International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 23-06-2025, Accepted: 24-07-2025, Published: 08-08-2025
Volume 10, Issue 4, 2025, Page No. 47-55

Stingless bee honey as a functional food: Composition, bioactivity, and the underexplored potential of Dammar Bee Honey (*Tetragonula iridipennis*)

Neha ES[*], Seeja Thomachan Panjikkaran, Reshma Suresh, Sunil K Panchal
Department of Community Science, School of Science, Western Sydney University, Richmond, NSW, Australia

Abstract
Stingless bee honey is increasingly recognized for its distinct physicochemical characteristics and diverse pharmacological properties. Rich in phenolic acids, flavonoids, organic acids, and non-conventional sugars, it demonstrates notable antioxidant, anti-inflammatory, and antimicrobial effects, underscoring its potential as a functional food and therapeutic agent. These bioactivities vary significantly depending on floral sources, geographical origin, and stingless bee species. Notably, honeys derived from *Tetragonula iridipennis*, an underrepresented species in global literature yet widely distributed across the Indian subcontinent, have shown promising antioxidant and anti-inflammatory potential, adding critical value to the spectrum of the honey's bioefficacy. However, commercialization remains challenged by deviations from existing honey quality standards, limited clinical validation, and inherently low production yields. This review consolidates existing evidence on the composition, therapeutic potential, and regulatory barriers of the honey, offering direction for future studies aimed at standardization and safe, evidence-based application in health and nutrition.

Keywords: Stingless bee honey, *Tetragonula iridipennis*, antioxidant potential, functional food

Introduction

Honey is a natural substance produced by bees from floral nectar, plant secretions, or excretions of sap-feeding insects. Depending on the source of its raw material, honey is classified as either blossom honey or nectar honey (Codex Alimentarius, 2001) [11, 12]. It is a highly complex food composed primarily of sugars, along with enzymes, amino acids, organic acids, carotenoids, vitamins, minerals, and aromatic compounds, all of which contribute to its nutritional and therapeutic value (Ávila *et al*., 2018) [4].

Stingless bees (tribe *Meliponini*), also known as meliponines, are eusocial insects characterized by their atrophied, non-functional stingers. Unlike the commonly studied *Apis mellifera*, stingless bees are found in tropical and subtropical regions, and their honey, commonly referred to as stingless bee honey (SBH), has attracted growing interest due to its distinct physicochemical properties and health-promoting potential (Santana *et al*., 2020; Souza *et al*., 2021). Among them, *Tetragonula iridipennis*, the dammar bee, is one of the most common species in India and Southeast Asia, yet remains underrepresented in contemporary SBH research.

SBH exhibits higher acidity, moisture content, and reducing sugar levels than conventional honey, alongside a more complex flavor, aroma, and texture profile (Badrulhisham *et al*., 2020; Majid *et al*., 2020). It has been associated with antibacterial, anti-inflammatory, neuroprotective, and wound-healing properties, partly due to its richness in phenolic acids, flavonoids, and other bioactive compounds (Zulkifli *et al*., 2023) [50]. The specific composition of SBH is influenced by botanical origin and geographical location, affecting its concentration of ascorbic acid, tocopherols, organic acids, and proteins. Dammar bee honey, for instance, has been traditionally used in Ayurvedic and folk medicine in southern India, yet scientific data on its bioactive composition and therapeutic efficacy are sparse.

While *Apis mellifera* remain, the primary species used in commercial honey production, stingless bees are gaining attention for their potential in niche and functional food markets (Zaldivar-Ortega *et al*., 2024) [48]. Both species belong to the family *Apidae*, yet differ taxonomically: *Apis mellifera* is classified under the tribe *Apini*, whereas stingless bees fall under *Meliponini*, encompassing genera such as *Melipona*, *ScaptoTetragonula*, and *Tetragonula* (Ali *et al*., 2020; Kek *et al*., 2017; Michener *et al*., 2012) [23, 33]. More than 500 stingless bee species have been identified globally, with the greatest diversity in Latin America, Africa, Asia, and Australia (Chuttong *et al*., 2016; Abd *et al*., 2017) [1, 10]. Despite this biodiversity, most biochemical studies disproportionately focus on a few species, with dammar bee honey notably lacking detailed physicochemical or pharmacological profiling.

Despite increasing interest, research on SBH remains limited. Most established honey quality standards are based on *Apis mellifera* and do not account for species-specific differences in stingless bee honey (Jimenez *et al*., 2016; Kek *et al*., 2017) [20, 22]. This gap in legislation and data has restricted SBH's global commercialization. Additionally, while Apis bees store honey in wax combs, stingless bees store it in cerumen pots, a unique feature that contributes to higher flavonoid content and antioxidant activity (Alvarez-Suarez *et al*., 2018). Among stingless bees, *Tetragonula iridipennis* (dammar bee) honey has shown early evidence of significant antioxidant and antimicrobial activity *in vitro*, but these findings are based on limited datasets and have yet to undergo rigorous comparative analysis or methodological harmonization.

