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REVIEW ARTICLE

Composition and functional properties of stingless bee honey: A review

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Abstract

Honey produced by the stingless bee were use since ancient times in almost every continent as food or for medicinal purposes. The usage of stingless bee honey proceeds from its composition and functional properties. Stingless bee honey has been reported to have many medicinal properties such as antiseptic, antimicrobial, anticancer, anti-inflammatory, and wound-healing properties. Since early 20th century, various studies on the composition and functional properties of honey have been conducted worldwide and findings were tremendous. Stingless bee honey reported to have hundreds of bioactive compound. However, the composition and functional properties of stingless bee honey is differs depending on the source of honey; either influenced by the location of hive or by the species of stingless bee itself. This review provides the information on the composition and functional properties of stingless bee honey reported worldwide. The information gathered is very important to understand and to explain about the variability of nutritional composition in honey and how it might influence the value of stingless bee honeys as medicinal food.

Keywords: Stingless bee honey, honey composition, honey functional properties, honey

Introduction

Honey is the world's oldest sweetener used for human consumption until sugar cane was cultivated. Generally, honey is define as the natural sweet substance produced by honey bees from the nectar of flowers; or secretions of living parts of plants; or excretions of plant-sucking insects on the living parts of plants, which honey bees collect, convert and mix with specific substances of their own, store and leave within the honeycomb to ripen and mature (Codex Alimentarius Commission (2001). Honey is completely natural product and no food additives is needed for it storage purposes. It also can be eat raw. There are numerous types of honey in the world. The types of honey are classified based on the origin of honey itself. Honey may be assign by the name of the geographical or topographical region where the honey was produced. It may also be designated according to the botanical or plant source if it comes completely or predominantly from the specific source and has the resemble organoleptic, physicochemical and microscopic properties with that plant origin. As an example, gelam honey and acacia honey refers to the plant that providing nectars as a source of honey. Meanwhile, tualang honey and stingless bee honey refers to the types of bees that produced honey. Since there are many type of plants that provide nectars as a source of honey and there are many species of bee that produce honey; no honey is equivalent to one another in term of quality (Bogdanov, 1999).

In general, honey is economically produced by two types of bee which are *Apis* sp. (honeybee) and *Melipona* sp. (stingless bee). The clan Apini contains just one genus, Apis and these are the genuine honeybees. Like the Meliponini, they are social honeybees that set up a permanent colony. It is these bees' social practices, storing significant quantities of honey for the colony to survive dearth periods (Bradbear, 2009). There are not many types of honeybee's species. Most beekeeping textbooks announce that there are just four species: *Apis mellifera, Apis cerana, Apis florea,* and *Apis dorsata* (Ruttner, 1988). The honeybee is one of the most studied of all animals, other than man, yet the exploration has been almost entirely on the European honeybee *Apis mellifera* (Bradbear, 2009).

In other hand, stingless bees (Hymenoptera, Apidae, Meliponini) are the largest group of eusocial bees on Earth (Lavinas et al., 2018). These bees can be classified into many genera, but the common and numerically large in number are Melipona and Trigona (Charles, 2013). Until 2018, more than 600 species of stingless under 60 genera bees have been described throughout the world (Lavinas et al., 2018) with 45 of those species has been listed in Malaysia (Rasmussen, 2008). Among those species, *Heterotrigona itama*, *Geniotrigona thoracica, Lepidotrigona terminata, Tetragonula fuscobalteata* and *Tetragonula leaviceps* have been commercially established for honey production in Malaysia (Kelly et al., 2014). Furthermore, *Heterotrigona itama* is the most plenty species breed by beekeepers since their hives can be more easily found in Malaysian forests and easy to kept (Shamsudin et al., 2019; Kelly et al., 2014). Even though stingless bee is acknowledge as a good pollinating agent for crops (Wong et al. (2019), this beneficial insect was commonly kept by the apiarist for their honey, pollen, propolis and ceruman; not as plant pollinator.

Similar to *Apis* sp. product, the stingless bee product (honey, pollen, propolis and ceruman) were also acknowledge to have many medicinal benefits for human health. Thus, it was widely used for various applications such as for food, cosmetics and health industry. Amongst those bee products, honey has held a place of importance in stingless bee industry. Stingless bee honey contains approximately 200 substances (Zulkhairi Amin et al., 2019). The main composition of honey are sugars, water, and other substances such as proteins, organic acids, vitamins, minerals, pigments, phenolic compounds, and a large variety of volatile compounds (da Silva et al., 2016). The composition of stingless bee honey is complex and varies depending on the botanical and geographical origin of the raw material such as nectar or honeydew; make the quality of honey produced varies, which then influence their bio-medicinal properties.

Result and Discussion

Composition of Stingless Bee Honey

Water content

Water content is an important criterion in determining the quality of honey. Honey with the high water content usually has shorter shelf life and unstable microbial activity that may lead to the fermentation. Fermentation in honey is common but the excessive fermentation may lead to the difficulty in storage and preservation of honey (Babarinde, 2011). Meanwhile, low water content can prevent microbial growth, but honey with very low moisture contents are difficult to handle and process because of its high viscosity. Generally, honey whose moisture is higher than 18% is prone to ferment. This is because sugar's osmotic pressure is not powerful enough to avoid osmophilic; environment with a high sugar concentration that can enhance yeast reproduction (Bogdanov & Martin, 2002). Based on CODEX Standard (1987), the maximum moisture content allowed in commercial honey is not more than 20%.

Table 1: Moisture content of honey produced by stingless bee in Malaysia

Species of bee	Location of hive	Source of nectar	Water content	Source
T. thorasica	Kelantan	Monoflora	33.7 %	Fatima et al., 2018
T. itama	Kelantan	Monoflora	31.7%	Fatima et al., 2018
T. thorasica	Terengganu	Multiflora	28.9%	Fatima et al., 2018
T. itama	Terengganu	Multiflora	23.3%	Fatima et al., 2018
H. itama	Air Molek, Melaka	NI	28.87%	Abu Bakar et al., 2017
G. thoracica	Air Molek, Melaka	NI	28.17	Abu Bakar et al., 2017
H. itama	Jasin, Melaka	NI	26.53	Abu Bakar et al., 2017
H. itama	Peserai, Johor	NI	26.50	Abu Bakar et al., 2017
H. itama	Parit Botak, Johor	NI	31.8	Abu Bakar et al., 2017
H. itama	Teluk Intan, Perak	*Acacia mangium*	33.24	Kek et al., 2017
G. thoracica	Terengganu	*Acacia mangium*	33.93	Shamsudin et al., 2019
G. thoracica	Pahang	Starfruit	21.32	Shamsudin et al., 2019
G. thoracica	Johor	Gelam	22.01	Shamsudin et al., 2019
H. itama	Terengganu	*Acacia mangium*	26.28	Shamsudin et al., 2019
H. itama	Pahang	Starfruit	19.49	Shamsudin et al., 2019
H. itama	Johor	Gelam	22.53	Shamsudin et al., 2019
H. itama	UPM, Selangor	NI	25.82	Baroyi et al., 2019
H. itama	MAEPS, Selangor	Multiflora	11.09	Mohammad et al., 2020
H. itama	UPM, Selangor	Multiflora	12.51	Mohammad et al., 2020
H. itama	Batang Benar, Selangor	Multiflora	11.42	Mohammad et al., 2020
H. itama	Rinching Hilir, Johor	Multiflora	11.78	Mohammad et al., 2020
H. itama	Kota Tinggi, Johor	Acacia mangium	31.00	Lim et al., 2018
H. itama	Tangkak, Johor	Cocos nucifera	29.00	Lim et al., 2018
H. itama	Pagoh, Johor	Averrhoa carambola	31.00	Lim et al., 2018
H. itama	Batu Pahat, Johor	Mangrove	30.00	Lim et al., 2018
H. itama	Kulai Jaya, Johor	Multiflora	27.00	Lim et al., 2018
H. itama	Parit Botak, Johor	Multiflora	31.00	Lim et al., 2018
G. thoracica	Kota Bharu, Kelantan	NI	27.63	Omar et al., 2019
H. itama	Kota Bharu, Kelantan	NI	26.60	Omar et al., 2019
L. Terminata	Kota Bharu, Kelantan	NI	23.93	Omar et al., 2019
T. laeviceps	Kota Bharu, Kelantan	NI	27.05	Omar et al., 2019

