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Stingless bee honey (Hymenoptera, Apidae, Meliponini): a review of quality control, chemical profile, and biological potential

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Abstract – Products made by bees are well-known for their beneficial properties and nutritional value. This association has been proven by scientific studies that describe their composition and biological activities. The aim of this study is to portray the state of the art on research regarding stingless bee honey. The search for standards that guide the trade of these products is still portrayed as a future perspective, since there are significant differences in relation to honey from *Apis mellifera* and it often requires additional treatments.

stingless bees / honey quality / chemical composition

1. INTRODUCTION

Stingless bees, also called meliponines, native, or indigenous bees, comprise a wide group of eusocial bees and present a range of variations in behavioral aspects, communication systems, foraging strategies, population densities, and nest architectures, among others (Nogueira-Neto 1997). More than 500 species of stingless bees have been described and 61 genera are distributed in Latin America, Australia, Africa, and tropical parts of Asia.

The use of rational breeding techniques, knowledge of the explored flora, the implementation of management techniques, and artificial feeding have allowed the expansion of meliponiculture (Jaffé et al. 2015). Many species

are popular and are raised to obtain products which generate jobs and income and, at the same time, maintain biodiversity (Kerr et al. 2001; Imperatriz-Fonseca and Nunes-Silva 2010; Contrera et al. 2011; Ollerton et al. 2011; Freitas and Nunes-Silva 2012; Bartelli and Nogueira-Ferreira 2014). In Brazil, many tree species and agricultural crops are pollinated by these bees and their effective pollination performance has been confirmed for more than 30 different agricultural crops (Heard 1999; Slaa et al. 2006; Castro et al. 2006). The importance of *Apis mellifera* in pollination has already been widely reported (Blettler et al. 2018) whereas for stingless bees, studies have been conducted to evaluate pollination efficiency considering the productive increase of cultivars, and the results indicate that these bees are considered promising for use as commercial pollinators (Roselino et al. 2009, 2010; Kiatoko et al. 2014).

In the Amazon region, there is a great diversity of bees, which can be attributed to the favorable

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conditions, such as warm weather and flora rich in species that supply nectar, pollen, and resins. In these regions, the honey has been the main product of extraction; however, studies have shown that many species of meliponines have considerable productive potential for propolis, geopropolis, batumens, and cerumens, in addition to pollen (Contrera et al. 2011).

In the last decade, researchers and environmentalists from around the world have shown great concern about the decline in the population of managed and wild pollinators (Potts et al. 2016), and have promoted a significant scientific advance related to the theme of bees. Many campaigns are being carried out to publicize their importance to human existence and in the maintenance of the ecosystem, and thus provoke a wave of worldwide interest on the subject and open new horizons for scientific research, especially regarding stingless bees, which are still little studied. Some recent reviews have been published on topics such as propolis (Anjum et al. 2018; Popova et al. 2019), reproductive behavior (Vollet-Neto et al. 2018), and palynological analysis (Souza et al. 2019). This review aims to discuss what the scientific community knows about honey from stingless bee honeys, when used not only as food but also its functional properties.

2. HONEY

Most studies regarding honey have been carried out with *Apis mellifera*, since this species has adapted to different regions around the world. However, the literature extolls the virtues of the different characteristics of honey from stingless bees, especially in relation to its moisture content, peculiar flavor, and more pronounced aroma (Alves et al. 2005).

The honey production strategy of *A. mellifera* consists of removing the moisture from the nectar to a certain level that the microorganisms can no longer reproduce and with that it can be stored for many years without deteriorating and maintaining practically the same characteristics of color, flavor, aroma, and physicochemical properties. Bees remove moisture by using their wings and add enzymes with the function of digesting sugars

and conserving honey. Honey is stored in combs made of wax produced by the workers' glands and after being closed, the honey no longer has contact with air (Seeley 1985).

The strategy used by stingless bees is different. They dehydrate honey to a reasonable, however, specific level (Vit et al. 1994; Souza et al. 2006). After being stored, microorganisms, mainly bacteria of the genus *Bacillus* and yeasts, will consume part of the sugar and transform it into alcohol through anaerobic fermentation and then this alcohol is transformed into acetic acid through aerobic fermentation. Sugar can also be transformed into other types of acids (and other by-products) through other types of non-alcoholic fermentation (Gilliam et al. 1985; Gilliam et al. 1990; Menezes et al. 2013). This fermentation alters the characteristics of the honey and is very specific, since each bee species has its own microbiome and the processing dynamics are different. There is evidence that microorganisms also add enzymes and other compounds to honey that can contribute to its conservation and digestion of nutrients (Menezes et al. 2013). In addition, the cerumen pot, in contrast to the *Apis mellifera* honeycomb, gradually transfers the aromas from the pots to the honey and, via their intensity, superimposes them on the honey, thus creating the specific identity of the bee species. It is possible that bioactive substances, such as antibiotics and antioxidants, are being incorporated into honey in these processes.

The composition of honey depends, among other factors, on the plant sources from which it is derived, the species of the bee, the physiological state of the colony, the state of maturity of the honey, and the weather conditions during the harvest (Campos et al. 2003). The honey of the meliponines species has as its main characteristic, the highest acidity and the highest water content (moisture), which makes it less dense than the honey from Africanized bees (*A. mellifera*). The chemical composition has been little studied, and the studies that exist are limited to the quantitative determination of its phenolic and flavonoid compounds.

Due to the particularities presented by honey from native bees, studies aiming at characterization have been carried out, with the objective of

determining their identity and controlling possible adulterations. These studies are important for the elaboration of a legislation that meets the quality control of honey of meliponines (Vit et al. 1994; Souza et al. 2006). In Brazil, the legislation regarding honey is intended for the classification of honey from *A. mellifera* (Brazil 2000) and does not deal with the characteristics of the product of stingless bees. Recently, however, some Brazilian states such as Bahia (Brazil 2014) and São Paulo (Brazil 2017) have defined specific parameters for honeys from stingless bees, aiming at quality control and the formalization of the sale of this product. With this, establishments that aim at the processing of honey and are accredited by the Federal Inspection Service are already managing to overcome the pre-existing bureaucratic barriers, register the honey from stingless bees, and commercialize it in the formal market.

3. PHYSICO-CHEMICAL PROFILE OF HONEYS FROM STINGLESS BEES

Most of the physical-chemical profiles were performed with bees occurring in Brazil, and the most studied honey of native bees is that from bees of the genus *Melipona*, as can be seen in Table 1. Analyses of honey from *Melipona scutellaris* harvested in different locations: Brejo Paraibano region, northeastern Brazil (Evangelista-Rodrigues et al. 2005), in Bahia (Souza et al. 2009b), Paraná (Nascimento et al. 2015), and in Santa Catarina (Biluca et al. 2016) showed that there is some variation in the content of hydroxymethylfurfural (HMF) between samples; this parameter indicates deterioration levels of honey. Taking as a reference the limits established in the standards applied to *A. mellifera* honey, the values obtained for the samples of *M. scutellaris* honeys would be in conformity for the free acidity index, diastase activity, HMF, sucrose, and ash content.