Environmental and botanical factors further influence SBH's physicochemical characteristics, color, and shelf life (Iglesias *et al*., 2012; Kulkarni *et al*., 2017) [19, 26]. The small size of stingless bees allows them to forage a wider diversity of flowers, contributing to a richer polyphenol profile and broader therapeutic potential (Ranneh *et al*., 2018) [42]. Given these features, SBH is increasingly recognized as a promising functional food with potential nutraceutical applications (Ali *et al*., 2020; Fletcher *et al*., 2020) [17]. A better understanding of species-specific honeys, such as that of *Tetragonula iridipennis*, is essential to unlock the full spectrum of benefits that SBH can offer.

1. Nutritional profile of stingless bee honey

Stingless bee honey (SBH) exhibits a unique nutritional and chemical profile that sets it apart from *Apis mellifera* honey, with notable implications for both food functionality and therapeutic use. Its nutritional properties, including carbohydrate content, moisture levels, protein concentration, ash content, and micronutrient profile, contribute to its functional food potential. Among various stingless bee species, *Tetragonula iridipennis* (dammar bee) honey is particularly noted in traditional medicine systems of southern India, yet remains underrepresented in compositional analyses. Preliminary investigations suggest that dammar bee honey exhibits a distinct sugar and organic acid profile that may influence its sweetness perception, acidity, and metabolic effects (Vit *et al*., 2024).

Studies have shown that stingless bee honey is rich in carbohydrates, primarily composed of reducing and non-reducing sugars. The total carbohydrate content in stingless bee honey ranges between 67.58 to 72.25 g/100 g, with an average value of 69.23 g/100 g, aligning with international norms, which require honey to contain at least 60 g/100 g of carbohydrates (Buba *et al*., 2013). Sugars in this honey primarily originate from nectar sources, which serve as the colony's carbohydrate supply. The highest carbohydrate content (72.25 g/100 g) was observed in multifruit botanical samples, whereas multiflora samples have the lowest content (67.58 g/100 g), making them relatively less sweet and more aqueous (Kek *et al*., 2017) [22]. This high carbohydrate concentration not only meets international standards but also enhances SBH's potential as a rapid energy source in functional foods.

Stingless bee honey is characteristically high in moisture (27.00–31.00 g/100 g), a trait that sets it apart from *Apis mellifera* honey and makes it more susceptible to fermentation, especially in warm, humid climates. This moisture level is largely influenced by botanical origin, with the highest moisture content observed in samples collected from acacia, mangrove, and multiflora sources, followed by coconut-based honey (29.00 g/100 g), while multifruit honey had the lowest moisture content (27.00 g/100 g) (Chuttong *et al*., 2016) [10]. Malaysian standards (MS 2683) specify that raw, unprocessed stingless bee honey should not exceed 35% moisture, and the reported values fall within this limit (Malaysian Standard). The high moisture content of stingless bee honey distinguishes it from *A. mellifera* honey and predisposes it to fermentation if not properly handled (da Silva *et al*., 2016) [16]. Dammar bee honey, in particular, has been observed to exhibit moisture levels at the higher end of this range, potentially due to its natural storage in cerumen pots and the humid microclimates of its native habitats. This contributes to both its perishable nature and its complex, tangy-sour flavor profile that distinguishes it from other stingless bee honeys. Beyond its high-water content, stingless bee honey also offers modest protein levels that contribute to its enzymatic activity and biofunctionality

This honey contains protein in concentrations ranging from 0.2 to 0.8 g/100 g, with the highest values observed in samples from coconut and multiflora botanical origins (0.8 g/100 g). In contrast, honey derived from mangrove and starfruit sources exhibits the lowest protein content (0.2 g/100 g) (Kek *et al*., 2014) [23]. Protein in honey is primarily composed of enzymes and free amino acids, which are introduced by bees during the ripening process. The dominant enzymes include amylase, invertase, and glucose oxidase, which contribute to honey's functional properties and health benefits.

Fat content in stingless bee honey is negligible, and research indicates that it does not contribute significantly to its nutritional profile. Kek *et al*. (2014) [23] reported negligible fat content in stingless bee honey, rendering it irrelevant to energy calculations. Similarly, Khalil *et al*. (2001) [24] stated that due to the minimal fat content, stingless bee honey is not considered a good source of lipids. This aligns with findings that honey, in general, is primarily composed of carbohydrates, with proteins and micronutrients present in small amounts.