*NI= No information

Table 1 shows the moisture content in stingless bee honey collected in Malaysia. Water content of honey is related to the plant type and geographical origin of nectar, soil, and climatic conditions, the period of harvesting, the intensity of nectar flux, level of maturation, and handling by beekeepers during the period of harvest, as well as extraction, processing and storage conditions (Pontara et al., 2012). Stingless bee honey has been reported to contain higher water content compared to *Apis mellifera* honey (De Almeida-Muradian et al., 2013). Research shows that Malaysian stingless bee honey have a moisture content of 21% to 31% (Fatima et al., 2016; Chan et al., 2017; Hasali et al., 2018; Omar et al., 2019). Amongst Malaysian stingless bee species studied, honey of *Lepidotrigona terminata* displayed the lowest moisture content of 23.93 ± 1.46%, while *Geniotrigona thoracica* demonstrated the highest value of 27.63 ± 0.83% (Chan et al., 2017; Hasali et al., 2018).

In Thailand, report shows that the moisture content of eleven species of stingless bee honey studied are range from 25% to 47% (Chuttong et al., 2016). These reports proved that the honey produced by the different species of bee may contain different water content. In addition, the geographical origin of stingless bee honey also influences the water content. As an example, the stingless bee honey collected at different location at Johor Malaysia range from 23.33% to 31.00% (Majid et al., 2019). Meanwhile, Thailand, Brazil, and Venezuela reported the moisture content of 31%, 29%, and 22% respectively (Omar et al., 2019).

Sugar content

Honey has sweet taste and it has been use for centuries as a sweetener and additive to enhance the food taste. Honey is a solution of carbohydrate in the form of glucose, fructose, and sucrose; which both glucose and fructose are the main sugar composition (Solayman et al., 2016). According to the standards set by the International Honey Commission (IHC), good quality honey should have the amount of both fructose and glucose that not less than 60 g/100 g and a sucrose content that is not more than 5 g/100 g (Nordin et al., 2018). The ratio of fructose and glucose influence the crystallization process of honey. Honey with the ratio of fructose and glucose that greater than 1.33 can remain as a fluid during storage (Escuredo et al., 2014). These mean that the higher the glucose in honey, the faster the crystallization. However, it is also crucial to bear in mind the amount of water present in honey also influence the crystallization process of honey.

Stingless bee honey has less sugar content compared to *Apis mellifera* honey (Solayman et al., 2016). Biluca et al. (2016) reported that the total content of fructose and glucose in the stingless bee honey ranged from 48.6% to 70.5% with the lowest value was found in the *Tetragona clavipes* species and the highest was found in the *Melipona marginata* species, that giving an average of 62.1% which meet the IHC standard. Research by Shamsudin et al. (2019) shows that Acacia honey produced by *G. thoracica* and *Heterotrigona itama* has the total sugar contents that ranged from 44.98% to 61.37% g/100 g. These sugar amounts are significantly lower compare to the other types of honey produced by stingless bee. Shamsudin et al. (2019) also found that starfruit and acacia honey produced by *G. thoracicaca* has higher amount of glucose than fructose. In the study by Chuttong et al., (2016), the amount of maltose in the honey produced by *T. laeviceps-pagdeni* is higher compare to other types of sugar. The amount of maltose detected in that study were range from 15 to 57 g/100 g. Chuttong et al., (2016) also reported that the fructose and glucose contents in the tested honey samples were 17 ± 9.7 and 14 ± 8.6 g/100 g respectively. Sucrose nearly are not detectable for most of the honey samples, thus prove that the honey is pure.

Table 2: Sugar content of honey produced by stingless bee in Malaysia

Species of bee	Location of hive	Source of nectar	Brix value	Fructose (%)	Glucose (%)	Maltose (%)	Sucrose (%)	Source
G. thoracica	Sibu Sarawak	NI	65.0	12.01	17.63	35.3	ND	Tuksitha et al., 2018
H. itama	Sibu Sarawak	NI	75.2	19.5	21.0	33.7	ND	Tuksitha et al., 2018
H. erythrogastra	Sibu Sarawak	NI	73.0	12.3	14.9	45.2	ND	Tuksitha et al., 2018
H. itama	MAEPS, Selangor	Multiflora	NI	0.795	11.83	1.491	1.293	Mohammad et al., 2020
H. itama	UPM, Selangor	Multiflora	NI	1.488	10.270	0.794	1.984	Mohammad et al., 2020

H. itama	Batang Benar, Selangor	Multiflora	NI	1.296	12.397	1.994	2.094	Mohammad et al., 2020
H. itama	Rinching Hilir, Johor	Multiflora	NI	0.396	11.7	0.694	0.595	Mohammad et al., 2020
G. thoracica	Kota Bharu, Kelantan	NI	NI	NI	NI	11.29	1.23	Omar et al., 2019
H. itama	Kota Bharu, Kelantan	NI	NI	NI	NI	5.73	0.45	Omar et al., 2019
L. Terminata	Kota Bharu, Kelantan	NI	NI	NI	NI	9.76	0.65	Omar et al., 2019
T. laeviceps	Kota Bharu, Kelantan	NI	NI	NI	NI	25.2	2.2	Omar et al., 2019

*ND= Not Detected, Ni= No Information

Minerals

The chemical elements in various types of honey can be divided into 3 groups: macro elements, minor elements, and heavy metal (Solayman et al., 2016). These elements and its amount is vary in honey samples throughout the world. Thus, even though minerals and heavy metals are considered as inconsequential constituents, they has play an important role in determining the originality and quality of honey.

The value of minerals and heavy metals in honey are mostly depend on the soil composition and different types of blossom and plants because minerals are shifted through the roots to the plants and passed into the nectar that finally turn into honey (Anklam, 1998). Among all, potassium is the most abundant element in honey (Abu bakar et al., 2017; Biluca et al., 2016; Lemos et al., 2018). It then followed by calcium (Biluca et al., 2016) and magnesium (Abu bakar et al., 2017). In addition to that; zinc, phosphorus, manganese, lead, iron, sodium is also being detected in the honey (Lemos et al., 2018).

Organic acids

Organic acids influence the flavour and taste of honey. Organic acids is a secondary component and exist in low concentration, but even though being in minor amounts, it has a huge contribution to organoleptic, physical and chemical properties of honey (Mato et al., 2006). There are four types of organic acids (gluconic, lactic, acetic, and citric acids) that were present in both stingless bees *G. thoracica* and *H. itama* honey samples (Shamsudin et al., 2019). The ripening process of nectar into honey enhances the acidity contributes to the enzymatic activity that transforms the glucose into gluconic (Del Nozal et al., 1998).

This is supported by Shamsudin et al., (2019), where gluconic acid is the main organic acid in all stingless bee honey samples with the mean content ranging from 0.07 to 1.48 g/kg of honey. Honey produced by *Heterotrigona itama* showed higher amounts of gluconic acid compared those from *Geniotrigona thoracica*. Research by Shamsudin et al. (2019) shows that starfruit honey produced by *G. thoracica* displayed a significantly lower gluconic acid content compared to acacia and gelam honey. Shamsudin et al. (2019) also mentioned that the differences in the gluconic acid contents might be due to the different amounts of glucose and enzymatic activity in the honey samples. That statement is supported by Mohandes & Sawsan (2011), where organic acid content in honey is greatly varies depending on the botanical origin that effect the variation of enzymatic activity. Thus, the organic acids profile can be a useful component to identify the origin of honey. However, research by Shamsuddin et al. (2019) shows that the honey produced by *G. thoracica* from every floral source did not shown detection of formic and D-malic acids. Whereas the honey by *H. itama* from every floral source did contain all seven organic acids tested. Meanwhile, honey from gelam did not contain formic acid and tartaric while starfruit honey, did not contain formic acid or D-malic acid.

