose (g/100g honey)	Maximum 5.0	Maximum 6.0	Maximum 2.0	Maximum 6.0	Maximum 5.0	ND	ND	Maximun 2.0
Free acidity (meq/100g honey)	Maximum 40.0	Maximum 70.0	Maximum 85.0	Maximum 75.0	Maximum 70.0	Maximum 300.0	Maximum 300.0	Maximum 150.0
Ash (g/100g honey)	Maximum 0.5	Maximum 0.5	Maximum 0.5	Maximum 0.5	Maximum 0.5	Maximum 0.2	Maximum 0.2	Maximum 0.5
Hydroxymethylfurfural (mg/kg honey)	Maximum 40.0	Maximum 40.0	Maximum 40.0	Maximum 40.0	Maximum 40.0	Maximum 20.0 [f]	Maximum 20.0 [f]	Maximum 20.0
Diastase activity (DN)	Minimum 8.0	Minimum 3.0	Minimum 3.0	Minimum 7.0	Minimum 8.0	-	Minimum 15.0 [f]	Minimum 0.1

ND: not detected. Source: [a] Vit (2023a,b); [b] Zawawi *et al*. (2022); [c] Persano-Oddo *et al*. (2008); [d] Vit *et al*. (2004); [e] Codex Stan (2019); [f] (Suhana Ahmad, personal communication).

biological properties and therapeutical uses, chemical fingerprinting of bee products, and sensory science.

The structured bibliometric sequence of analysis provided in this review may be useful to approach other disciplines in chemistry, food science and technology, medicine, and pharmacology among others, for ranking topics of interest and interpreting their evolution over time. The Scopus database provided rankings on productivity of authors, institutions, countries, sources, subject areas, and financial agencies that were tabulated for the ten tops. Science mapping with the Bibliometrix software permitted visualization of networking graphs for co-authors collaboration and their keywords' co-occurrence like VOSviewer, but also expanded the bibliometric parameters, and accessed cloud word, collaborative map, and thematic map.

Compared to VOSviewer, Bibliometrix has additional statistical techniques available for exploring in further research such as the factorial analysis: Conceptual Structure Map by Multiple Correspondence Analysis (MCA), and the Topic Dendrogram of Author Keywords by Hierarchical Cluster Analysis (HCA). Historiography is also possible. This is an evolving science itself, using lexicon from others sciences such as mapping and landscaping (from geography), dendrograms (from evolutionary biology), historiography (from history), spectroscopy (from chemistry and medicine), and surfacing (from oceanography), to mention the most common terms observed along the preparation of this review.

We hope that national and international policy makers in meliponiculture and stingless bee honey science will talk about this review that has helped shaping their thoughts for significant applications, and motivated needed actions. The wide-reaching for this document will be achieved by published open access (OA). A dataset initiated with the first document by Alvaro Wille (1962) from Costa Rica, on meliponine field work in the forest was revisited with current literature. The most recent published document by Vit *et al*. (2023) provided integrative methodology required for an intercontinental experiment on pot-honey variations during post-harvest. Monitoring the chemical transformations of pot-honey with classic physicochemical analysis, HPLC for sugars and flavonoids, and ^{1}H-NMR for 36 metabolites –some of them derived from fermentation– was an institutional collaborative challenge. Therefore, the microbial origin of those metabolites was also monitored by classic agar plate counts and microbiome by gene sequencing techniques to complete the multidisciplinary approach, including the entomological and botanical I.D. of the pot-honeys. Before that, the discovery of surfactants in the *Scaptotrigona vitorum* pot-honey (Vit, 2022), and the paradigm of 'active honey' based on a microbial reservoir (Brudzynski, 2021) biosynthesizing active molecules in-honey (P. Vit, personal observation). Promising discoveries in the honey biotechnology of stingless bee nests are envisaged. A chemical biodiversity in microbial metabolites of pot-honey is beyond the seven honey quality factors used in the honey standards: Water and ash –representing the inorganic components– reducing sugars, sucrose, free acidity, and HMF –representing the major organic fraction– and the enzymatic fraction diastase activity. An ongoing metadata analysis physicochemical properties profiling of stingless bee honey from 23 countries of the world has been submitted by Ahmad *et al*., aiming at advancing on the proposal of international standards.