Ash content, an indicator of mineral concentration, ranges from 0.15 to 0.90 g/100 g in stingless bee honey with coconut-derived samples reaching up to 0.90 g/100 g, suggesting a richer mineral profile. This variation is likely driven by botanical source, with darker honeys typically correlating with higher ash content, a trend observed across multiple studies (Kek *et al*., 2014; Buba *et al*., 2013) [23]. Potassium is the predominant mineral, with concentrations of 325.29 mg/100 g in honey and 581.86 mg/100 g in pollen. Sodium content is recorded at 126.02 mg/100 g in honey and 190.13 mg/100 g in pollen, while vitamin A levels are 0.008 IU in honey and 22.12 IU in pollen (Mohd *et al*., 2017) [34].

Stingless bee honey exhibits a wide variation in diastase activity, an essential enzymatic parameter for honey quality. Evidence suggests that only six samples displayed significant diastase activity, with values ranging from 4.34 to 49.6 Göthe units. The lowest activity was observed in the S. bicunctata species, whereas the highest was found in T. angustula species. These findings align with previous reports, which also highlight substantial variation in diastase activity among stingless bee honeys, with values ranging from 1.50 to 21.0 Göthe units (Guerrini *et al*., 2009; Chuttong *et al*., 2016) [10]. The variability in diastase activity could be attributed to differences in nectar sources, bee species, and environmental conditions.

Another critical parameter influencing honey quality is hydroxymethylfurfural (5-HMF), a marker of honey freshness and heat exposure. It is a six-carbon heterocyclic organic compound containing both aldehyde and hydroxymethyl functional groups, formed primarily through the degradation of sugars via the Maillard reaction, a non-enzymatic browning process. The formation of HMF is strongly influenced by thermal processing and prolonged storage, making it a key parameter in assessing honey authenticity and deterioration.

The chemical composition of honey plays a significant role in HMF accumulation, particularly the presence of simple sugars (glucose and fructose), acids, and minerals, all of which are closely linked to the floral origin of the honey (Sousa *et al*., 2016). Additionally, environmental factors such as climate conditions contribute to variations in HMF content. Honey samples from tropical regions, which experience prolonged exposure to high temperatures, tend to have elevated HMF levels, emphasizing the need for careful storage and handling to maintain quality (Chuttong *et al*., 2016; Suntiparapop *et al*., 2015) [10].

According to the Codex Alimentarius Commission (2001) [11, 12], the maximum permissible level of 5-HMF in *Apis mellifera* honey is 40 mg kg-1. In contrast, research by De Sousa *et al*. (2016) [14] analyzing 24 stingless bee honey samples from the semi-arid region of Brazil did not detect 5-HMF, reinforcing the idea that stingless bee honey is resistant to 5-HMF formation. Similarly, Biluca *et al*. (2014) reported that stingless bee honey exhibits resistance to 5-HMF accumulation even when subjected to high temperatures (75 °C, 85 °C, 95 °C), likely due to its high moisture content, acidity, and predominant fructose composition. The absence of HMF in stingless bee honey, even under high heat, suggests an intrinsic chemical resilience possibly linked to its fructose-acid balance. This resilience may enable novel applications in functional foods that undergo thermal processing. However, environmental factors such as prolonged exposure to high temperatures, particularly in tropical regions, can still influence 5-HMF levels (Suntiparapop *et al*., 2012; Silva *et al*., 2013; Chuttong *et al*., 2016) [10]. Thus, the physicochemical properties of stingless bee honey play a crucial role in its stability and quality, making it an interesting subject for further research and potential applications in food and health industries.

The presence of trace heavy metals in stingless bee honey has been noted, with lead concentrations of 0.0042% in honey and 0.0037% in pollen. Although these concentrations are minimal, their presence may reflect environmental contamination, warranting continued surveillance to ensure food safety.

The nutritional composition of this honey highlights its potential as a superfood. The carbohydrate content ensures a rich energy source, while the presence of essential minerals and bioactive enzymes adds to its health benefits. However, its high moisture content necessitates careful handling to prevent fermentation. Taken together, the nutritional composition of stingless bee honey, notably including that of underexplored varieties like dammar bee honey, supports its classification as a functional food and underscores its therapeutic promise, especially in regions seeking natural, bioactive-rich alternatives to refined sugars and synthetic supplements. Future studies should prioritize bioavailability assessments and long-term clinical effects to translate this potential into targeted applications in nutrition and medicine.

2. Bioactive compounds and antioxidants in stingless bee honey

The increasing interest in stingless bee honey over the past two decades has positioned it as a valuable resource for the food, pharmaceutical, and cosmetic industries. Extensive research across different regions has identified numerous bioactive compounds in this honey, highlighting its therapeutic potential. The phenolic composition of stingless bee honey is largely influenced by its botanical origin, which includes pollens, nectars, resins, and essential oils available to the bees. As a result, honey from various floral sources exhibits distinct bioactive properties. Dammar bee honey, produced by *Tetragonula iridipennis*, offers a particularly intriguing phytochemical profile due to its collection from tropical forest flora of southern India, though its compositional diversity remains underrepresented in current literature.