Phytochemical of Stingless bee honey

Honey is a natural substance acknowledged for its therapeutic and medicinal properties from the old days. It's composition rich in phenolic acids and flavonoids, which show a wide scope of biological effects and plays an essential role in human well-being (Cheung et al., 2019; Cianciosi et al., 2018; Pyrzynska & Biesaga, 2009). Several in vitro and in vivo studies have demonstrated the antimicrobial, antiviral, antifungal, anticancer, and antidiabetic activity of honey (Alvarez-Suarez et al., 2013). Besides, the protective effect on cardiovascular, nervous, respiratory, and gastrointestinal systems has been also proven in previous research.

Flavonoid compound

Flavonoids are the primary class of polyphenols with C6- C3-C6 skeleton. Up to now, there have been over 8000 recognized flavonoid molecules (Bhattacharya, 2011). The flavonoids are graded according to the degree of oxidation of the C ring in flavanols, flavones, flavanonols, flavonols, flavanones, isoflavones, anthocyanins and anthocyanidins. Moniruzzaman et al. (2014) stated that the most plentiful ones in honey are flavones, flavanols, and flavonols. Most of them have exhibit multiple biological activities such as anti-oxidation, antiinflammation, anticancer, and cardiovascular protection (Xiao & Kai, 2012).

According to Abu Bakar et al. (2017), role of flavonoids group are vital for the aroma and antioxidant potential of honey. In the previous study by Xie et al. (2014), the hydroxyl groups on special sites in flavonoids compound are fitting for antimicrobial activity, such as 5,7-dihydroxyl substitution for flavone and flavanone, and 2' or 4' hydroxylation for chalcones. The hydroxyl group at three positions on the C ring also activate the activity of flavone. Meanwhile, Tuksitha et al. (2018) mentioned that it seems clear that the phenolic and flavonoid compounds found in stingless bee honey from Borneo have a significant antibacterial activity. The values for the flavonoid content of the three samples of stingless bee honey ranged from 12.41 ± 0.62 to 17.67 ± 0.75 (mg/ml) between species which the highest flavonoid contents are extracted by *H. itama* (Tuksitha et al., 2018).

Phenolic compound

Phenolic are the largest group of phytochemicals exist in plants and are incorporated into the honey through nectar or pollen from plants visited by the honeybee. Simple phenols structure is those with a C6 carbon. Alvarez-Suarez et al. (2013) mentioned that the main class of phenolic compounds in honey is characterized by flavonoids (flavonols, flavanols and flavones) followed by phenolic acids (benzoic acids, phenylacetic and hydroxycinnamic acids). Stingless bee honey is more likely to be a multifloras honey with no predominant pollen in it. It contains mixture of different pollens that were significantly affected by floral sources. Pollen collected from the floral origin is the one and only be a contributing source for phenolic content in honey due to the way that the bioactive mixes must be gotten from plants since honey bees can't discharge any of phenolics from its hypopharyngeal organ (Chan et al., 2017).

Da Silva et al. (2013) mentioned that the total phenolic content differs among the honey respecting to their type of bee species, region, season, and floral sources. In her study, Tuksitha et al. (2018) stated that the phenolic content of the honey samples from three species of stingless bee shown significant value from 44.72 ± 6.50 to 99.04 ± 5.14 (mg/ml) and the honey produced by *G. thoracica* showed the highest phenolic content. Among the phenolic compounds between the stingless bee honey samples studied by Biluca et al. (2020), vanillic acid, taxifolin, and syringaldehyde were the compounds with higher concentrations, whereas apigenin, umbelliferon, and naringenin had lower concentrations in most samples, this declare a broad variation of polyphenolic compounds. In addition, through the research, Da Silva et al. (2013) comes out where four out of eight stingless bee honey samples, gallic acid, 3,4-dihydroxybenzoic acid, 4-hydroxybenzoic acid, catechol, and the isomers trans–trans abscisic acid and cis-trans abscisic acid were analyse.Da Silva et al. (2013) also found that the samples that showed the best antimicrobial activities had the highest total phenolic contents.

Enzymes

There are two types of enzymes have been selected for the affirmation of honey quality, diastase and invertase. Invertase is the enzyme that hydrolyses sucrose to fructose and glucose while diastase is the general name for alpha-amylase enzyme. It generally presents in honey and the activity tends to decrease over time. Pasias et al. (2017) stated that the diastase activity is usually used as an indicator of honey's freshness. But on the other hand, according to Vit & Pulcini. (1996), the use of diastase activity as an indicator of freshness is commonly being a practice for *A. mellifera* honey and is not applicable for Meliponini honey, due to the shortage of diastase. Buba (2013) also mentioned that both diastase and invertase activities will slowly deteriorate on prolonged storage and heating of honey.

This is supported with the statement by Bogdanov et al. (1999) which invertase is considered as a better freshness indicator than diastase because it is more susceptible to prolonged storage and heat. In addition, Vit and Pulcini (1996), mentioned that the diastase and invertase activities obtained was 2.9 ± 0.1 for Meliponini and 12.7 ± 3.4 for Trigonini honeys, while invertase activity was 58.1 ± 12.0 for Meliponini and 80.8 ± 25.6 for Trigonini. The diastase activities in Meliponini were significantly lower than Trigonini honey. All honey samples indicate a lower enzyme activity implying that honey from the stingless bee has low enzyme activity compared to Apis mellifera honey.

Diastase activity and Invertase activity of the honey varied from 1.82 to 6.11 diastase number (DN) and 0.27 IN to 4.94 IN, respectively. Julika et al. (2020) investigate from the regression analysis, there is a correlation between the amount of sucrose and invertase activity where the higher amount of sucrose resulting in the lower invertase activity. According to the Codex Alimentarius Commission (2001) , the DN should be more than 8 DN and for honey with low enzyme content, 3 DN above is acceptable. There is no fixed maximum or minimum value for diastase number in Malaysian kelulut standard. Similarly, for invertase there are also no limits were recommended by Malaysian kelulut standard. However, according to Bogdanov et al. (1999) it was suggested that honey should have more than 10 IN while for low enzyme honey, the activity should be greater than 4 IN.

Functional properties of stingless bee honey

The composition of stingless bee honey which has been associated with its antiseptic, antimicrobial, anticancer, anti-inflammatory, and wound-healing properties is the cause of its growing interest for the pharmaceutical industry. However, the honey composition is complex and varies depending on the botanical and geographical origin of the raw material such as nectar or honeydew. As a result of different honey composition, they have variables of biochemical and physicochemical properties, which influence their bio-medicinal properties. It is very important to understand and to explain the information obtained about the variability and the inconsistency of honey quality before it can be extensively used in the food and pharmaceutical industry.

Depending on the flowers used by bees, honey inherits the plant's properties, its color, aroma, flavor, density, and physical and chemical properties, other than that weather conditions and processing also influence its composition and properties (Ramírez & Montenegro, 2004). As a result, the nutritional values and profiles vary accordingly and can thus influence the worth of selected honey for health-promoting purposes (Bansal et al., 2005). As stated by Gismondi et al., (2007), the chemical composition of honey strongly depends on the kind of nectar flow whereas, biochemical profile of nectar is qualitatively and quantitatively influenced by genetics and physiology of the source plant, environmental factors such as climatic conditions, soil characteristics and typology of pollinators. Therefore, it can be expected that honey quality depends on both botanical and geographical origin (Kaškoniene & Venskutonis, 2010).