The inner motivation of stingless bee scientists fascinated by the organization of their colonies, their roles in nature, and the diversity of collected and processed materials in their nests will continue to be a leading force in this field of research. The great cultural contrasts observed solely between the ethnic names given to stingless bees such as a unique Kelulut for all stingless bee species from Malaysia and Indonesia, and a plethora of charming or practical words to call just one Neotropical stingless bee *Tetragonisca angustula* (Latreille, 1811) and *Tetragonisca fiebrigi* (Schwarz, 1938) is evidence of how humans interact with their native stingless bees.

By gaining ground in our understanding of the documents on chemical quality of stingless bee honey, this bibliometric analysis has the potential to inform, benefit, and lead future investigations in diverse countries with updated state-of the art. Our findings showed scientific research geographically distributed in Brazil, Malaysia, Mexico, United States of America, Indonesia, Venezuela, United Kingdom, Australia, Germany, and Thailand. The bibliometric mapping on chemical quality of stingless bee honey research in six decades has a potential goal. Strengthening future research planning is achieved by identifying knowledge gaps that could influence government policy in terms of resource allocation or stingless bee conservation to harness their vast arrays of chemical products for nutritional, therapeutic, and fine chemical development. The six-decade bibliometric reference on chemical quality of pot-honey is also a scientific beacon for the chimerical creation of international stingless bee honey standards by the Codex Alimentarius.

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REFERENCES

ADAB (2014) Agência de Defesa Agropecuária da Bahia. Portaria ADAB nº 207 de 21/11/2014. Regulamento Técnico de Identidade e Qualidade do Mel de Abelha Social sem Ferrão, do Gênero Melipona. Bahia, Brazil. pp. 1-4.

ADAF (2016) Agência de Defesa Agropecuária e Florestal do Estado do Amazonas. Portaria ADAF n◦ 253 de 31 de outubro de 2016. Regulamento Técnico de Identidade e Qualidade do Mel de Abelha Social Sem Ferrão para o Estado do Amazonas. Brazil. pp. 1-9.

ADAPAR (2017) Agência de Defesa Agropecuária do Paraná. Portaria N◦ 63, de 10 de março de 2017. Regulamento Técnico de Identidade e Qualidade do Mel de Abelhas Sem Ferrão para o Estado do Paraná. Brazil, 9 pp.

Aria M, Cuccurullo C (2017) Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of informetrics 11*: 959-975. https://doi.org/10.1016/j.joi.2017.08.007

Bassindale R, Harrison Matthews L (1955) Biology of the stingless bee *Trigonu* (*Hypotrigona*) *gribodoi* Magretti (Meliponidae). *Proceedings of the Zoological Society of London 125*: 49-62.

Brudzynski K (2021) Honey as an ecological reservoir of antibacterial compounds produced by antagonistic microbial interactions in plant nectars, honey and honey bee. *Antibiotics 10*: 551. https://doi.org/10.3390/antibiotics10050551

Chen X, Yu G, Cheng G, Hao T (2019) Research topics, author profiles, and collaboration networks in the top-ranked journal on educational technology over the past 40 years: a

bibliometric analysis. *Journal of Computers in Education 6*: 563-585. https://doi.org/10.1007/s40692-019-00149-1

Codex Stan (2019) Standard for Honey. CXS 12-1981 Adopted in 1981. Revised in 1987, 2001. Amended in 2019. Codex Alimentarius. FAO. WHO. International Food Standards. pp. 1-8 (1981) (World-wide standard) Rev. 1 (1987) Available at https://www.fao.org/3/w0076e/w0076e30.htm Five languages https://www.fao.org/fao-who-codexalimentarius/sh

Costa dos Santos A, Biluca FC, Brugnerotto P, Gonzaga LV, Oliveira Costa AC, Fett R (2022) Brazilian stingless bee honey: Physicochemical properties and aliphatic organic acids content. *Food Research International 158*: 111516. https://doi.org/10.1016/j.foodres.2022.111516

Crane E (1975) *Honey. A comprehensive survey*. Heinemann: London, UK. 607 pp.