Regarding the level of free acidity of honey from the genus *Melipona*, the honey from *Melipona flavolineata*, harvested in Brazil, had the highest index, whose value was 143.67 meq/kg (Lemos et al. 2017), while *Melipona quadrifasciata anthidioides*, produced honey with an index of 17 meq/kg, also harvested in

Brazil (Duarte et al. 2018). For the dehumidified honey of *Melipona quadrifasciata*, an index of 7.5 meq/kg was obtained (Carvalho et al. 2009). Of the total, 27% of the samples evaluated are above the required standard due to the fermentation that occurs naturally in honey from stingless bees, so this parameter is not recommended for use in assessing the quality of honey from stingless bees.

Melipona asilvai honey, although harvested in the Northeastern region of Brazil, has significant differences in HMF content, conductivity, and acidity (Souza et al. 2004; Souza et al. 2009a; Duarte et al. 2018). The exact period of the harvest and analysis of these samples must be considered in order to justify the differences.

Comparing the data in the literature (Table 1) with the legislation for *A. mellifera*, it can be seen that the vast majority of the data obtained in the studies exceed the standard limits established for *Apis mellifera* honey, where the high moisture and acidity (Brazil 2000), humidity and free acidity are notable (Codex Alimentarius Commission 2001). Ash, sucrose, HMF contents, and diastase activity are less problematic, but eventually samples are outside the established limits. Therefore, the future regulations should review the standard limits to fit the majority of studied stingless bee honeys.

The laws of the state of São Paulo, Bahia, and Amazonas, which are aimed at regulating the quality of Meliponini honeys, represent a great advance in this issue in Brazil. There are still some gaps that need to be addressed, and probably changed in the future, but they are already allowing stingless bee keepers and honey industries to sell Meliponini honey in the official market. One of the parameters that should be revised is the free acidity levels. São Paulo and Bahia laws kept the same limit established for *Apis mellifera* honey (50 meq/kg) and Amazonas increased the tolerance to 80 meq/kg. This parameter is used to evaluate if the honey of apiculture industry has fermented. Because of natural fermentation that occurs in Meliponini honey (Menezes et al. 2013), it does not make much sense for stingless bee industry. About 30% of the samples are above the limit of 50 meq/kg and eventually higher than 80 meq/kg. For the content of reducing sugars, the

Table 1. Physico-chemical analysis honey samples from native stingless bees

Species	Physico-chemical parameters											References	
	Honey	Acidity (meq/kg)	Reducing sugars (g/100 g)	Diastatic activity (Gothe)	Conductivity (mS/cm)	HMF (mg/kg)	pH	Protein (%)	Sucrose (g/100 g)	Ash (g/100 g)	Moisture (g/100 g)		Country
<i>Cephalotrigona capitata</i>	In natura	34.33	75.21	0.18	0.73	35.4	3.04	-	0.36	0.19	32.1	Brazil	Nascimento et al. (2015)
<i>Frisocomella doederleini</i>	In natura	27.4	49.1	-	-	-	3.5	-	5.1	1.1	17.3	Brazil	Sousa et al. (2013)
<i>F. doederleini</i>	In natura	93.50	60.15	-	6.19	4.33	3.82	-	0.22	0.22	27.12	Brazil	Santisteban et al. (2019)
<i>F. flavicornis</i>	In natura	31.6	49.7	-	-	-	3.5	0.1	5.9	0.3	27.9	Brazil	Sousa et al. (2013)
<i>F. varia</i>	In natura	28.8	75	19.1	1.2	28	5.2	-	-	-	30	Brazil	Duarte et al. (2018)
	In natura	73	61	7.8	-	1.1	-	1.34	4.8	0.76	19.9	Venezuela	Vit et al. (1994)
<i>Gemotrigona thoracica</i>	In natura	-	-	-	-	-	3.36	0.96	-	-	28.17	Malaysia	Abu Bakar et al. (2017)
<i>Heterotrigona itama</i>	In natura	-	-	-	-	-	3.32	2.8	-	0.44	28.43	Malaysia	Abu Bakar et al. (2017)
<i>Homotrigona fimbriata</i>	In natura	528	22.4	-	2.6	46	3.3	-	-	1	41	Tailandia	Chutong et al. (2016)
<i>Hypotrigona</i> sp.	In natura	35.57	60.49	-	0.3	-	3.75	5.74	1.83	-	17.5	Nigeria	Nweze et al. (2017)
<i>Lepidotrigona doipauensis</i>	In natura	197.5	27.8	1.7	1.19	2.3	3.5	-	-	0.66	32	Thailand	Chutong et al. (2016)
<i>L. flavobasis</i>	In natura	168	29	3.1	1.3	8.5	3.7	-	-	0.51	28	Thailand	Chutong et al. (2016)
<i>L. terminata</i>	In natura	194	13	0.29	0.78	-	3.5	-	-	0.24	30	Thailand	
<i>Listotrigona furva</i>	In natura	53	60	-	0.34	0.21	3.9	-	-	0.32	28	Thailand	
<i>Melipona rufiventris mandory</i>	In natura	38.2	65.6	< 3	0.25	<L	4.21	-	<L	-	27.7	Brazil	Biluca et al. (2016)
<i>M. ashvai</i>	In natura	54.23	61.26	-	5.47	14.71	3.55	0.33	3.34	0.09	37.53	Brazil	Souza et al. (2009a)
	In natura	22	67	2	0.3	61	4.3	-	-	-	30	Brazil	Duarte et al. (2018)
	In natura	41.64	73.84	-	3.63	2.44	3.27	-	4.7	-	29.49	Brazil	Souza et al. (2004)
<i>M. beecheii</i>	In natura	41.52	-	1.3	0.58	9.23	3.2	2.71	-	0.46	28.62	Cuba	Alvarez-Suarez et al. (2018)
<i>M. bicolor</i>	In natura	91.62	60.14	< 3	0.58	<L	3.77	-	<L	-	34.68	Brazil	Biluca et al. (2016)
	In natura	48.58	68.43	0.12	0.54	31.58	3.32	-	0.57	0.18	36.18	Brazil	Nascimento et al. (2015)
<i>M. capixaba</i>	In natura	79.28	-	-	-	-	3.62	-	-	-	30.51	Brazil	Lage et al. (2012)
<i>M. compressipes</i>	In natura	23.88	60.39	-	-	-	3.74	-	0.14	-	26.7	Brazil	de Almeida-Muradian and Maissuda (2007)
<i>M. compressipes fasciculata</i>	In natura	48.4	75.7	1.1	-	1	-	0.49	1.6	0.3	23.4	Venezuela	Vit et al. (1994)
<i>M. erinita</i>	In natura	37.8	52.7	-	-	-	4.1	0.1	5.4	0.1	29.6	Brazil	Sousa et al. (2013)
<i>M. eburnea</i>	In natura	-	-	-	-	-	-	-	-	-	28.8	Venezuela	Rodriguez-Malaver et al. (2009)
	In natura	-	-	-	-	-	-	-	-	-	23.8	Venezuela	Rodriguez-Malaver et al. (2009)
<i>M. fasciculata</i>	In natura	18.91	70.57	-	-	17.81	4.56	-	2.17	-	29.03	Brazil	Lemos et al. (2017)
	In natura	17.64	63.47	-	-	6.54	-	-	3.89	-	24.33	Brazil	Menezes et al. (2018)
<i>M. favaosa</i>	Pasteurized	16.08	63.83	-	-	9.46	-	-	1.59	-	23.68	Brazil	Menezes et al. (2018)
	In natura	62.9	72.1	0.9	-	1.2	-	0.41	1.5	0.29	25.5	Venezuela	Vit et al. (1994)