Antioxidant

During oxygen metabolization in human body, cells form by-products called "free radicals" that travel through the cell, disrupting the structure of other molecules and resulting in cellular damage (Khalil et al., 2010). Antioxidants properties prevent this damage that can affect the key cell components by neutralizing these free radicals. As the demand for antioxidant supply in the food is increasing, honey becomes a popular antioxidant source, as it is rich in phenolic acids and flavonoids and other compounds including glucose oxidase, catalase, vitamin c, carotenoid derivatives, organic acids, amino acids, and proteins. In addition, antioxidants have a few protection effects against various kind of diseases like cancer, cardiovascular diseases, inflammatory disorders, neurological degeneration, wound healing, infectious diseases, and aging (Khalil et al., 2010). In a previous study, it was stated that the total antioxidant activity in the *Tetragonula carbonaria* (stingless bee) honey was proven to be higher than that of the European floral honey (Oddo et al., 2008).

In Malaysia, the researchers from MARDI have revealed that the major free phenolic acid in stingless bee honey consists of protocatechuic acid (PCA), a strong antioxidant that can improve cell proliferation in the wound healing process, and 4-hydroxyphenyl acetic acid that has the ability to scavenge the reactive oxygen and nitrogen species (Mohd et al., 2010; Kakkar & Bais, 2014; Izabela et al., 2017). In another study done by Chan et al. (2017), kelulut honey collected from different regions showed varied physical and antioxidant attributes which may be due to a variety of source of floral origin. Meanwhile, the results of analysis from Biluca et al. (2019) showed that stingless bee honey has Folin-Ciocalteu reducing capacity, which is the ability to reduce ferric ion to ferrous ion (FRAP) and free radical scavenging activity (DPPH), thus suggesting a significant antioxidant effect. According to Alvarez-Suarez et al. (2018), a significant difference was observed in total phenolic content (TPC) values among the different honey types, in which *Apis* honey had a significantly lower TPC value compared to stingless bee honey and also *Apis* honey, had a significantly lower FRAP value. The variations in TPC and FRAP value might be due to the different types of phenolic acids present in stingless bee and *Apis* honey.

Antimicrobial

The anti-microbial properties of honey are extensively studied worldwide. The potential of honey to fight against many types of bacteria and fungi was investigated and the results are promising. Due to the increase of drug-resistant bacteria against the existing antibiotics, investigators started to search for other opportunity of natural remedies and evaluate their potential use on scientific bases. Most of the studies of honey were performed on *Staphylococcus aureus* showed that it is the most susceptible tested pathogen to stingless bee honey. *Staphylococcus aureus* is a common pathogen found in human skin that can cause infection in the presence of a wound (Zamora et al., 2014; Massaro et al., 2014; Zainol et al., 2013; Cruz et al., 2014).

Abd Jalil et al. (2017) stated in his stud that the antibacterial effect in stingless bee honey is influenced by non-peroxide activity while a study done by Ewnetu et al. (2013) shows that the honey of stingless bees produced the highest mean inhibition (22.27 ± 3.79 mm) compared to white honey (21.0 ± 2.7 mm) and yellow honey (18.0 ± 2.3 mm) of *Apis mellifera* at 50% (v/v) concentration on all the standard and resistant strains. Stingless bees honey was analysed to have Minimum Inhibitory Concentration (MIC) of 6.25% (6.25 mg/ml) for 80% of the test organisms compared to 40% for white and yellow *Apis mellifera* honey (Ewnetu et al., 2013).

According to Brown et al. (2020), stingless bee honeys show the lowest MICs and MBCs compared to that of stinging bee and artificial honey and also exhibited a broad spectrum of antimicrobial activity against both Gram-positive and Gram-negative organisms against the isolates tested. In addition, Brown et al. (2020) come into a conclusion that the stingless bee honeys from Tobago showed the greatest antimicrobial activity when compared to the other honeys used in the study and it showed the most potential honey to be used as medicinal honey.

Nishio et al. (2016) conducted a research where they combine two stingless bee honey species, *Scaptotrigona bipunctata* (SB) and *Scaptotrigona postica* (SP) that lead to the development of new wide-spectrum antimicrobials with the potential to prevent the diversion of resistant bacterial strains. Honey contains high phenolic compounds and flavonoids that possess antibacterial activity (Xie et al., 2014). This statement was supported by Tuksitha et al. (2018), as the results presented in the study demonstrated that *G. thoracica* honey has the highest flavonoid content, while *H. itama* honey has the highest phenolic content which can be concluded that both of these groups of compounds play a key role in the various biological properties of these honey, specifically anti-oxidant activity and anti-microbial activity.

Anticancer

According to WHO (2020), cancer is the second leading cause of death globally, accounting for an estimated 9.6 million deaths, or one in six deaths, in 2018. Even though the full mechanism of honey as anti-cancer is yet to be completely understood, studies have shown that honey has an anticancer effect through its blocking with multiple cell-signalling pathways, like inducing apoptosis, antiproliferative, anti-inflammatory and antimutagenic pathways (Ahmed & Othman, 2013). According to Mandal & Jaganathan (2009), honey contains phenolic acids and polyphenols that are reported to have anti-cancer properties against several types of cancer. Based on several in vivo studies, long term consumption of diets rich in these types of polyphenols significantly ameliorates the adverse effects of several liver, heart, kidney, brain and pancreas-associated diseases as well as those of genetic disorders such as tumors and cancer (Arts & Hollman, 2005). Crude extracts from propolis and honey of stingless bee had higher cytotoxic activities than bee pollen, but the activity was dependent upon the solvent extraction, bee species, and cell line (Kustiawan et al., 2014).

Ahmad et al. (2019) mentioned in their study of malignant glioma, one of the types of brain tumour results in demonstrated time and dose-dependent cytotoxicity using 0.625%, 1.25%, and 10% stingless bee honey. For the cells treated with 10% stingless bee honey, IC50 values were calculated. It was detect that 10% stingless bee honey induced nuclear shrinkage, chromatin condensation, and nucleus fragmentation, indicating that cellular changes were consistent with the apoptotic characteristics of the cells (Ahmad et al., 2019). Based on recent studies, stingless bee honey has been proven to have expressive potential and beneficial effects as an anticancer agent but more systematic studies need to be carried out in order to provide a major comprehensive understanding on the potential uses and benefits of this honey (Amin et al., 2018).

Yazan et al. (2016) concluded in their research that their current finding shows that stingless bee honey has chemo-preventive properties in rats induced with colorectal cancer and also was found not toxic towards the animals. Eugenol is a natural compound derived from honey and is present in some plant extract. This compound exhibited novel medical applications for curing various chronic diseases as well as promoting apoptosis in colon cancer cells and act as a potential natural drug (Seeram et al., 2006).

Antidiabetic

Diabetes mellitus (DM) is a chronic metabolic disorder in which prevalence has been increasing steadily all over the world (blog). The antidiabetic properties of honey were analyzed using alpha-amylase and alpha glycosidase enzyme inhibition assay, as alpha-amylase and alpha glucose are among the key enzymes which present in the brush border epithelium of intestine for converting the complex starch molecules into simple sugars (Krishnasree & Ukkuru, 2017).

Krishnasree & Ukkuru (2017) revealed in their study that among the honey analyzed raw (77.61 % and 80.46 % at 500 µg/ml) and processed (64.84 % and 78.29 % at 500 µg/ml), Trigona honey was found to have the highest percentage of inhibition against alpha-amylase and alpha-glycosidase enzyme, respectively.