One of the defining characteristics of stingless bee honey is the way it is produced. Unlike traditional honeybees, stingless bees store their honey within cerumen pots, structures composed of plant resins, beeswax, and secretions from their abdominal glands. This unique storage method plays a significant role in the bioactive profile of the honey. Initially, physical changes occur due to moisture loss, followed by biological fermentation involving yeasts and bacteria. Additionally, a chemical transformation takes place when worker bees introduce enzymes that break down nectar sucrose into fructose and glucose. These factors collectively shape the honey’s phytochemical composition, with cerumen derived compounds further enriching its properties. The resinous microenvironment of dammar bee cerumen pots may contribute distinct secondary metabolites, potentially elevating its antioxidant or antimicrobial potency in comparison to other stingless bee species.

Stingless bee honey is known for its rich bioactive and antioxidant content, which includes carotenoids, amino acids, proteins, enzymes, Maillard reaction products, organic acids, and polyphenols, particularly flavonoids and phenolic acids. The composition of phenolic compounds in stingless bee honey exhibits remarkable diversity, influenced by geographical origin, floral sources, and bee species. A comprehensive analysis by Pote *et al*. (2025) identified 26 phenolic compounds, including 12 phenolic acids, 9 flavonoids, 3 phenolic aldehydes, 1 coumarin, and 1 diterpene. Among them, salicylic acid, *p*-coumaric acid, naringin, and taxifolin were frequently detected across multiple honey samples, whereas mandelic acid, sinapic acid, vanillin, umbelliferone, and sinapaldehyde were observed in only isolated samples. The predominant phenolic compounds identified in higher concentrations included vanillic acid (1220–1070 µg/100 g), taxifolin (12.0–1910 µg/100 g), and syringaldehyde (2150 µg/100 g), while compounds such as apigenin (3.20–16.3 µg/100 g), umbelliferone (3.81 µg/100 g), and naringenin (4.00–32.0 µg/100 g) were present in lower amounts. Though not yet fully profiled, dammar bee honey is likely to possess many of these polyphenols, with anecdotal accounts suggesting a high concentration of aromatic acids and flavonoid glycosides consistent with resin-rich cerumen environments.

Previous studies have also documented phenolic compounds in stingless bee honey, reporting the presence of fraxin, scopoletin, bergamotin, luteolin, quercitrin, naringenin, and isorhamnetin (Guerrini *et al*., 2009); 3,4-dihydroxybenzyl, gallic, vanillic, cinnamic, and abscisic acids (Silva *et al*., 2013); 4-hydroxybenzoic acid, salicylic acid, syringic acid, *p*-coumaric acid, catechol, and taxifolin; as well as ferulic acid, ellagic acid, myricetin, catechin, rutin, kaempferol, hesperetin, and chrysin (de Sousa *et al*., 2016) [14]. The increasing reports of polyphenolic diversity in stingless bee honey suggest that its composition is highly variable and dependent on environmental factors. Since plants synthesize bioactive compounds as a response to environmental stressors such as UV exposure, temperature fluctuations, and nutrient availability, it is likely that these compounds are transferred to the honey through nectar collection. Consequently, the geographical location of apiaries and the floral resources available to bees play a crucial role in determining the phenolic profile of the honey (Kaškonienė & Venskutonis, 2010; Da Silva *et al*., 2016) [16, 21]. This holds true for dammar bee honey, which is frequently harvested from biodiverse forest margins and lateritic zones in India—ecosystems known for their rich secondary metabolite production in flora.

Variations in polyphenol composition have been observed not only among honey samples from different regions but also within samples from the same apiary and harvest period, particularly when produced by different bee species. This suggests that the floral preference of each bee species contributes significantly to the variation in bioactive compounds. Notably, recent findings report the presence of mandelic acid, caffeic acid, chlorogenic acid, rosmarinic acid, aromadendrin, isoquercitrin, eriodictyol, vanillin, umbelliferone, syringaldehyde, sinapaldehyde, and carnosol in stingless bee honey for the first time (Biluca *et al*., 2017) [7]. This compositional diversity may be even more pronounced in undercharacterized honeys such as that produced by *Tetragonula iridipennis* (dammar bee), given their niche floral habitats and unique cerumen-based honey storage. These findings highlight the complexity and uniqueness of phenolic composition in stingless bee honey, reinforcing its potential as a functional food with diverse bioactive properties.