Table 1 (continued)

Species	Physico-chemical parameters											References
	Honey	Acidity (meq/kg)	Reducing sugars (g/100 g)	Dianstatic activity (Göthe)	Conductivity (mS/cm)	HMF (mg/kg)	pH	Protein (%)	Sucrose (g/100 g)	Ash (g/100 g)	Moisture (g/100 g)	
<i>M. flovilleata</i>	<i>In natura</i>	36.8	70.3	2.86	2.06	17.1	-	0.71	2	0.15	24.2	Venezuela
	<i>In natura</i>	143.67	59.31	-	-	34.62	3.41	-	5.52	-	35.11	Brazil
	<i>Pasteurized</i>	38.85	63.09	-	-	3.59	-	-	2.12	-	28.53	Brazil
<i>M. grandis</i>	<i>In natura</i>	32.46	62.70	-	-	43.10	-	-	1.62	-	27.40	Brazil
	<i>In natura</i>	-	-	-	-	-	-	-	-	-	27.5	Venezuela
<i>M. itota</i>	<i>In natura</i>	-	-	-	-	-	-	-	-	-	28	Venezuela
<i>M. lateralis kangarumensis</i>	<i>In natura</i>	40.7	64.8	2.76	1.65	3.9	-	0.23	1.1	0.11	28.8	Venezuela
	<i>In natura</i>	43.48	74.82	-	3.52	5.79	-	2.91	2.91	-	28.78	Brazil
<i>M. manducata</i>	<i>In natura</i>	37.7	75.5	-	2.84	30.85	3.71	0.17	2.85	0.09	31.4	Brazil
	<i>In natura</i>	22.55	67.39	0.19	0.62	48.09	2.93	-	0.85	0.14	32.44	Brazil
<i>M. marginata</i>	<i>In natura</i>	79.82	63.5	<3	0.44	<L	3.67	-	<L	-	32.65	Brazil
	<i>In natura</i>	61.51	-	-	-	-	4.19	-	-	-	-	Brazil
<i>M. mondury</i>	<i>In natura</i>	37.89	67.77	0.2	0.51	51.38	3.5	0.85	0.85	0.25	29.97	Brazil
	<i>In natura</i>	61.1	67.45	<3	0.69	<L	5.18	-	<L	-	29.75	Brazil
<i>M. paraensis</i>	<i>In natura</i>	30.4	60.8	2.9	1.37	3.4	-	0.14	1.2	0.14	26.4	Venezuela
	<i>In natura</i>	17	75	3	0.5	3.3	4.2	-	6.6	-	31	Brazil
<i>M. q. anthidioides</i>	<i>In natura</i>	33.5	52.8	-	-	-	3.8	0.2	6.6	0.58	28.1	Brazil
	<i>In natura</i>	42.52	61.77	11.25	0.33	<L	3.71	-	<L	-	32.47	Brazil
<i>M. quadrifasciata</i>	<i>In natura</i>	35	71.63	0.13	0.58	42.63	3.18	-	0.85	0.16	36.89	Brazil
	Dehumidified	7.5	72.99	1.34	5.97	3.82	6.04	-	2.52	0.41	16.9	Brazil
<i>M. quadrifasciata</i>	<i>In natura</i>	6.27	60.42	1.40	4.46	1.27	6.64	-	1.28	0.39	25.20	Brazil
	Dehumidified	28.5	74.63	1.65	2.17	4.39	3.46	-	2.96	0.12	16.90	Brazil
<i>M. quadrifasciata anthidioides</i>	<i>In natura</i>	28.0	60.06	2.14	2.26	1.45	3.74	-	1.32	1.15	>30.0	Brazil
	<i>In natura</i>	40.8	68.29	-	5.49	16.04	3.99	0.29	3.09	0.1	32.09	Brazil
<i>M. quinquefasciata</i>	<i>In natura</i>	36.9	64	-	-	-	3.5	0.3	5.8	0.1	28.8	Brazil
	<i>In natura</i>	42	-	-	-	-	4.24	-	-	-	-	Brazil
<i>M. scutellaris</i>	<i>In natura</i>	28.33	-	-	-	18.92	4.66	-	-	0.17	25.26	Brazil
	<i>In natura</i>	27.25	66.41	0.11	0.54	40.86	3.48	-	0.7	0.16	33.98	Brazil
<i>M. scutellaris</i>	<i>In natura</i>	28.7	62.7	<3	0.15	<L	4.52	-	<L	-	23.4	Brazil
	<i>In natura</i>	37	59	2	0.7	21	4.2	-	-	-	30	Brazil
<i>M. scutellaris</i>	Dehumidified	53.5	67.57	1.73	2.9	6.65	3.71	-	1.51	0.18	16	Brazil
	<i>In natura</i>	55.0	53.91	2.16	2.72	2.21	3.53	-	1.11	0.18	>30.0	Brazil
<i>M. scutellaris</i>	Dehumidified	28.5	70.92	2.18	2.72	3.02	3.67	-	4.35	0.17	16.5	Brazil
	<i>In natura</i>	-	-	-	-	-	-	-	-	-	-	-

Table I (continued)