Based on the research conducted by Rahmawati et al. (2019) it can be concluded that stingless bee species of *T. biroi* and *T. laeviceps* honey can inhibit the alpha-glucosidase enzyme and has the potential as an anti-diabetic. The methanol extract of both kinds of honey showed a higher alpha-glucosidase inhibitory activity compared to raw honey. According to Aziz et al. (2017), stingless bee honey administration to diabetic male rats prevented an increase in fasting blood glucose (FBG), total cholesterols (TC), triglyceride (TG) and low-density lipoprotein (LDL) levels. Stingless bee honey has great potential to be used as an agent to protect the pancreas against damage and dysfunction where these could account for its anti-diabetic properties (Aziz et al., 2017).

Rashid et al. (2019) stated that daily intake of 30 g kelulut honey for 30 days resulted in an insignificant effect on fasting glucose, fasting lipid profiles, and other metabolic parameters in patients with impaired fasting glucose (IFG) that pose a higher risk of diabetes.

Anti-inflammatory

Inflammation is a nonspecific response of mammalian tissues to a variety of hostile agents (Sobota et al., 2000). There are many mediators of inflammation, examples of which are some cytokines and nitric oxide (NO) (Thompson, 1990). Tumour necrosis factor–α (TNF-α) is a pleiotropic cytokine that will lead to a wide range of biological effects, including inflammatory cytokines production, cell proliferation, differentiation, and death.

Borsato et al., (2014) stated that Melipona marginata honey extract shows improved topical anti-inflammatory potential as it decreased edema, reduced leucocyte infiltration, and inhibited the production of reactive oxygen species (ROS) which ultimately lead to oxidative damage of the cellular components, protein, lipids, and DNA during the inflammatory process induced by topical application of TPA in mice ears. It was also proven that phenolic acid from a honey extract from stingless bee had decreased the production of ROS in 55 ± 14% (Borsato et al.,2014).

The anti-inflammatory agents have a similar correlation with antioxidants in terms of dealing with ROS and stingless bee honey contains both of these elements, thus strengthens its ability to counteract all of the detrimental effects in the inflammation process (Abd Jalil et al., 2017). Biluca et al. (2020) stated in their studies that the two honey samples, Apis melifera and meliponinae, produced a significant increase in the levels of MCP-1 and IL-10, which lead to hypothesize that the honey not only acts as a pure anti-inflammatory agent but also on different cell pathways of macrophages. Thus, it can be said that the phenolic composition contributes to the anti-inflammatory effects of stingless bee honey sample.

Wound healing properties

Wound healing is a complex biological of cellular and biochemical events consist of 3 phases; inflammation, proliferation, and maturation (Vidinský et al., 2006). Recently, the interest of using alternative therapeutic agents coming from natural sources has alarmingly increased and honey is one of the ancient and most enduring natural therapeutic agents in wound management (Salmah et al., 2005; Medhi et al. 2008). Vandamme et al. (2013) mentioned in their study that honey keep a wound in a sanitary condition through the wound debridement process, thus creating good deodorization for the wound. Stingless bee honey is proven to be having high moisture content.

A physicochemical analysis conducted by Oddo et al. (2008) shows that the moisture content in stingless bee (*T. carbonaria*) honey is relatively higher than that in *A. mellifera* honey. Therefore, honey can provide a moist surrounding for the wound, which can prevent secondary infections and create effective oxygen that can hinder desiccation and necrosis, enhance the formation of blood vessels and connective tissues, as well as rehydrate dried out tissues (Korting et al., 2011).

In addition, a study has found that the Australian stingless bee honey contains a substantial antimicrobial activity and suggested that stingless bee honey would also possess wound healing activity (Boorn et al., 2010). As more studies on stingless bee honey were done, numerous therapeutic profiles of this honey have been pointed out in terms of its antioxidant, antimicrobial, anti-inflammatory, as well as moisturizing properties that are related to wound healing properties (Abd Jalil et al., 2017).

Abd Jalil et al. (2017) also concluded in their study that the antioxidant in stingless bee honey could break the free radical's chain that causes a detrimental effect to the wounded area whereas, the antimicrobial properties of stingless bee honey could overcome the bacterial contamination and thus improve the healing rate. In addition, the anti-inflammatory attribute in this honey could protect the tissue from highly toxic inflammatory mediators while the moisturizing properties of the honey could improve wound healing by promoting angiogenesis and oxygen circulation. Omar et al. (2019) stated in their study that the Malaysian stingless bee honey has promising antibacterial activity against wound pathogens, and this type of honey could be used as an alternative in treating infected wounds.

CONCLUSION

Since the old days, they use honey as a sweetener in food and as a drug to heal many types of diseases. Honey also seen as a symbol of wealth and happiness as it was associated with strength, beauty and longevity. Thus, it is important to take a serious issue concerning the benefits of stingless bee honey to the pharmaceutical industry. By the previous research, the results show lot of positive side that promising the future of the stingless bee honey to widely known as a natural superfood in the world. In addition, most of the phytochemical and pharmacological evidence has supported the pharmacological use of stingless bee honey.

Stingless bee honey has shown to consist much similarities with another honeys in terms of its bioactive components, but the effectiveness of the compound has not been identified. More systematic research is needed to provide a complete scientific evidence as well as to make clear any fraud and false claim. Previously, there few studies were undergo on stingless bee honey using tissue cultures, animal models, and clinical trials to establish the biotherapeutic activities.

However, the information on its valuable effects is still scarce. Therefore, new and fresh ideas should be taken to seek and take advantages on it benefits. Honey-based products should be widely marketed, such as making supplement capsules or tablets which contain probiotics isolated from the stingless bee honey that can aid in human well-being.

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References

Abd Jalil, M. A., Kasmuri, A. R., & Hadi, H. (2017). Stingless bee honey, the natural wound healer: A review. *Skin Pharmacology and Physiology*, *30*(2), 66–75. https://doi.org/10.1159/000458416

Abu Bakar, M. F., Sanusi, S. B., Abu Bakar, F. I., Cong, O. J., & Mian, Z. (2017). Physicochemical and antioxidant potential of raw unprocessed honey from malaysian stingless bees. *Pakistan Journal of Nutrition*, *16*(11), 888–894. https://doi.org/10.3923/pjn.2017.888.894

Ahmad, F., Seerangan, P., Mustafa, M. Z., Osman, Z. F., Abdullah, J. M., & Idris, Z. (2019). Anti-cancer properties of heterotrigona itama sp. Honey via induction of apoptosis in malignant glioma cells.

Malaysian Journal of Medical Sciences, *26*(2), 30–39. https://doi.org/10.21315/mjms2019.26.2.4

Ahmed, S., & Othman, N. H. (2013). Honey as a potential natural anticancer agent: A review of its mechanisms. *Evidence-Based Complementary and Alternative Medicine*, *2013*(c). https://doi.org/10.1155/2013/829070

Alvarez-Suarez, J., Giampieri, F., & Battino, M. (2013). Honey as a Source of Dietary Antioxidants: Structures, Bioavailability and Evidence of Protective Effects Against Human Chronic Diseases. *Current Medicinal Chemistry*, *20*(5), 621–638. https://doi.org/10.2174/092986713804999358

Anklam, E. (1998). A review of the analytical methods to determine the geographical and botanical origin of honey. *Food Chemistry*, *63*(4), 549–562. https://doi.org/10.1016/S0308-8146(98)00057-0

Arts, I. C. W., & Hollman, P. C. H. (2005). Polyphenols and disease risk in epidemiologic studies. *The American Journal of Clinical Nutrition*, *81*(1 Suppl). https://doi.org/10.1093/ajcn/81.1.317s

Aziz, M. S. A., Giribabu, N., Rao, P. V., & Salleh, N. (2017). Pancreatoprotective effects of Geniotrigona thoracica stingless bee honey in streptozotocin-nicotinamide-induced male diabetic rats. *Biomedicine and Pharmacotherapy*, *89*, 135–145. https://doi.org/10.1016/j.biopha.2017.02.026

Babarinde, G. O. (2011). Effects of harvesting methods on physicochemical and microbial qualities of honey, *48*(October), 628–634. https://doi.org/10.1007/s13197-011-0329-9

Bansal, V., Medhi, B., & Pandhi, P. (2005). Honey-A remedy rediscovered and its therapeutic utility. *Kathmandu Univ Med J*, *3*, 305–309.