In honey from stingless bees, native to Mexico, carotenoid levels were reported to range between 0.6–6.2 mg/kg. Similarly, protein content varies by species; for instance, in certain Brazilian species, protein levels range from 0.2 to 0.5 g/100 g, with proline concentrations spanning 20.5 to 4.6 mg/kg. Total phenolic content in honey samples has been recorded between 1.3 and 126.0 mg of gallic acid equivalent (GAE) per 100 g, while total flavonoid content varies from 1.9 to 4.2 mg of quercetin equivalent (QE) per 100 g (Xolalpa *et al*., 2024) [47]. Comparable quantification for dammar bee honey is lacking but expected to reflect a similarly variable phytochemical fingerprint, especially considering its collection from forested regions rich in resinous plant species.

Further analysis of Brazilian stingless bee honey identified 26 distinct phenolic compounds, including phenolic acids, flavonoids, phenolic aldehydes, coumarins, and diterpenes. Among these, salicylic acid, p-coumaric acid, naringin, and taxifolin were the most abundant. Other studies have confirmed the presence of multiple phenolic compounds such as catechol, taxifolin, and flavonoids like quercetin, myricetin, and kaempferol in various stingless bee honey species (Lavinas *et al*., 2023) [28]

In a Brazilian study by Silva *et al*. (2013) focusing on Melipona subnitida honey, researchers identified gallic, vanillic, and cumaric acids, along with abscisic acid isomers. Similarly, honey from Melipona beecheii exhibited a range of phenolic compounds, including quercetin, coumaric acid, isorhamnetin, and ferulic acid (Alvarez *et al*., 2018). Studies on honey from Amazonian stingless bees further confirmed the presence of gallic acid and quercetin as dominant compounds (Biluca *et al*., 2020) [8].

The bioactive potential of gallic acid is particularly noteworthy, as it has been linked to antimicrobial, antioxidant, and anticancer properties. It has demonstrated efficacy in inhibiting prostate carcinoma cells and promoting apoptosis in cervical cancer cells. Given its known antimicrobial properties and traditional wound-healing applications, dammar bee honey may contain gallic acid or structurally similar compounds, although this remains to be confirmed through targeted profiling. The phenolic composition of stingless bee honey closely resembles that of Apis mellifera honey, with botanical origins playing a crucial role in determining its antioxidant and antimicrobial potency.

Investigations conducted in Northeastern Brazil indicated that Melipona (Michmelia) seminigra merrillae honey possessed remarkable antioxidant potential (Silva *et al*., 2013). Additional studies on *T. mexicana*, *Melipona fasciculata*, *Melipona subnitida*, and *Melipona aff. Fuscopilosa* honey revealed considerable *in vitro* antioxidant activity, with T. carbonaria honey exhibiting the highest antioxidant effect, underscoring the variability in honey's antioxidant properties depending on its origin (Rao *et al.*, 2016) [43].

Biluca *et al*. (2016) [6] analyzed thirty-three samples across ten honey varieties, reporting antiradical activity (DPPH) values between 1.4 mg EAA/100 g and 18.5 mg EAA/100 g. Silva *et al*. (2013) further examined stingless bee honey, recording values from 10.6 to 12.9 mg EAA/100 g. Research from the Brazilian semi-arid region identified a unique monofloral honey from an uncommon stingless bee species, exhibiting radical scavenging activity (RSA) via DPPH in the range of 11.2 ± 1.3% to 46.9 ± 1.9% (Sousa *et al*., 2016b). TEAC-Trolox equivalent antioxidant capacity (ORAC) values fluctuated between 8.9 ± 0.1 and 54.3 ± 0.3 μmol Trolox equivalents/100 g, while FRAP-based reducing power assessments yielded results of 61.1 mmol Fe (II)/100 g for M. Mexicana and 624.0 mmol Fe (II)/100 g for M. marginata (Biluca *et al*., 2016) [6]. Monofloral honeys from M. subnitida Ducke and M. scutellaris Latrelle exhibited ABTS radical inhibition up to four times greater than DPPH. Furthermore, significant correlations ($p \leq 0.01$) were observed between ORAC and RSA ($r^2 = 0.93$), TPC ($r^2 = 0.96$), TFC ($r^2 = 0.89$), DPPH ($r^2 = 0.93$), and ABTS ($r^2 = 0.98$) (de Sousa *et al*., 2016) [14].

The antioxidant activity of S. mexicana honey collected over four years was found to range between 15.0% and 19.0% for DPPH radical scavenging. FRAP reducing power values varied from 50.4 to 61.1 μmol Trolox equivalents/100 g, though reductions were noted at storage temperatures of 25.4°C and 45°C. Fresh samples exhibited greater reducing power, suggesting the involvement of compounds like ascorbic acid in stabilizing free radicals (Jimenez *et al*., 2016) [20].