Department of Standards Malaysia (2017) Kelulut (Stingless bee) honey – Specification MS 2683: 2017. https://es.scribd.com/document/398215369/Kelulut-Stingless-bee-honey-Specification

Dhillon P (2021) How to be a good peer reviewer of scientific manuscripts. *The FEBS Journal 288*: 2750-2756. https://febs.onlinelibrary.wiley.com/doi/full/10.1111/febs.15705

Falagas ME, Pitsouni EL, Malietzis GA, Pappas G (2008) Comparison of PubMed, Scopus, Web of Science, and Google Scholar: Strengths and weaknesses. *FASEB Journal 22*: 338-342. https://doi.org/10.1096/fj.07-9492LSF

Gonnet M, Lavie P, Nogueira-Neto P (1964) Étude de quelques characteristiques des miels récoltés para certains Méliponines brésiliens. *Comptes Rendus de l'Académie des Sciences Paris 258*: 3107-3109. https://doi.org/10.1111/j.1096-3642.1955.tb00591.x

IDAF (2019) Instituto de Defesa Agropecuária e Florestal do Espírito Santo. Instrução Normativa nº 001, de 17 de abril de 2019. Regulamento Técnico de Identidade e Qualidade do Mel de Abelhas Sem Ferrão para o Estado do Espírito Santo, Brazil. pp. 1-7.

INEN (2015) Instituto Ecuatoriano de Normalización. Pot-Honey Standard Project in Ecuador. INEN, Quito, Ecuador. http://www.saber.ula.ve/stinglessbeehoney/norms.php

Jacobs N (2022) Co-term network analysis as a means of describing the information landscapes of knowledge communities across sectors. *Journal of Documentation 58*: 548-562. https://doi.org/10.1108/00220410210441577

López-Palacios S (1986) *Catálogo para una Flora Apícola Venezolana*. Consejo de Desarrollo Científico y Humanístico, Universidad de Los Andes: Mérida, Venezuela. 211 pp.

Michener CD (2007) *The bees of the world*. 2nd Ed. Johns Hopkins University Press. Baltimore, USA. 992 pp.

Myers L (2022) Top 40 green hex codes for growth, freshness & abundance. https://louisem.com/419029/green-hex-codes

Oromokoma C, Kasangaki P, Akite P, Mugume R, Kajobe R, Mangusho G, Matovu M, Chemurot M (2023) First physicochemical analysis of stingless bee honey from Uganda. *Journal of Apicultural Research*. https://doi.org/10.1080/00218839.2023.2167362

Persano Oddo L, Heard TA, Rodríguez-Malaver A, Pérez RA, Fernández-Muiño M, Sancho MT, Sesta G, Lusco L, Vit P (2008) Composition and antioxidant activity of *Trigona carbonaria* honey from Australia. *Journal of Medicinal Food 11*: 789-794. https://doi.org/10.1089/jmf.2007.0724

Popova M, Gerginova D, Trusheva B, Simova S, Tamfu AN, Ceylan O, Clark K, Bankova V (2021) Preliminary study of chemical profiles of honey, cerumen, and propolis of the African stingless bee *Meliponula ferruginea*. *Foods 10*: 997. https://doi.org/10.3390/foods10050997

Pranckute R (2021) Web of Science (WoS) and Scopus: The titans of bibliographic information in today's academic world. *Publications 9*: 12. https://doi.org/10.3390/publications9010012

Rowley J, Sbaffi L, Sugden M, Gilbert A (2022) Factors influencing researchers' journal selection decisions. *Journal of Information Science 48*: 321-335. https://doi.org/10.1177/0165551520958591

SAR (2020) Secretaria de Estado da Agricultura e da Pesca e do Desenvolvimento Rural. Portaria SAR nº 37/2020, de 04/11/2020. Norma Interna Regulamentadora do Mel de Abelhas Sem Ferrão no Estado de Santa Catarina, Brazil. pp. 16-24.