Species	Physico-chemical parameters										References	
	Honey	Acidity (meq/kg)	Reducing sugars (g/100 g)	Dianstatic activity (Grothe)	Conductivity (mS/cm)	HMF (mg/kg)	pH	Protein (%)	Sucrose (g/100 g)	Ash (g/100 g)		Moisture (g/100 g)
<i>M. seminigra</i>	In natura	27.75	56.98	3.01	2.64	1.33	3.57	-	3.17	0.18	26.0	Brazil
	In natura	86.2	49.8	-	-	-	4.1	1.8	5.3	0.1	35.4	Brazil
	In natura	19.87	70.71	-	5.7	1.99	4.43	0.25	1.81	0.19	29.13	Brazil
	In natura	26.54	61.49	-	-	-	3.78	-	0.18	-	30.4	Brazil
<i>Melipona</i> sp.	In natura	30.44	69.12	0.2	0.55	29.5	3.72	-	1.61	0.22	27.85	Brazil
	In natura	35.7	49.4	15.63	3.92	8.6	3.6	0.23	3.8	0.38	38.7	Brazil
	In natura	12.59	75.64	-	0.24	5.5	4.21	5.5	5.06	-	13.86	Nigeria
	In natura	32.49	-	42.87	1.03	7.56	-	0.28	4.86	0.02	24.8	Brazil
<i>M. irmitatis</i>	In natura	22	75	3	0.6	51	4.6	-	-	-	27	Brazil
	In natura	38.1	52.6	-	-	-	4.4	0.9	3.7	0.2	31.1	Brazil
	Heated	39.1	80.94	-	-	56.53	3.8	-	-	-	25.17	Brazil
	In natura	24.24	76.66	1	-	1.3	-	0.48	1.48	0.12	25.7	Venezuela
<i>Nannotrigona testaceicornis</i>	In natura	24.2	73.7	1	-	1.3	-	0.48	1.5	0.12	25.7	Venezuela
	In natura	64.5	42.2	-	-	-	5	1.7	10.2	0.6	34.7	Brazil
	In natura	125	72	10	1.2	72	4.1	-	-	-	35	Brazil
	In natura	48.95	62.95	4.34	0.63	<L	4.48	-	<L	-	23.95	Brazil
<i>Scaptotrigona bicinctata</i>	In natura	68.3	56.48	-	0.4	16.4	3.82	-	-	0.45	20.61	Mexico
	In natura	35.6	46.3	-	-	-	5.1	0.4	1.5	0.3	28.3	Brazil
	In natura	60.98	62.34	-	-	24.71	3.89	-	4.83	-	30.22	Brazil
	In natura	28.78	66.32	0.62	0.62	58.27	3.58	-	1.22	0.21	29.84	Brazil
<i>S. xanthotricha</i>	In natura	38.57	60.01	-	-	4.85	3.97	-	4.65	0.36	19.07	Brazil
	In natura	128.9	42	0.4	1.64	1.2	4	2.02	1.8	-	16.4	Australia
	In natura	91.2	48.6	19.1	1.01	<L	4.28	-	<L	-	25.2	Brazil
	In natura	25	52	0.34	0.43	5.9	3.7	-	-	0.24	28	Thailand
<i>Tetragona clavipes</i>	In natura	45.23	55.46	32.28	1.34	9.39	4.1	0.37	0.95	0.39	24.37	Brazil
	In natura	27	66.65	22.43	0.72	27.99	4.08	-	0.82	0.33	25.99	Brazil
	In natura	41.15	63.75	49.6	0.95	<L	4.77	-	<L	-	23.75	Brazil
	In natura	48.3	65.9	23	7.32	9.8	-	1.42	2.1	0.38	23.2	Venezuela
<i>Tetragonia collina</i>	In natura	79	43	-	-	-	3.72	-	-	-	24	Argentina
	In natura	39.2	53.6	16.7	0.66	1.3	4.2	-	4.2	0.21	24.3	Colombia
	Dehumidified	68.25	76.92	4.05	-	53.89	3.83	-	3.85	-	17.5	Brazil
	In natura	59	72	9	1.4	18	5.6	-	-	-	19	Brazil
<i>Tetragonisca clavipes</i>	In natura	96.5	32.7	4.7	1.35	22	3.6	-	-	0.67	26	Thailand
	In natura	-	-	-	-	-	-	-	-	-	-	-

Table I (continued)

Species	Physico-chemical parameters											References
	Honey	Acidity (meq/kg)	Reducing sugars (g/100 g)	Dianstatic activity (Grothe)	Conductivity (mS/cm)	HMF (mg/kg)	pH	Protein (%)	Sucrose (g/100 g)	Ash (g/100 g)	Moisture (g/100 g)	
<i>Tetragonula laevis</i>	<i>In natura</i>	81.37	47.87	-	0.62	1.07	3.62	-	-	26.98	Thailand	Suntipapanop et al. (2015)
<i>Tetragonula laevis-pagdeni</i> complex	<i>In natura</i>	76	-	0.63	0.59	5.4	3.6	-	0.03	28	Thailand	Chuttong et al. (2016)
<i>Tetragonula testaceitarsis</i>	<i>In natura</i>	70.5	41	0.22	0.59	2.4	3.2	-	0.21	30.5	Thailand	
<i>Trigona apicalis</i>	<i>In natura</i>	495	12.65	4.9	2.6	0.26	3.4	-	1.4	42	Thailand	
<i>Trigona melanoleuca</i>	<i>In natura</i>	592	7.45	0.15	2.8	2.8	3.6	-	3.1	43	Thailand	
<i>Trigona fuscipennis</i>	<i>In natura</i>	46.7	56.6	<3	0.31	<L	3.44	-	-	34.4	Brazil	Biluca et al. (2016)
<i>Trigona</i> sp.	<i>In natura</i>	78.14	29.34	16.67	0.57	3.18	3.35	-	0.2	13.26	Thailand	Issaro et al. (2013)
<i>Trigonalaevis</i> Smith	<i>In natura</i>	50.83	27.37	13.64	0.57	3.32	3.44	-	0.14	15.73	Thailand	
<i>Trigona</i> pagdenis Schwarz	<i>In natura</i>	20	41.64	11.11	0.45	3.97	4.01	-	0.22	14.66	Thailand	
Amazonas State Regulations	Dehumidified	80 max	50 min	3 max	-	40 max	-	-	6 max	22 max	Brazil	Brazil (2016)
	Chilled	80 max	50 min	3 max	-	40 max	-	-	6 max	23–35 max	Brazil	
	<i>In Natura</i>	80 max	50 min	3 max	-	40 max	-	-	6 max	23–35 max	Brazil	
São Paulo State Regulations	Dehumidified	50 max	60 min	-	-	20 max	2.9–4.5	-	6 max	20 max	Brazil	Brazil (2017)
	Pasteurized	50 max	60 min	-	-	20 max	2.9–4.5	-	6 max	40 max	Brazil	
	Matured	50 max	60 min	-	-	20 max	2.9–4.5	-	6 max	40 max	Brazil	
	<i>In Natura</i>	50 max	60 min	-	-	20 max	2.9–4.5	-	6 max	40 max	Brazil	
Bahia State Regulations	Chilled	50 max	60 min	3 max	-	10 max	-	-	6 max	20–30 max	Brazil	Brazil (2014)
	Dehumidified	50 max	60 min	3 max	-	10 max	-	-	6 max	19 max	Brazil	
Legislation IN n° 11 International	-	50 max	65 min	8 min	-	60 max	-	-	6 max	20 max	Brazil	Brazil (2000)
	-	50 max	60 min	-	-	60 max	-	-	5 max	20 max	-	Codex Alimentarius Commission (2001)

<L limit of quantification

value determined by these regulations is less than 50 g/100 g. For the moisture level, it can be observed in the regulations that the levels required for fresh and chilled honey are allowed to reach a maximum of 35 g/100 g, while the proposals allow for up to 40 g/100 g. These differences may be associated with the floral origin of the honeys.