Results indicated that raw honey from mixed forest sources exhibited the highest radical scavenging activity, with an IC50 value of 43.996±0.377 mg/ml. Additionally, this honey sample had the highest total phenolic and flavonoid contents, measuring 89.916±0.358 mg GAE/100 g and 58.093±0.294 mg QE/100 g, respectively. The total phenolic content of stingless bee honey varies significantly depending on bee species, geographical location, and botanical origin. In the studied samples, total phenolic content ranged from 10.3 to 98.0 mg GAE 100 g^{-1}, with *M. quadrifaciata* honey exhibiting the lowest values and *T. angustula* honey showing the highest values. Preliminary investigations into dammar bee honey suggest comparable antioxidant potential, but quantitative assessments using DPPH, FRAP, or ORAC assays are critically needed to validate these observations. These findings align with previous studies, where phenolic content in stingless bee honey ranged from 1.30 to 66.0 mg GAE 100 g^{-1} in samples from Paraiba and the Amazon, Brazil. Notably, these values are comparable to those found in *Apis mellifera* honey, which can range between 4.00 and 139 mg GAE 100 g^{-1}, depending on regional and botanical factors

The antioxidant activity of stingless bee honey, measured using DPPH radical scavenging assays, showed considerable variation across samples. The lowest recorded activity was 1.41 mg EAA 100 g−1 (*M. marginata*), while the highest was 18.5 mg EAA 100 g−1 from the same species, likely due to geographical and botanical differences. Silva *et al*. (2013) reported similar findings, with values ranging from 10.6 to 12.9 mg EAA 100 g−1. Comparatively, *Apis mellifera* honey demonstrates a broader range of antioxidant activity (1.91–150 mg EAA 100 g−1), which is primarily influenced by nectar source, geographical region, and bee species (Boussaid *et al*., 2014; Habib *et al*., 2014) [18].

FRAP analysis further confirmed the variability in antioxidant properties among stingless bee honeys. The reducing power of Fe^{3+} varied significantly, with values ranging from 61.1 μmol Fe II 100 g−1 in *M. bicolor* honey to 624 μmol Fe II 100 g−1 in *M. marginata* honey. Notably, FRAP analysis for stingless bee honey is limited in existing literature, but comparisons with *Apis mellifera* honey indicate that values typically range between 4.01 and 498 μmol Fe II 100 g−1, with some studies reporting values up to 1000 μmol Fe II 100 g−1 depending on botanical origin (Can *et al*., 2015). Thus, dammar bee honey, owing to its unique production niche and apparent richness in resin-derived phenolics, may emerge as a particularly potent, though currently overlooked, functional food candidate.

3. Health benefits and therapeutic potential of stingless bee honey

SBH has long been recognized for its medicinal properties and traditional uses in food and medicine. Among these, dammar bee honey (*Tetragonula iridipennis*), native to parts of India, is gaining attention for its traditional use in Ayurvedic and tribal medicine for similar therapeutic purposes.

SBH is often consumed alone or with a hot drink and is commonly used in traditional remedies. Indigenous communities have utilized SBH in combination with ingredients such as lemon, agave mezcal, and *Crescentia alata* pulp to treat colds, coughs, and respiratory illnesses like bronchitis. Furthermore, SBH holds a significant place in Maya traditional medicine, where it has been employed as a remedy for high fever, wound and burn treatment, and even as an antidote for poisonous stings. These therapeutic applications, along with its recognition as a functional food, highlight the diverse health benefits of stingless bee honey.

The therapeutic potential of Melipona beecheii honey was historically recognized by the ancient Maya for its restorative effects on ill individuals (Michener, 2012) [33]. Stingless bee honey has been credited with supporting digestive, respiratory, reproductive, dermatological, and ocular health. Traditional medicine practices incorporate honey in treatments for tumors, eye conditions (such as cataracts and conjunctivitis), inflammation, throat infections, blood purification, kidney ailments, and wound healing. The most prevalent medicinal application, accounting for 27% of uses, pertained to blood-related treatments (Rao *et al*., 2016) [43]. Similarly, dammar bee honey has been used in Indian indigenous systems for treating wounds, respiratory infections, and gastric ailments, though scientific validation is still emerging.

Research on GenioTetragonula thoracica honey, a stingless bee species native to tropical Southeast Asia, highlighted its ability to mitigate pancreatic damage and regulate metabolic imbalances in diabetic conditions. Findings by Aziz *et al.* (2017) [5] suggested that this honey prevents fasting blood glucose spikes, regulates cholesterol and triglyceride levels, and enhances serum insulin levels. Histopathological evaluations indicated reduced oxidative stress, inflammation, and apoptosis in pancreatic islets upon honey administration. The presence of bioactive compounds, such as 2-amino-3-methyl-1-butanol, dulcitol, L-galactose, and ethyl glucuronide, was identified through LC-MS analysis (Aziz *et al*., 2017) [5].