Secretaría de Regulación y Gestión Sanitaria y Secretaría de Alimentos y Bioeconomía (2019) Miel de *Tetragonisca fiebrigi* (yateí). Resolución Conjunta 17/2019 RESFC-2019-17-APN-SRYGS#MSYDS 02/05/2019 N° 29258/19 v. 02/05/2019. https://www.boletinoficial.gob.ar/detalleAviso/primera/206764/20190502

Sooklim C, Samakkara W, Thongmee A, Duangphakdee O, Soontorngun N (2022) Enhanced aroma and flavour profile of fermented *Tetragonula pagdeni* Schwarz honey by a novel yeast *T. delbrueckii* GT-ROSE1 with superior fermentability. *Food Bioscience 50*: 102001. https://doi.org/10.1016/j.fbio.2022.102001

Souza B, Roubik D, Barth O, Heard T, Enríquez E, Carvalho C, Marchini L, Villas-Bôas J, Locatelli J, Persano Oddo L, Almeida-Muradian L, Bogdanov S, Vit P (2006) Composition of stingless bee honey: Setting quality standards. *Interciencia 31*: 867-875.

Starmer WT, Lachance MA (2011) Yeast ecology. In *The Yeasts*. CP Kurtzman, WJ Fell, T Boekhout (Eds.). Elsevier, London, UK. pp. 65-83.

Tay A (2022) Bibliometrix – A powerful and popular new bibliometric tool used in the domain of business and management. Data Services. Singapore Management University. Singapore. https://library.smu.edu.sg/topics-insights/bibliometrix

Van Eck NJ, Waltman L (2021) VOSviewer Manual. Manual for VOSviewer version 1.6.17. Universiteit Leiden & CWTS Meaningful metrics. Leiden, Netherlands. 53 pp. https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.17.pdf

Vit P (2013) Modificaciones comentadas de la norma Miel de Abejas, hacia la norma Miel de Venezuela: Inclusión de miel de pote y exclusión de mieles falsas. In P Vit, DW Roubik (Eds.). *Stingless bees process honey and pollen in cerumen pots*. Facultad de Farmacia y Bioanálisis, Universidad de Los Andes. Mérida, Venezuela. pp. 1-8.

Vit P (2017) The Biodiversity of Neotropical Meliponini in a honey world dominated by *Apis mellifera*. *International Conference for Physical, Life and Health Sciences*, Boston, Faculty of Medicine, Harvard, Boston, USA. 22-26 May.

Vit P (2022). A honey authenticity test by interphase emulsion reveals biosurfactant activity and biotechnology in the stingless bee nest of *Scaptotrigona vitorum* 'Catiana' from Ecuador. *Interciencia 47*: 416-425. https://www.interciencia.net/wp-content/uploads/2022/10/01_6935_A_Vit_v47n10_10.pdf

Vit P (2023a) Proposal of quality standards for *Tetragonisca angustula* (Latreille, 1811) honey based on data from Brazil, Colombia, Costa Rica, Ecuador, Guatemala, and Venezuela. *2nd ICbees International Congress on Bee Sciences*, online, Turkey 14-16 June.

Vit P (2023b) Proposal of quality standards for *Tetragonisca Moure*, 1946 honey based on *Tetragonisca angustula* (Latreille, 1811) and *Tetragonisca fiebrigi* (Schwarz, 1938) honey data from Argentina, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, and Venezuela. pp. 19-23. *Seminario Premio Mujeres en Ciencia 2023*, Mérida, Venezuela. 15 June.

Vit P, Chuttong B, Zawawi N, Diaz M, van der Meulen J, Ahmad HF, Tomas-Barberan FA, Meccia G, Danmek K, Moreno JE, Roubik D, Barth OM, Lachenmeier DW, Engel MS (2022) A novel integrative methodology for research on pot-honey variations during post-harvest. *Sociobiology 69*: e8251. http://periodicos.uefs.br/index.php/sociobiology/article/view/8251/7571

Vit P, Medina M, Enriquez ME (2004). Quality standards for medicinal uses of Meliponinae honey in Guatemala, Mexico and Venezuela. *Bee World 85*: 2-5. https://doi.org/10.1080/0005772X.2004.11099603

Vit P, Pedro SRM, Maza F, Kunert C (2017) Prospective contribution for Ecuadorian *Scaptotrigona* pot-honey norm. *45th APIMONDIA International Apicultural Congress*, Istanbul, Turkey, September 29–October 4.