When comparing the physico-chemical parameters determined with European (Codex Alimentarius Commission 2001) and Brazilian legislation (Brazil 2000), the acidity index, reducing sugars, diastase activity, HMF, and humidity are the ones that present quite different values from those established. Of the 106 studies listed in Table I, 29 had acidity levels above the reference value, 31 contained levels lower than those established for reducing sugars, over 33 had diastase activity below what is permitted by legislation, 12 had HMF levels higher than established levels, and 82 humidity levels were above those stipulated. For sucrose and ash contents, in the vast majority of studies, the values are in accordance with legal limits. When the comparison takes place with what the Brazilian states of Amazonas, São Paulo, and Bahia define as standard, we can observe that this quantity is smaller, only 5 samples of honey provided values above those stipulates for acidity levels, for reducing sugars, 15 of them did not meet the regulations, for diastase activity, even though the proposals establish a maximum of 3 on the Gothe scale, 27 presented higher values. For the HMF content, 10 provided values above the regulations and for humidity, only 2 honey samples were not in compliance. Analyzing the data, it can be noted that what makes the honey of native bees and *Apis mellifera* considerably different are not only the high levels of acidity and humidity but also other factors as well. For example, the content of reducing sugars and diastase activity shows significant discrepancies from those stipulated for non-stingless bee honey.

Almeida-Muradian et al. (2013) studied samples of honeys from *Apis mellifera* and *Melipona subnitida* and found that the honey of *A. mellifera* showed values within the established limits, while that of the stingless bee presented values for diastase activity 5 times greater than the minimum stipulated, and the honey moisture was

also slightly above the norm (Table I). The results of the palynological analysis showed that even though they were subjected to the same flora, bees of different species access different plant sources.

Table I also includes data from different methods used in the treatment of honey. The expressive moisture content creates product instability over time, as it is very susceptible to fermentation. To overcome the problems arising from this, good harvesting practices are necessary, and these should aim at reducing contamination by microorganisms. Once harvested, some processing methods can be applied to assist in the conservation of this product. These are refrigeration, dehumidification, pasteurization, and maturation (Venturieri et al. 2007; Contrera et al. 2011).

Freitas et al. (2010) used heating in order to evaluate the physico-chemical parameters of the honey from *Melipona subnitida* in its natural form. After heating in an oven at 70 °C for different periods, the results indicated that the heat treatment decreased the acidity and humidity; however, the content of HMF and reducing sugars increased significantly. When compared with regulation proposals, with the exception of the HMF content, the other parameters were in accordance with the established levels.

Alves et al. (2012) evaluated the physico-chemical and sensory stability of the dehumidified honey of *Tetragonisca angustula*. The results showed good physico-chemical stability for the parameters of humidity, reducing sugars, apparent sucrose, pH, acidity, and HMF during a storage period of 180 days. However, only the pH and humidity corresponded to the values established in the regulation proposal by Camargo et al. (2017) for dehumidified honey. In comparison with the regulations of the Amazonas state, the parameters for acidity, reducing sugars, and humidity are in accordance.

Menezes et al. (2018) adopted pasteurization as a measure to minimize the proliferation of microorganisms in the honey from *M. fasciculata* and *M. flavolineata*. The process significantly influenced the moisture, pH, apparent sucrose, and HMF of the honeys, but did not influence acidity, ash, and reducing sugars.

The results show that when the moisture content of honey from stingless bees is adjusted, the

other parameters are altered. Therefore, there is no treatment that meets the peculiarities of the honey produced by these bees nor does it make any treatment universally suitable for quality parameters. Thus, proposed regulations already admit specific values for the parameters in the different forms of processing. Carvalho et al. (2009) studied Melipona honeys which had been harvested in different places and subjected to the dehumidification process. The honey produced by *M. quadrifasciata*, which was harvested on the island of Itapara and compared *in natura* with dehumidified form, showed an increase in the acidity index, reducing sugars, HMF, and sucrose, and a decrease in the diastase activity values, pH, and, consequently, humidity. These changes are compatible with what is expected for this treatment. This profile was also observed in the samples from Costa do Sauipe, Bahia State, Brazil. The honeys showed relevant differences for some parameters, such as the total acidity index which was lower for honey harvested on the Island of Itapara. For this honey, the pH is lower than for the honey harvested on the Costa do Sauipe. In relation to the honey from *M. scutellaris*, honey harvested in Tucano showed alterations in the content of sucrose and HMF, and showed an increase after the treatment, whereas the one harvested in Serrinha presented an increase in the levels of sucrose, HMF, and reducing sugars. The values for most of the evaluated parameters are in accordance with those established in the proposals and in the regulations of the state of Amazonas.

The studies also gather a significant amount of data on the honeys of species of the genera *Scaptotrigona* and *Tetragonisca*, and for the later of these two genus, seven of the eight studies were carried out with *T. angustula* species.

4. METABOLITES AND BIOLOGICAL ACTIVITY OF HONEYS FROM STINGLESS BEES

The literature has little data regarding the chemical composition of honey from stingless bees, and studies tend to focus on the quantification of phenolics compounds and flavonoids. These determinations are supported by positive

correlations between the presence of these compounds with antioxidant activity (Table II).

The phenolic content was the most commonly determined parameter in the honeys studied so far (Table II). The phenolic content of *M. subnitida* was 0.6 mg AGEq 100 g⁻¹ in honey from the state of Amazonas (Brazil) and 854.62 mg AGEq 100 g⁻¹ in honey from the state of Sergipe (Brazil). Other studies with other species have also revealed different phenolic contents for *M. fasciculata* and *M. flavolineata* (Oliveira et al. 2012), as well as for *M. s. merrillae* (Silva et al. 2013). These differences in content for the same species indicate that it will be difficult to create an adequate parameter for quality, since the flora is very diverse. Perhaps the way forward is to create a geographic seal after monitoring the parameters at different times of the year and for several years.

Different methods were used to determine the antioxidant capacity of stingless bee honeys, with DPPH and ABTS free radical scavenging being the most commonly used. When the data in Table II for the activity using these two methods is analyzed, it appears that the values vary widely.

Ávila et al. (2019) evaluated the antioxidant action of meliponine honeys using three different methods and the ORAC method the values were more expressive.

The study by Duarte et al. (2018) with 31 samples of meliponine honey from the same meliponary, in the state of Alagoas, Brazil, describes the differences in the content of phenolic compounds and flavonoids, which suggests preferences for different types of nectar.