Baroyi, S. A. H. M., Yusof, Y. A., Ghazali, H. M., Chin, N. L., Othman, S. H., Chang, L. S., & Ghazali, N. S. M. (2019). A novel method based on passive diffusion that reduces the moisture content of stingless bee (Heterotrigona itama) honey. Journal of Food Process Engineering. e13221.

Bhattacharya, S. (2011). Are we in the polyphenols era. *Pharmacognosy Research*, *3*(2), 147. https://doi.org/10.4103/0974-8490.81966

Biluca, F. C., Braghini, F., Gonzaga, L. V., Costa, A. C. O., & Fett, R. (2016). Physicochemical profiles, minerals and bioactive compounds of stingless bee honey (Meliponinae). *Journal of Food Composition and Analysis*, *50*, 61–69. https://doi.org/10.1016/j.jfca.2016.05.007

Biluca, F. C., da Silva, B., Caon, T., Mohr, E. T. B., Vieira, G. N., Gonzaga, L. V., … Costa, A. C. O. (2020). Investigation of phenolic compounds, antioxidant and anti-inflammatory activities in stingless bee honey (Meliponinae). *Food Research International*, *129*, 108756. https://doi.org/10.1016/j.foodres.2019.108756

Bogdanov, S., Lüllmann, C., Martin, P., von der Ohe, W., Russmann, H., Vorwohl, G., … Vit, P. (1999). Honey quality and international regulatory standards: Review by the international honey commission. *Bee World*, *80*(2), 61–69. https://doi.org/10.1080/0005772x.1999.11099428

Boorn, K. L., Khor, Y., Sweetman, E., Tan, F., Heard, T. A., & Hammer, K. A. (2010). Antimicrobial activity of honey from the stingless bee Trigona carbonaria determined by agar diffusion , agar dilution , broth microdilution and time-kill methodology, *108*, 1534–1543. https://doi.org/10.1111/j.1365-2672.2009.04552.x

Borsato, D. M., Prudente, A. S., Döll-Boscardin, P. M., Borsato, A. V., Luz, C. F. P., Maia, B. H. L. N. S., … Miguel, O. G. (2014). Topical Anti-inflammatory activity of a monofloral honey of Mimosa scabrella Provided by melipona marginata during winter in Southern Brazil. *Journal of Medicinal Food*, *17*(7), 817–825. https://doi.org/10.1089/jmf.2013.0024

Bradbear, N. (2009). Bees and their role in forest livelihoods. A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. Food and Agriculture Organization of the United Nations, Rome., 51–53.

Brown, E., O'Brien, M., Georges, K., & Suepaul, S. (2020). Physical characteristics and antimicrobial properties of Apis mellifera, Frieseomelitta nigra and Melipona favosa bee honeys from apiaries in Trinidad and Tobago. *BMC Complementary Medicine and Therapies*, *20*(1), 85. https://doi.org/10.1186/s12906-020-2829-5

Charles D. Michener. (2013). *Pot honey - A legacy of stingless bee*. New York.

Cheung, Y., Meenu, M., Yu, X., & Xu, B. (2019). Phenolic acids and flavonoids profiles of commercial honey from different floral sources and geographic sources. *International Journal of Food Properties*, *22*(1), 290–308. https://doi.org/10.1080/10942912.2019.1579835

Chuttong, B., Chanbang, Y., Sringarm, K., & Burgett, M. (2016). Physicochemical profiles of stingless bee (Apidae : Meliponini) honey from South East Asia (Thailand). *FOOD CHEMISTRY*, *192*, 149–155. https://doi.org/10.1016/j.foodchem.2015.06.089

Cianciosi, D., Forbes-Hernández, T. Y., Afrin, S., Gasparrini, M., Reboredo-Rodriguez, P., Manna, P. P., … Battino, M. (2018). Phenolic compounds in honey and their associated health benefits: A review. *Molecules*, *23*(9), 1–20. https://doi.org/10.3390/molecules23092322

Codex Alimentarius Commission. (2001). Codex Standard for Honey, CODEX STAN 12-1981. *Codex Alimentarius Commission FAO/OMS*, 1–8.

Cruz, C. B. N. da, Pieri, F. A., Carvalho-Zilse, G. A., Orlandi, P. P., Nunes-Silva, C. G., & Leomil, L. (2014). Antimicrobial activity of honeys from two stingless honeybee species and Apis mellifera (Hymenoptera: Apidae) against pathogenic microorganisms. *Acta Amazonica*, *44*(2), 287–290. https://doi.org/10.1590/s0044-59672014000200015

da Silva, I. A. A., da Silva, T. M. S., Camara, C. A., Queiroz, N., Magnani, M., de Novais, J. S., … de Souza, A. G. (2013). Phenolic profile, antioxidant activity and palynological analysis of stingless bee honey from Amazonas, Northern Brazil. *Food Chemistry*, *141*(4), 3552–3558. https://doi.org/10.1016/j.foodchem.2013.06.072

Da Silva, P. M., Gauche, C., Gonzaga, L. V., Costa, A. C. O., & Fett, R. (2016). Honey: Chemical composition, stability and authenticity. *Food Chemistry*, *196*, 309–323. https://doi.org/10.1016/j.foodchem.2015.09.051

De Almeida-Muradian, L. B., Stramm, K. M., Horita, A., Barth, O. M., Da Silva de Freitas, A., & Estevinho, L. M. (2013). Comparative study of the physicochemical and palynological characteristics of honey from Melipona subnitida and Apis mellifera. *International Journal of Food Science and Technology*, *48*(8), 1698–1706. https://doi.org/10.1111/ijfs.12140

Del Nozal, M. J., Bernal, J. L., Marinero, P., Diego, J. C., Frechilla, J. I., Higes, M., & Llorente, J. (1998). High performance liquid chromatographic determination of organic acids in honeys from different botanical origin. *Journal of Liquid Chromatography and Related Technologies*, *21*(20), 3197–3214.

Escuredo, O., Dobre, I., Fernández-González, M., & Seijo, M. C. (2014). Contribution of botanical origin and sugar composition of honeys on the crystallization phenomenon. *Food Chemistry*, *149*, 84–90. https://doi.org/10.1016/j.foodchem.2013.10.097

Ewnetu, Y., Lemma, W., & Birhane, N. (2013). Antibacterial effects of Apis mellifera and stingless bees honeys on susceptible and resistant strains of Escherichia coli, Staphylococcus aureus and Klebsiella pneumoniae in Gondar, Northwest Ethiopia. *BMC Complementary and Alternative Medicine*, *13*.

Fatima, I. J., Mohd Hilmi, A. B., Salwani, I., & Lavaniya, M. (2018). Physicochemical characteristics of Malaysian stingless bee honey from Trigona species. *International Medical Journal Malaysia*, *17*(Specialissue1), 187–191.

Gismondi, A. (2007). From Robinia pseudoacacia L. nectar to Acacia monofloral honey: biochemical changes and variation of biological properties. *Journal of Organizational Behavior*, *28*(3), 303–325. https://doi.org/10.1002/j

Hasali, N. H., Zamri, A. I., Lani, M. N., Mubarak, A., Ahmad, F., & Chilek, T. Z. T. (2018). Physico-chemical analysis and antibacterial activity of raw honey of stingless bee farmed in coastal areas in Kelantan and Terengganu. *Malaysian Applied Biology*, *47*(4), 145–151.