Vit P, Pedro SRM, Roubik D (2013). Eds. *Pot-honey. A legacy of stingless bees*. Springer. New York, USA. 654 pp.

Vit P, Pedro SRM, Roubik D (2018). Eds, *Pot-pollen in stingless bee melittology*. Springer. Cham, Switzerland. 481 pp.

Vit P, Persano Oddo L, Marano ML, Salas de Mejías E (1998) Venezuelan stingless bee honeys characterised by multivariate analysis of compositional factors. *Apidologie 29*: 377-389. https://doi.org/10.1051/apido:19980501

Vit P, Titera D (2022) Evaluación de etiquetas de miel de abejas producida en la República Checa: Una forma de comunicación entre apicultores y consumidores. *Vida Apícola 234*: 26-34.

Vit P, van der Meulen J, Pedro SRM, Esperança I, Zakaria R, Beckh G, Maza F, Meccia G, Engel MS (2023) Impact of genus (*Geotrigona*, *Melipona*, *Scaptotrigona*) in the ^{1}H-NMR organic profile, and authenticity test by interphase emulsion of honey processed in cerumen pots by stingless bees in Ecuador. *Current Research in Food Science 6*: 100386. https://doi.org/10.1016/j.crfs.2022.11.005

Wille A (1962) A technique for collecting stingless bees under jungle conditions. *Insectes Sociaux 9*: 291-293.

Zakaria R, Ahmi A, Ahmad AH, Othman Z, Azman KF, Aziz CBA, Ismail CAN, Shafin N (2021) Visualising and mapping a decade of literature on honey research: a bibliometric analysis from 2011 to 2020. *Journal of*

Apicultural Research 60: 359-368. https://doi.org/10.1080/00218839.2021.1898789

Zawawi N, Zhang J, Hungerford NL, Yates HAS, Webber DC, Farrell M, Tinggi U, Bhandari B, Fletcher MT (2022) Unique physicochemical properties and rare reducing sugar trehalulose mandate new international regulation for stingless bee honey. *Food Chemistry 373*: 131566 https://doi.org/10.1016/j.foodchem.2021.131566

Zhu J, Liu W (2020) A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics 123*: 321-335. https://doi.org/10.1007/s11192-020-03387-8.

Supplementary material available at:

http://www.saber.ula.ve/stinglessbeehoney/bibliometrics.php

Supplementary FIGURES Vit *et al*. biblio SBH 2023 (http://www.saber.ula.ve/stinglessbeehoney/pdfs/Supplementary_FIGURES_Vit_et_al._biblio_SBH_2023.pdf).

Supplementary TABLES Vit *et al*. biblio SBH 2023 (https://github.com/vitolivier/biblio-SBH/blob/bhttp://www.saber.ula.ve/stinglessbeehoney/pdfs/Supplementary_TABLES_Vit_et_al._biblio_SBH_2023.pdf).

Supplementary TEXT S1 Vit *et al*. biblio SBH 2023 (http://www.saber.ula.ve/stinglessbeehoney/pdfs/Supplementary_TEXT_S1_Vit_et_al._biblio_SBH_2023.pdf).

Supplementary TEXT S2 Vit *et al*. biblio SBH 2023 (http://www.saber.ula.ve/stinglessbeehoney/pdfs/Supplementary_TEXT_%20S2_Vit_et_al._biblio_SBH_2023.pdf).

Supplementary TEXT S3 Vit *et al*. biblio SBH 2023 (https://github.com/vitolivier/biblio-SBH/blob/bhttp://www.saber.ula.ve/stinglessbeehoney/pdfs/Supplementary_TEXT_S3_Vit_et_al._biblio_SBH_2023.pdf).