For the honey of *M. s. merrillae* harvested in different locations in the state of Amazonas, differences in phenolic content were observed. Samples obtained in Pauíni and Maués showed the highest levels: 64.0 ± 0.03 and 66.0 ± 0.05 mgAGEq 100 g⁻¹, respectively. However, these samples were expected to have better antioxidant activity, but compared with those with lower concentrations, there was no significant difference (Silva et al. 2013). The authors also carried out the characterization of this stingless bee honey and detected by means of high-performance liquid chromatography (HPLC) the presence of 14 phenolic compounds in the ethyl acetate fraction. The presence of some of the

Table II. Phenolic and flavonoid content and antioxidant activity in honeys from stingless bees

Species	Phenolics (mgAGE GAEq 100 g ⁻¹)	Flavonoids (mgQEq 100 g ⁻¹)	Antioxidant activity	
			DPPH	ABTS
<i>Frieseomelitta doederleini</i>	1.19 ± 0.06	0.16 ± 0.02	13.38 mg mL ⁻¹	4.94 mg mL ⁻¹
<i>F. varia</i>	89.2	29.2	-	-
<i>Hypotrigena</i> sp.	52.74 ± 3.60	4.14 ± 10.65	-	-
<i>Melipona bicolor</i>	22.04–70.8	n.d.	9.71–33.49 (μmolTE/kg)	1.61–23.73 (μmolTE/kg)
<i>M. eburnea</i>	n.d.	8.9 ± 0.7	-	206.0 ± 9.9 μmoles TE/100 g
<i>M. flavolineata</i>	26.39	n.d.	48.92 mg 100 g	-
	236.71	n.d.	6.85 mg 100 g	-
	56.78	n.d.	32.03 mg 100 g	-
<i>M. fasciculata</i>	25.53	n.d.	54.43 mg 100 g	-
	88.81	n.d.	15.58 mg 100 g	-
	59.78	n.d.	31.04 mg 100 g	-
<i>M. grandis</i>	n.d.	3.1 ± 1.3	-	107.0 ± 17.3 μmoles TE/100 g
<i>M. marginata</i>	25.4–41.4	n.d.	12.44–18.23 (μmolTE/kg)	7.34–13.67 (μmolTE/kg)
<i>M. s. merrillae</i>	26.5 ± 0.05	n.d.	-	0.3 ± 0.01 μg mL ⁻¹
	17.0 ± 0.02	n.d.	-	0.3 ± 0.02 μg mL ⁻¹
	64.0 ± 0.03	n.d.	-	0.2 ± 0.03 μg mL ⁻¹
	34.0 ± 0.01	n.d.	-	0.2 ± 0.01 μg mL ⁻¹
	43.0 ± 0.02	n.d.	-	0.2 ± 0.02 μg mL ⁻¹
	36.0 ± 0.01	n.d.	-	0.2 ± 0.03 μg mL ⁻¹
	66.0 ± 0.05	n.d.	-	0.2 ± 0.01 μg mL ⁻¹
<i>M. anthidioides</i>	78 ± 48	45 ± 37	-	-
<i>M. asilvai</i>	32 ± 9	8 ± 2	-	-
	82.91 ± 1	79.73 ± 1.6	41.33 ± 0.9 mg/mL	-
<i>M. beecheii</i>	94.39 ± 14.55	4.19 ± 0.37	42.23 ± 1.66 μg mL ⁻¹	-
<i>M. compressipes</i>	30.71 ± 2.01	44.63 ± 2.3	37.79 ± 1.2 mg/mL	-
<i>M. crinita</i>	n.d.	7.3 ± 0.6	-	237.4 ± 13.1 μmoles TE/100 g
<i>M. illota</i>	n.d.	2.6 ± 0.1	-	93.8 ± 10.1 μmoles TE/100 g
<i>M. mandacaiá</i>	61.72 ± 1.1	45.42 ± 2	28.1 ± 0.6 mg/mL	-
<i>M. q. anthidioides</i>	161.8 ± 3.4	43.09 ± 2	40.03 ± 0.4 mg/mL	-
<i>M. q. quadrifasciata</i>	82.19 ± 1.2	75.45 ± 2.71	25.39 ± 0.5 mg/mL	-
<i>M. quadrifasciata</i>	31.5–58.5	n.d.	18.12–26.95 (μmolTE/kg)	2.63–31.32 (μmolTE/kg)
<i>M. scutellaris</i>	62 ± 15	29 ± 14	-	-
<i>M. scutellaris</i>	192.01 ± 2.8	30.24 ± 2	51.44 ± 0.7 mg/mL	-

Table II (continued)

<i>Melipona</i> sp.	37.20 ± 14.18	8.64 ± 4.69	-	-	-
<i>M. subnitida</i>	38 ± 11	11 ± 2	-	-	-
<i>M. subnitida</i>	0.6	n.d.	5.9 µg mL ⁻¹	-	-
<i>M. subnitida</i>	854.62 ± 3.8	279.73 ± 4.6	37.69 ± 1 mg/mL	-	-
<i>Nannotrigona melanocera</i>	n.d.	31.0 ± 1.2	-	569.6 ± 7.3 µmoles TE/100 g	-
<i>Partamona epiphytophila</i>	n.d.	5.9 ± 0.3	-	115.7 ± 3.5 µmoles TE/100 g	-
<i>Plebeia</i> sp.	104 ± 20	35 ± 13	-	-	-
<i>Ptilotrigona lurida</i>	n.d.	23.4 ± 1.1	-	205.7 ± 11.3 µmoles TE/100 g	-
<i>Scaptotrigona bipuncata</i>	27.7–66.1	n.d.	14.61–39.10 (µmolTE/kg)	11.35–34.73 (µmolTE/kg)	-
<i>S. mexicana</i>	25.85–40.1	n.d.	15.65–19.04%	-	-
<i>S. polystica</i>	n.d.	17.6 ± 0.7	-	330.2 ± 14.8 µmoles TE/100 g	-
<i>Scaura latitarsis</i>	n.d.	17.7 ± 0.9	-	255.8 ± 5.0 µmoles TE/100 g	-
<i>Tetragona clavipes</i>	136 ± 32	55 ± 20	-	-	-
<i>Tetragonisca angustula</i>	n.d.	18.8 ± 0.7	-	-	-
<i>Trigona</i> sp.	22.81 ± 7.9	9.79 ± 10.1	-	327.7 ± 2.9 µmoles TE/100 g	-
Species	Antioxidant activity		Country	References	
	FRAP	β -Carotene/ linoleic acid			
<i>Friesveinellita doederleini</i>	-	-	Brazil	Santisteban et al. (2019)	
<i>F. varia</i>	-	-	Brazil	Duarte et al. (2018)	
<i>Hypotrigona</i> sp.	666.88 ± 1.73 µmol Fe(II)/100 g	-	Nigeria	Nweze et al. (2017)	
<i>Melipona bicolor</i>	-	-	Brazil	Ávila et al. (2019)	
<i>M. eburnea</i>	-	-	Peru	Rodríguez-Malaver et al. (2009)	
<i>M. flavolineata</i>	-	-	Brazil	Oliveira et al. (2012)	
<i>M. fasciculata</i>	-	-	Brazil	-	
<i>M. fasciculata</i>	-	-	Brazil	-	
<i>M. fasciculata</i>	-	-	Brazil	-	
<i>M. fasciculata</i>	-	-	Brazil	-	
<i>M. grandis</i>	-	-	Peru	Rodríguez-Malaver et al. (2009)	
<i>M. marginata</i>	-	-	Brazil	Ávila et al. (2019)	
		47.49–82.87 (µmolTE/kg)			