The potential antidiabetic properties of stingless bee honey (SBH) have gained attention due to its ability to modulate key enzymes involved in glucose metabolism. Studies have shown that SBH exhibits strong inhibition of α-amylase and α-glucosidase, enzymes responsible for breaking down complex carbohydrates into simple sugars. This inhibitory effect suggests that SBH may help regulate postprandial blood glucose levels more effectively than European bee honey (EBH) (Krishnasree and Mary, 2017) [26]. Additionally, *in vivo* studies have demonstrated that SBH administration in diabetic rats did not lead to an increase in fasting blood glucose, total cholesterol, triglycerides, or low-density lipoprotein, further supporting its potential role in diabetes management (Aziz *et al*., 2017) [5].

In ophthalmic applications, stingless bee honey has been found to counteract cataracts induced by sodium selenite in Wistar rats when used as an eyewash. Furthermore, the antimicrobial properties of Meliponula spp. honey were tested against bacterial conjunctivitis caused by Staphylococcus aureus and Pseudomonas aeruginosa in Hartley guinea pigs, demonstrating efficacy comparable to gentamicin, a standard antibiotic (Ilechie *et al*., 2012). Similarly, Meliponula bucandei honey from Ghana exhibited antimicrobial activity against Staphylococcus aureus, Staphylococcus epidermidis, and Pseudomonas aeruginosa, outperforming eight conventional ophthalmic antibiotics by reducing both infection and inflammation. Preliminary investigations on dammar bee honey indicate it may offer ocular benefits due to its antioxidant and antimicrobial richness, although focused studies are still limited.

Australian stingless bee honey has been recognized for its antimicrobial efficacy, which contributes to wound healing. M. marginata honey was also observed to exert anti-inflammatory effects on the skin, potentially due to the synergistic action of its phenolic components. The therapeutic impact of stingless bee honey has been linked to the interaction of sugar and hydrogen peroxide, which promote wound recovery. Research indicates that stingless bee honey possesses an antioxidant profile similar to or greater than that of conventional honey, aiding in neutralizing free radicals responsible for tissue damage (Abd Jalil *et al*., 2017) [1].

Stingless bee honey possesses unique antimicrobial properties due to its storage in resinous structures composed of wax and cuticular antimicrobial compounds, enriched with propolis, a plant-derived resin known for its bioactive properties (Abd Jalil *et al*., 2017) [1]. Unlike *Apis mellifera* honey, which is stored solely in wax combs, stingless bee honey is more exposed to plant-based antimicrobial compounds, increasing its potential antibacterial activity. Studies have demonstrated that various types of stingless bee honey, including those from *Tetragonula carbonaria*, *ScaptoTetragonula bipunctata*, and *ScaptoTetragonula postica*, exhibit significant inhibitory effects against both

Gram-positive and Gram-negative bacteria, including multidrug-resistant strains (Nishio *et al*., 2016) [35]. Additionally, honey from *Melipona beecheii* and *Tetragonisca angustula* has shown superior antimicrobial activity against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* compared to *Apis mellifera* honey (Alvarez-Suarez *et al*., 2018). Honey from *Tetragonula iridipennis*, stored in propolis-rich cerumen pots, also reflects this resin-enhanced antimicrobial effect, with broad-spectrum activity against clinical pathogens.

The antibacterial activity of stingless bee honey is influenced by factors such as its floral source, seasonal variations, and its composition of bioactive compounds. In particular, honey from *Tetragonula iridipennis*, commonly found in parts of South and Southeast Asia, exhibits promising antibacterial efficacy attributed to its unique phytochemical and resin-enriched composition. Studies suggest that certain floral sources, such as Juazeiro, exhibit higher antimicrobial activity, with bacterial susceptibility ranking from *Salmonella* spp. to *Listeria monocytogenes* (de Sousa *et al*., 2016) [14]. Furthermore, the presence of hydrogen peroxide, methylglyoxal, and antimicrobial peptides like bee defensin-1 contribute to its bactericidal effects (Massaro *et al*., 2014) [31]. However, the exact contribution of these components remains unclear, as they may act synergistically or independently depending on the targeted bacterial speciesill. Preliminary observations suggest that dammar bee honey, due to its high acidity and resin-infused storage structures, may exert enhanced antimicrobial effects even in low concentrations, though systematic evaluations are still emerging. Seasonal variations also play a role, with *Melipona compressipes manaosensis* honey collected during the dry season exhibiting higher antibacterial activity than that collected in the wet season.

Beyond its antimicrobial potential, stingless bee honey offers significant benefits in wound healing. Traditional healers in regions of southern India have long used *Tetragonula iridipennis* honey topically for cuts, burns, and chronic wounds, citing its quick-acting soothing and regenerative effects. It helps prevent wound infections, maintains a moist healing environment, promotes cell proliferation, reduces pain, and prevents skin damage such as abrasions and maceration (Esa *et al*., 2022) [16]. These therapeutic effects are attributed to its antioxidant, antibacterial, anti-inflammatory, and moisturizing properties. Additionally, honey-based hydrogels formulated with stingless bee honey have shown promise in enhancing epithelialization and accelerating wound healing, making them a strong candidate for advanced wound dressings. Given its physicochemical richness, dammar bee honey holds promise for developing region-specific wound care products, particularly in humid climates where microbial resistance complicates healing. Further clinical studies are essential to optimize its applications and develop highly effective wound care solutions based on stingless bee honey (Esa *et al*., 2022) [16].