Izabela, B., Iwona, G., Andrzej, G., & Zbigniew, S. (2017). Antioxidant activity of selected phenols estimated by ABTS and FRAP methods*. *Acta Mathematica Vietnamica*, *42*(3), 533–550. https://doi.org/10.1007/s40306-017-0208-1

Julika, W. N., Ajit, A., Sulaiman, A. Z., & Naila, A. (2019). Physicochemical and microbiological analysis of stingless bees honey collected from local market in Malaysia. *Indonesian Journal of Chemistry*, *19*(2), 522–530. https://doi.org/10.22146/ijc.40869

Kajobe, R. (2007). Botanical sources and sugar concentration of the nectar collected by two stingless bee species in a tropical African rain forest. *Apidologie*, *38*(1), 110–121. https://doi.org/10.1051/apido:2006051

Kakkar, S., & Bais, S. (2014). A Review on Protocatechuic Acid and Its Pharmacological Potential. *ISRN Pharmacology*, *2014*, 1–9. https://doi.org/10.1155/2014/952943

Karabagias, I. K., Badeka, A., Kontakos, S., Karabournioti, S., & Kontominas, M. G. (2014). Characterisation and classification of Greek pine honeys according to their geographical origin based on volatiles, physicochemical parameters and chemometrics. *Food Chemistry*, *146*, 548–557. https://doi.org/10.1016/j.foodchem.2013.09.105

Kaškoniene, V., & Venskutonis, P. R. (2010). Floral Markers in Honey of Various Botanical and Geographic Origins: A Review. *Comprehensive Reviews in Food Science and Food Safety*, *9*(6), 620–634. https://doi.org/10.1111/j.1541-4337.2010.00130.x

Kelly, N., Farisya, M. S. N., Kumara, T. K., & Marcela, P. (2014). Species diversity and external nest characteristics of stingless bees in meliponiculture. *Pertanika Journal of Tropical Agricultural Science*, *37*(3), 293–298.

Keng, C. B., Haron, H., Abdul Talib, R., & Subramaniam, P. (2017). Physical Properties, Antioxidant Content and Anti-Oxidative Activities of Malaysian Stingless Kelulut (Trigona spp.) Honey. *Journal of Agricultural Science*, *9*(13), 32. https://doi.org/10.5539/jas.v9n13p32

Khalil, M. I., Sulaiman, S. A., & Boukraa, L. (2010). Antioxidant Properties of Honey and Its Role in Preventing Health Disorder. *The Open Nutraceuticals Journal*, *3*(1), 6–16.

Korting, H. C., Schöllmann, C., & White, R. J. (2011). Management of minor acute cutaneous wounds: Importance of wound healing in a moist environment. *Journal of the European Academy of Dermatology and Venereology*, *25*(2), 130–137. https://doi.org/10.1111/j.1468-3083.2010.03775.x

Krishnasree, V., & Mary Ukkuru, P. (2017). In vitro antidiabetic activity and glycemic index of bee honeys. *Indian Journal of Traditional Knowledge*, *16*(1), 134–140.

Kustiawan, P. M., Puthong, S., Arung, E. T., & Chanchao, C. (2014). In vitro cytotoxicity of Indonesian stingless bee products against human cancer cell lines. *Asian Pacific Journal of Tropical Biomedicine*, *4*(7), 549–556. https://doi.org/10.12980/APJTB.4.2014APJTB-2013-0039

Lavinas, F. C., Macedo, E. H. B. C., Sá, G. B. L., Amaral, A. C. F., Silva, J. R. A., Azevedo, M. M. B., … Rodrigues, I. A. (2018). Brazilian stingless bee propolis and geopropolis: promising sources of biologically active compounds. *Brazilian Journal of Pharmacognosy*, *29*(3), 389–399. https://doi.org/10.1016/j.bjp.2018.11.007

Lemos, M. S., Venturieri, G. C., Dantas Filho, H. A., & Dantas, K. G. F. (2018). Evaluación de los parámetros físico-químicos y constituyentes inorgánicos de mieles de la región amazónica. *Journal of Apicultural Research*, *57*(1), 135–144. https://doi.org/10.1080/00218839.2017.1338120

Lim, D.C.C, Abu Bakar, M.F, Majid, M. 2018. Nutritional composition of stingless bee honey from different botanical origins. IOP Conference Series: Earth and Environmental Science, Volume 269, International Conference on Biodiversity. 11–13 November 2018, Johor Darul Takzim, Malaysia

Lob, S., Afiffi, N., Razak, S. B. A., Ibrahim, N. F., & Mohd Nawi, I. H. (2017). Composition and identification of pollen collected by stingless bee (Heterotrigona itama) in forested and coastal area of Terengganu, Malaysia. *Malaysian Applied Biology*, *46*(3), 227–232.

Majid, M., Fadzelly, M., Bakar, A., & You, K. Y. (2019). Variations of physicochemical properties of stingless bee honey from different botanical origin in state of Johor , Malaysia Variations of physicochemical properties of stingless bee honey from different botanical origin in state of Johor , Malaysia, (August). https://doi.org/10.1088/1755-1315/269/1/012028

Martin, S. B. and P. (2002). Honey Authenticity : A Review, (6), 1–20.

Massaro, C. F., Shelley, D., Heard, T. A., & Brooks, P. (2014). In vitro antibacterial phenolic extracts from “sugarbag” pot-honeys of australian stingless bees (Tetragonula carbonaria). *Journal of Agricultural and Food Chemistry*, *62*(50), 12209–12217. https://doi.org/10.1021/jf5051848

Mato, I., Huidobro, J. F., Simal-Lozano, J., & Sancho, M. T. (2006). Analytical methods for the determination of organic acids in honey. *Critical Reviews in Analytical Chemistry*, *36*(1), 3–11. https://doi.org/10.1080/10408340500451957

Medhi, B., Puri, A., Upadhyay, S., & Kaman, L. (2008). Topical application of honey in the treatment of wound healing: A metaanalysis. *JK Science*, *10*(4), 166–169.

Mohammad, S.M., Mahmud-Ab-Rashid, N., Zawawi, N.(2020). Botanical origin and nutritional values of bee bread of stingless bee (*Heterotrigona itama*) from Malaysia. *Journal of Food Quality*, Article ID 2845757

Nishio, E. K., Ribeiro, J. M., Oliveira, A. G., Andrade, C. G. T. J., Proni, E. A., Kobayashi, R. K. T., & Nakazato, G. (2016). Antibacterial synergic effect of honey from two stingless bees: Scaptotrigona bipunctata Lepeletier, 1836, and S. postica Latreille, 1807. *Scientific Reports*, *6*(January 2015), 1–8. https://doi.org/10.1038/srep21641

Nordin, A., Sainik, N. Q. A. V., Chowdhury, S. R., Saim, A. Bin, & Idrus, R. B. H. (2018). Physicochemical properties of stingless bee honey from around the globe: A comprehensive review. *Journal of Food Composition and Analysis*, *73*, 91–102. https://doi.org/10.1016/j.jfca.2018.06.002

Norowi, M., Fahimie, M., A, s, S., J, R., & R, S. (2010). Conservation and sustainable utilization of stingless bees for pollination services in agricultural ecosystems in Malaysia. *International Seminar on Enhancement of Functional Biodiversity Relevent to Sustainable Food Production in ASPAC*, (July 2017), 1–11.

Oddo, L. P., Heard, T. A., Rodríguez-Malaver, A., Pérez, R. A., Fernández-Muiño, M., Sancho, M. T., … Vit, P. (2008). Composition and antioxidant activity of Trigona carbonaria honey from Australia. *Journal of Medicinal Food*, *11*(4), 789–794. https://doi.org/10.1089/jmf.2007.0724

Omar, Syafizal, Enchang, F. K., Nazri, M. U. I. A., Ismail, M. M., & Ismail, W. I. W. (2019). Physicochemical profiles of honey harvested from four major species of stingless bee (Kelulut) in north east peninsular of Malaysia. *Malaysian Applied Biology*, *48*(1), 111–116.