Table II (continued)

<i>M. s. merrillae</i>	-	-	-	Brazil	Silva et al. (2013)
	-	-	-	Brazil	
	-	-	-	Brazil	
	-	-	-	Brazil	
	-	-	-	Brazil	
	-	-	-	Brazil	
	-	-	-	Brazil	
	-	-	-	Brazil	
<i>M. anthidioides</i>	-	-	-	Brazil	Duarte et al. (2018)
<i>M. asilvai</i>	-	-	-	Brazil	
	-	-	-	Brazil	Oliveira et al. (2017)
<i>M. beechei</i>	38.54 ± 11.37	μmol Fe(II)/100 g	-	Cuba	Alvarez-Suarez et al. (2018)
<i>M. compressipes</i>	-	-	-	Brazil	Oliveira et al. (2017)
<i>M. crinita</i>	-	-	-	Peru	Rodríguez-Malaver et al. (2009)
<i>M. illota</i>	-	-	-	Peru	Rodríguez-Malaver et al. (2009)
<i>M. mandacaiá</i>	-	-	-	Brazil	Oliveira et al. (2017)
<i>M. q. anthidioides</i>	-	-	-	Brazil	
<i>M. q. quadrifasciata</i>	-	-	-	Brazil	
<i>M. quadrifasciata</i>	-	-	49.29–94.35	Brazil	Ávila et al. (2019)
<i>M. scutellaris</i>	-	-	-	Brazil	Duarte et al. (2018)
<i>M. scutellaris</i>	-	-	-	Brazil	Oliveira et al. (2017)
<i>Melipona</i> sp.	426.93 ± 11.55	μmol Fe(II)/100 g	-	Nigeria	Nweze et al. (2017)
<i>M. subnitida</i>	-	-	-	Brazil	Duarte et al. (2018)
<i>M. subnitida</i>	-	-	-	Brazil	Bastos et al. (2009)
<i>M. subnitida</i>	-	-	-	Brazil	Oliveira et al. (2017)
<i>Nannotrigona melanocera</i>	-	-	-	Peru	Rodríguez-Malaver et al. (2009)
<i>Partamona epiphytophila</i>	-	-	-	Peru	
<i>Plebeia</i> sp.	-	-	-	Brazil	Duarte et al. (2018)
<i>Ptilotrigona lurida</i>	-	-	-	Peru	Rodríguez-Malaver et al. (2009)
<i>Scaptotrigona bipunctata</i>	-	-	35.49–85.48	Brazil	Ávila et al. (2019)
<i>S. mexicana</i>	50.42–61.10	μmol TE/100 g	40.45–70.45%	Mexico	Jimenez et al. (2016)
<i>S. polysfica</i>	-	-	-	Peru	Rodríguez-Malaver et al. (2009)

Table II (continued)

<i>Scaura latitarsis</i>	-	-	Peru	Duarte et al. (2018)
<i>Tetragona clavipes</i>	-	-	Brazil	Rodríguez-Malaver et al. (2009)
<i>Tetragonisca angustula</i>	-	-	Peru	Ranneh et al. (2018)
<i>Trigona</i> sp.	-	-	Malaysian	

GAE gallic acid equivalent, *QE* quercetin equivalents, *TE* trolox equivalents, *ORAC* oxygen radical absorbance capacity, n.d.: not determined

^a DPPH capacity of scavenge the 2,2-diphenyl-1-picrylhydrazyl free radical

^b ABTS 2,2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid radical activity

^c FRAP reducing power of iron(III)/ferricyanide complex

constituents coincided with the honeys from the same floral source. The study reported the presence of the flavonoid taxifoline in honey from stingless bees and the presence of catechol in Brazilian honeys for the first time. In addition, some of the samples showed effective potential in inhibiting microbial growth.

Oliveira et al. (2012) carried out studies on honeys from the state of Pará (Brazil) and found differences in the phenolic content and antioxidant activity using DPPH on samples from different locations for the species *M. flavolineata* and *M. fasciculata*. These authors used high-performance liquid chromatography for identification by comparing with standards of compounds present in stingless bee honeys, and found differences in the composition with major constituents of quercetin and gallic acid.

Biluca et al. (2016) determined the content of phenolic compounds in samples of honeys from ten species of stingless bees; in different periods of the year, the variation in the contents of these compounds was justified by the difference in botanical origin; however, the quantification values are shown in graphs, the minimum values being 10.3 mg of gallic acid 100g⁻¹ and maximum 98 mg of gallic acid 100g⁻¹ of honey, found for the bees *Melipona quadifasciata* and *Tetragonisca angustula*, respectively. Biluca et al. (2017) identified and quantified the presence of mandelic acid, caffeic acid, chlorogenic acid, rosmarinic acid, aromadendrene, isoquercitrin, eriodictyol, vanillin, umbelliferone, syringaldehyde, synap aldehyde, and carnosol in native bee honeys and significant correlation of compounds with antioxidant activity expressed by these honeys. Alvarez-Suarez et al. (2018) identified 19 compounds in *M. beecheii* honey using HPLC-DAD-ESI MS/MS, among those identified were C-pentosyl-C-hexosyl-apigenin, coumaric acid, isorhamnetin, kaempferol, luteolin, apigenin, quercetin, ferulic acid, and dihydrocaffeic acid.

The aroma of honey, although it seems characteristic, is influenced by the great variety of volatile compounds from floral origin. In addition, several other factors can contribute to the “flavor” of honey, such as the bee’s own physiology, as well as procedures after harvest in relation to the heating, storage, and other factors (Campos et al.

2000). Costa et al. (2018) analyzed honey from *Melipona subnitida* and *M. scutellaris* using extraction via HS-SPME and gas chromatography coupled with mass spectrometry and detected a total of 114 volatile compounds, of which the highest contents were terpenes, followed by esters, norisoprenoids, benzene derivatives, furans, ketones, hydrocarbons, alcohols, aldehydes, acids, in addition to a sulfur compound. Although the samples come from different plant origins, the presence of certain compounds in all honeys was noted, and others were detected in the samples of only one of the studied species. Compounds belonging to these classes have also been found in honey from *Apis mellifera* (Alissandrakis et al. 2007a, b; Alissandrakis et al. 2009; Anastasaki et al. 2009; Ceballos et al. 2010; Jerković et al. 2010a, b; Alissandrakis et al. 2011; Jerković et al. 2011a, b).