MAPEO DE SEIS DÉCADAS DE INVESTIGACIÓN EN MIEL DE ABEJAS SIN AGUIJÓN: CALIDAD QUÍMICA Y BIBLIOMETRÍA

Patricia Vit, Temitope Cyrus Ekundayo y Zhengwei Wang

RESUMEN

Las abejas sin aguijón (Apidae: Apinae: Meliponini) procesan la miel en vasijas de cerumen, por lo que se denomina miel de pote. Casi 600 especies de abejas sin aguijón producen miel tropical. A pesar de que la Comisión del Codex Alimentarius descuidó la regulación internacional de este relevante producto de meliponinos, las normas locales y nacionales están creciendo desde el año 2014. Además del mayor contenido de agua y de acidez libre, un descubrimiento reciente del azúcar trehalulosa en la miel de pote es un rasgo distintivo adicional. La gran biodiversidad entomológica tiene un impacto en la composición química y la bioactividad de la miel, así como el origen botánico que ha sido menos estudiado debido a la gran cantidad de especies de abejas sin aguijón en comparación con la única Apis mellifera. *Se realizó una revisión bibliométrica (1962-2022) para analizar la evolución de la literatura científica sobre miel de abejas sin aguijón, los autores prolíficos, las instituciones más activas, los países más productivos, las principales revistas utilizadas para difundir la investigación sobre la miel de abejas sin aguijón, identificar mapas temáticos y sus conexiones con las disciplinas científicas utilizando la base de datos Scopus y el software* bibliometrix. *Se describió la estructura taxonómica de esta revisión bibliométrica. En estas seis décadas, se destacó una autora venezolana, la Universidad de Los Andes fue la tercera institución con mayor número de publicaciones y Venezuela ocupó el sexto lugar como país más productivo luego de Brasil, Malasia, México, Estados Unidos e Indonesia. Se visualizó una nube de palabras, mapa de árbol, dendrograma y mapa conceptual. Se mapeó la red de las fuentes y la evolución de las palabras claves del autor por VOSviewer. Esta revisión fue el primer análisis integral de mapeo científico en miel de abejas sin aguijón.*

MAPEANDO SEIS DÉCADAS DE PESQUISA EM MEL DE ABELHAS SEM FERRÃO: QUALIDADE QUÍMICA E BIBLIOMETRIA

Patricia Vit, Temitope Cyrus Ekundayo e Zhengwei Wang

RESUMO

As abelhas sem ferrão (Apidae: Apinae: Meliponini) processam o mel em potes de cera, por isso é chamado de mel de pote. Quase 600 espécies de abelhas sem ferrão produzem mel tropical. Apesar do fato de que a Comissão do Codex Alimentarius negligenciou a regulamentação internacional deste importante produto de meliponina, os padrões locais e nacionais estão crescendo desde 2014. Além do maior teor de água e acidez livre, uma recente descoberta de açúcar trehalulose em mel de pote é um adicional característica distintiva. A grande biodiversidade entomológica tem impacto na composição química e bioatividade do mel, assim como a origem botânica que tem sido menos estudada devido ao grande número de espécies de abelhas sem ferrão em comparação com a única Apis mellifera. *Foi realizada uma revisão bibliométrica (1962-2022) para analisar a evolução da literatura científica sobre o mel sem ferrão, os autores prolíficos, as instituições mais ativas, os países mais produtivos, os principais periódicos utilizados para divulgar as pesquisas sobre mel, identifica mapas temáticos e suas conexões com disciplinas científicas utilizando a base de dados Scopus e o software Bibliometrix. A estrutura taxonômica desta revisão bibliométrica foi descrita. Nessas seis décadas, uma autora venezuelana se destacou, a Universidad de Los Andes foi a terceira instituição com maior número de publicações e a Venezuela ocupou o sexto lugar como país mais produtivo depois de Brasil, Malásia, México, Estados Unidos e Indonésia. Uma nuvem de palavras, mapa de árvore, dendrograma e mapa conceitual foram visualizados. A rede de fontes e a evolução das palavras-chave do autor foram mapeadas pelo VOSviewer. Esta revisão foi a primeira análise abrangente do mapeamento científico em mel de abelhas sem ferrão.*