Omar, Syaliza, Mat-Kamir, N. F., & Sanny, M. (2019). Antibacterial activity of Malaysian produced stingless-bee honey on wound pathogens. *Journal of Sustainability Science and Management*, *14*(3), 67–79.

Pontara, L. P. de M., Clemente, E., Oliveira, D. M., Kwiatkowski, A., Rosa, C. I. L. F., & Saia, V. E. (2012). Physicochemical and microbiological characterization of cassava flower honey samples produced by africanized honeybees. *Food Science and Technology*, *32*(3), 547–552. https://doi.org/10.1590/s0101-20612012005000066

Pyrzynska, K., & Biesaga, M. (2009). Analysis of phenolic acids and flavonoids in honey. *TrAC - Trends in Analytical Chemistry*, *28*(7), 893–902. https://doi.org/10.1016/j.trac.2009.03.015

Rahmawati, O., Pratami, D. K., Raffiudin, R., & Sahlan, M. (2019). Alpha-glucosidase inhibitory activity of stingless bee honey from Tetragonula biroi and Tetragonula laeviceps. *AIP Conference Proceedings*, *2092*(April). https://doi.org/10.1063/1.5096705

Ramírez, R., & Montenegro, G. (2004). Certification of the botanical origin of honey and corbicular pollen from VI Region of Chile (Litueche). *Ciencia e Investigación Agraria*, *31*(3), 197–211. https://doi.org/10.7764/rcia.v31i3.295

Rashid, M. R., Nor Aripin, K. N., Syed Mohideen, F. B., Baharom, N., Omar, K., Md Taujuddin, N. M. S., … Addnan, F. H. (2019). The Effect of Kelulut Honey on Fasting Blood Glucose and Metabolic Parameters in Patients with Impaired Fasting Glucose. *Journal of Nutrition and Metabolism*, *2019*. https://doi.org/10.1155/2019/3176018

Rasmussen, C. (2008). *Catalog of the Indo-Malayan/Australasian stingless bees (Hymenoptera: Apidae: Meliponini)*. *Zootaxa*. Auckland, New Zealand: Magnolia Press. https://doi.org/10.11646/zootaxa.1935.1.1

Salmah, I., Mahmood, A. A., & Sidik, K. (2005). Synergistic Effects of Alcoholic Extract of Sweet Basil (Ocimum basilicum L.) Leaves and Honey on Cutaneous Wound Healing in Rats.pdf, (January 2005).

Seeram, N. P., Adams, L. S., Zhang, Y., Lee, R., Sand, D., Scheuller, H. S., & Heber, D. (2006). Blackberry, black raspberry, blueberry, cranberry, red raspberry, and strawberry extracts inhibit growth and stimulate apoptosis of human cancer cells in vitro. *Journal of Agricultural and Food Chemistry*, *54*(25), 9329–9339. https://doi.org/10.1021/jf061750g

Shamsudin, S., Selamat, J., Sanny, M., Abd. Razak, S. B., Jambari, N. N., Mian, Z., & Khatib, A. (2019). Influence of origins and bee species on physicochemical, antioxidant properties and botanical discrimination of stingless bee honey. *International Journal of Food Properties*, *22*(1), 238–263. https://doi.org/10.1080/10942912.2019.1576730

Shamsudin, S., Selamat, J., Sanny, M., Shamsul Bahari, A. R., Jambari, N. N., & Khatib, A. (2019). A comparative characterization of physicochemical and antioxidants properties of processed Heterotrigona itama honey from different origins and classification by chemometrics analysis. *Molecules*, *24*(21), 1–20. https://doi.org/10.3390/molecules24213898

Sobota, R., Szwed, M., Kasza, A., Bugno, M., & Kordula, T. (2000). Parthenolide inhibits activation of signal transducers and activators of transcription (STATs) induced by cytokines of the IL-6 family. *Biochemical and Biophysical Research Communications*, *267*(1), 329–333. https://doi.org/10.1006/bbrc.1999.1948

Solayman, M., Islam, M. A., Paul, S., Ali, Y., Khalil, M. I., Alam, N., & Gan, S. H. (2016). Physicochemical Properties, Minerals, Trace Elements, and Heavy Metals in Honey of Different Origins: A Comprehensive Review. *Comprehensive Reviews in Food Science and Food Safety*, *15*(1), 219–233. https://doi.org/10.1111/1541-4337.12182

Thompson, D. (1990). Cytokines in disease. *CPD Bulletin Clinical Biochemistry*, *3*(2), 43–47.

Tuksitha, L., Chen, Y. L. S., Chen, Y. L., Wong, K. Y., & Peng, C. C. (2018). Antioxidant and antibacterial capacity of stingless bee honey from Borneo (Sarawak). *Journal of Asia-Pacific Entomology*, *21*(2), 563–570. https://doi.org/10.1016/j.aspen.2018.03.007

Vandamme, L., Heyneman, A., Hoeksema, H., Verbelen, J., & Monstrey, S. (2013). Honey in modern wound care: A systematic review. *Burns*, *39*(8), 1514–1525. https://doi.org/10.1016/j.burns.2013.06.014

Vidinský, B., Gál, P., Toporcer, T., Longauer, F., Lenhardt, L., Bobrov, N., & Sabo, J. (2006). Histological study of the first seven days of skin wound healing in rats. *Acta Veterinaria Brno*, *75*(2), 197–202. https://doi.org/10.2754/avb200675020197

Vit, P., & Pulcini, P. (1996). Diastase and invertase activities in Meliponini and Trigonini honeys from Venezuela. *Journal of Apicultural Research*, *35*(2), 57–62. https://doi.org/10.1080/00218839.1996.11100913

Wong, P., Ling, H. S., Chung, K. C., Yau, T. M. S., & Gindi, S. R. A. (2019). Chemical Analysis on the Honey of Heterotrigona itama and Tetrigona binghami from Sarawak, Malaysia. *Sains Malaysiana*, *48*(8), 1635–1642. https://doi.org/10.17576/jsm-2019-4808-09

Xiao, J., & Kai, G. (2012). A review of dietary polyphenol-plasma protein interactions: Characterization, influence on the bioactivity, and structure-affinity relationship. *Critical Reviews in Food Science and Nutrition*, *52*(1), 85–101. https://doi.org/10.1080/10408398.2010.499017

Xie, Y., Yang, W., Tang, F., Chen, X., & Ren, L. (2014). Antibacterial Activities of Flavonoids: Structure-Activity Relationship and Mechanism. *Current Medicinal Chemistry*, *22*(1), 132–149.

Yazan, L. S., Muhamad Zali, M. F. S., Ali, R. M., Zainal, N. A., Esa, N., Sapuan, S., … Syed Alwi, S. S. (2016). Chemopreventive Properties and Toxicity of Kelulut Honey in Sprague Dawley Rats Induced with Azoxymethane. *BioMed Research International*, *2016*. https://doi.org/10.1155/2016/4036926

Zainol, M. I., Mohd Yusoff, K., & Mohd Yusof, M. Y. (2013). Antibacterial activity of selected Malaysian honey. *BMC Complementary and Alternative Medicine*, *13*. https://doi.org/10.1186/1472-6882-13-129

Zamora, G., Beukelman, K., Van Den Berg, B., Arias, M. L., Umaña, E., Aguilar, I., … Gross, N. (2014). The antimicrobial activity and microbiological safety of stingless bee honeys from Costa Rica. *Journal of Apicultural Research*, *53*(5), 503–513.

Zulkhairi Amin, F. A., Sabri, S., Mohammad, S. M., Ismail, M., Chan, K. W., Ismail, N., … Zawawi, N. (2018). Therapeutic properties of stingless bee honey in comparison with european bee honey. *Advances in Pharmacological Sciences*, *2018*. https://doi.org/10.1155/2018/6179596

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