Silva et al. (2017) studied the composition of volatiles obtained by static headspace gas chromatography of eight species of bees native to the state of Paraná (Brazil) and identified 44 compounds, including derivatives of linalool, hotrienol, and esters, and attributed the composition to the geographical origin of the samples.

In addition to the anti-toxicity activity, other biological properties have also been investigated, due to the therapeutic use of honey produced by bees of the genus *Apis* and by stingless bees (Amin et al. 2018). The antimicrobial activity is the category that presents the most data, the honey of *Tetragonisca angustula* was the most commonly studied. Miorin et al. (2003) performed a microbial sensitivity test against *Staphylococcus aureus* and obtained a minimum inhibitory concentration that ranged from 142.87 to 214, 33 mg mL⁻¹, demonstrating an action lower than that of *Apis mellifera*, also evaluated in the study. Demera and Angert (2004) used agar diffusion and found that honey significantly inhibited the tested yeasts *Saccharomyces cerevisiae* (ATCC 287) and *Candida albicans* (ATCC 90028). Sgariglia et al. (2010) found similar results with growth inhibition of *Escherichia coli* (IEV301), *Pseudomonas aeruginosa* (IEV 305), *Staphylococcus aureus* (IEV7), *Staphylococcus aureus* (IEV 20), and *Enterococcus faecalis* (IEV 208). Mercês et al. (2013) evaluated the antimicrobial action of honey from *T. angustula*, both by the agar diffusion method

and by broth macrodilution, and only obtain activity against *S. aureus* and *E. coli* with a minimum inhibitory concentration equal to 28.2 mg mL⁻¹ and 132 mg mL⁻¹, respectively.

For anti-tumor activity, the results indicate that honeys have significant action with different mechanisms on tumor cell lines (Vit et al. 2013). Kustiawan et al. (2014) evaluated extracts of honey from different species of native bees and all of them presented cytotoxicity on hepatoblastoma cells. Ahmad et al. (2019) induced apoptosis in malignant glioma cells for cytotoxic analysis of *Heterotrigone itama* honey. The results demonstrated cytotoxicity at certain periods and dosages, since honey induced nuclear shrinkage, chromatin condensation, and nucleus fragmentation. In addition to the cytotoxic action of honey, the investigation of its potential as a chemopreventive agent was carried out by Yazan et al. (2016), whose results showed that honey from *Trigona* sp. significantly reduced the total number of aberrant crypt foci, aberrant crypts, and multiplicity of colorectal crypts.

Regarding the anti-inflammatory effects, the studies by Borsato et al. (2014) and Ruiz-Ruiz et al. (2017) demonstrated different therapeutic effects that honey can have for this action. Borsato et al. (2014) evaluated the potential of *Melipona marginata* honey in reducing ear inflammation in test subjects and observed that the topical application of honey extract (1.0 mg/ear) was able to reduce ear edema. This extract decreased myeloperoxidase activity, which suggests a lower leukocyte infiltration and was confirmed by histological analysis. In addition, it also provided a reduction in the production of reactive oxygen species. Ruiz-Ruiz et al. (2017) carried out an in vitro determination using the evaluation of protein denaturation and observed that the flavonoid fraction of the methanol extract showed itself to be potent in inhibiting the denaturation of albumin and in membrane stabilization.

Ilechie et al. (2012) used different concentrations of fresh honey from *Meliponula* ssp. to treat bacterial conjunctivitis caused by *Staphylococcus aureus* or *Pseudomonas aeruginosa* induced in vivo in Hartley guinea pigs and found that the effect of honey was comparable with that of gentamicin, a standard antibiotic. In view of the

results, the authors suggest the use of honey as an alternative treatment for infections. Similar results were found by Kwapong et al. (2013) with *Meliponula bucaudei* honey, which showed antimicrobial activity in vitro against bacteria isolated from eye infections (*Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Pseudomonas aeruginosa*). The inhibitory effect of honey in reducing inflammation and infection was superior to the commonly used ophthalmic antibiotics.

Kwakman et al. (2010) suggest that the bioactive properties of honey are attributed to specific factors, such as the synergistic action of sugar and hydrogen peroxide for wound healing. In studies carried out with *Apis mellifera* honey, the samples that suffered a decrease in the accumulated H_2O_2 levels had a marked reduction in the antibacterial action against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* resistant strains. According to the authors, this indicates that H_2O_2 is important for the bactericidal activity of honey, but additional factors must also be present. For Yaghoobi et al. (2013), honey induces leukocytes to release cytokines, which initiate tissue repair cascades, in addition to activating the immune response to infection.

An outstanding finding was done recently by Fletcher et al. (2020) about the sugar composition of stingless bee honey. They found a high concentration of trehalulose, between 13 to 44 g per 100 g, in honey from five different stingless bee species across Neotropical and Indo-Australian regions. Trehalulose is a specific kind of disaccharide, considered to be beneficial for human health because of its acariogenic and low glycaemic index properties. Besides, it is 70% as sweet as sucrose and not readily crystallized, therefore has commercial application in food industry (Fletcher et al. 2020).

5. FUTURE PERSPECTIVES

Significant differences are found between the stingless bee honey and *Apis mellifera* honey, as well as between the different species of stingless bees. This reinforces the need to develop rules and regulations aimed exclusively at determining the quality of honey from stingless bees. The growing demand for products from stingless bee also justifies

additional studies and more complete approaches, due to the large number of species that are still poorly studied or that have not even been studied yet. Additional conservation treatments should be considered to increase the shelf life of honey, as well as to facilitate commercialization by informal producers. The chemical profile of native bee honeys has been little explored, which limits the quantification of classes of compounds, so more comprehensive studies regarding chemical characterization are needed. The advancement of scientific knowledge related to the particularities of honey of each species of stingless bee will be of fundamental importance in order to increase the value of its products, especially if it is conducted to identify and enhance regional aspects. This type of study has an urgent appeal in view of the current scenario in which the importance of conservation of the environment has been much questioned worldwide. As such, it will allow honey farmers to generate income effectively from the standing forest.

AUTHORS' CONTRIBUTIONS

ECAS and AF discussion of chemical data and wrote the paper and participated in the revisions of it; CM discussion of aspects of morphology, management, and conservation of stingless bees.

Miel d'abeille sans dard (Hyménoptères, Apidés, Méléponnes): Un examen du contrôle de la qualité, du profil chimique et du potentiel biologique.

abeilles sans dard / qualité du miel / composition chimique.

Honig von Stachellosen Bienen (Hymenoptera, Apidae, Meliponini): Ein Review über Qualitätskontrolle, chemisches Profil und biologisches Potential.

Stachellose Bienen / Honigqualität / chemische Zusammensetzung.

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