4. Dammar bee honey (*Tetragonula iridipennis*): an underexplored subset of stingless bee honey

Among the diverse species of stingless bees, *Tetragonula iridipennis*, commonly known as the dammar bee, is native to parts of India and Southeast Asia and produces a unique variety of honey with distinct compositional and functional characteristics. Despite its deep roots in traditional medicine, where it has been used for treating wounds, respiratory ailments, and digestive disorders, dammar bee honey has received comparatively little scientific attention in modern literature (Kumar *et al*., 2024) [27]. Indigenous communities have long regarded it as more “medicinal” than conventional *Apis mellifera* honey, owing to its sour taste, dark color, and rapid spoilage rate, features that reflect its high moisture and acidity. However, scientific validation of its ethnomedicinal uses remains sparse, with most existing evidence being anecdotal or based on general stingless bee honey profiles. This lack of species-specific characterization presents a critical gap in our understanding, especially considering that different stingless bee species can produce markedly different honeys depending on their physiology, resin use, and foraging behavior.

Recent preliminary studies suggest that dammar bee honey possesses a unique physicochemical profile that may contribute to its biological activity. It is typically more acidic and hydrophilic than other honeys, with relatively high moisture content and an abundance of organic acids, reducing sugars, and trace bioactive phytochemicals such as flavonoids and phenolic acids (Vit *et al*., 2024). These components are believed to play a key role in the honey’s antimicrobial and antioxidant properties, though detailed studies on these bioactivities are still limited. Available *in vitro* findings show promising antioxidant potential, possibly due to the presence of non-enzymatic compounds that act as radical scavengers. However, comparative studies between dammar bee honey and other stingless bee honeys remain almost nonexistent. Without rigorous biochemical and therapeutic profiling, this honey remains an underutilized natural product with unfulfilled commercial and nutraceutical potential. Given its regional abundance and cultural relevance, dammar bee honey warrants deeper scientific investigation, particularly into its anti-inflammatory, cytoprotective, and immunomodulatory effects, as part of the broader effort to map the functional food potential of stingless bee honeys. The current review addresses this need by placing *T. iridipennis* within the wider context of stingless bee honey research, while highlighting its promise for future functional and therapeutic applications.

5. Factors Affecting Honey Composition

Beyond the inherent biological characteristics of stingless bees, environmental factors and post-harvest handling play a crucial role in shaping the composition of stingless bee honey (SBH). Several key variables influence its physicochemical and bioactive properties, contributing to variations observed across different regions and seasons.

One of the primary determinants of SBH composition is seasonal variation in nectar availability, which is influenced by climatic changes. Fluctuations in temperature, humidity, and rainfall can alter the metabolic response of plants, thereby modifying the sugar profile, acidity, and phytochemical content of nectar. Consequently, these seasonal shifts impact the final composition of honey produced by stingless bees (Noiset *et al*., 2025) [37].

Additionally, differences in the sampling period may introduce variability even within honey collected from the same bee species and geographic location. Variations in nectar sources and environmental conditions over time result in compositional differences between honey samples harvested in different months or years. Such inconsistencies highlight the importance of standardized sampling protocols to ensure reproducibility in honey research and quality assessments.

Post-harvest handling, including storage and processing methods, also significantly affects SBH properties. Exposure to heat during processing or prolonged storage under suboptimal conditions can accelerate biochemical reactions such as the Maillard reaction, leading to the formation of compounds like hydroxymethylfurfural (HMF) and altering honey's sensory and nutritional qualities. Maintaining controlled storage conditions and minimizing thermal exposure are essential to preserving the bioactive integrity of SBH.

Overall, the interplay between environmental conditions, plant metabolism, and post-harvest handling dictates the final composition of SBH. Further research is needed to comprehensively characterize these interactions, particularly in diverse ecological settings, to enhance the understanding of SBH's functional properties and optimize its commercial potential.

6. Stingless bee vs. Apis mellifera honey

Stingless bee honey exhibits distinct physicochemical properties compared to Apis mellifera honey, often deviating from the standards set by the Codex Alimentarius (2001) [11, 12]. One of the most notable differences is its high moisture content, which has been consistently observed across all studied samples. This elevated moisture level contributes to its unique viscosity and potential susceptibility to fermentation. Additionally, approximately 50% of stingless bee honey samples exhibit increased free acidity, which may influence its taste and stability (Zulkhairi *et al*., 2018) [49].

In terms of compositional parameters, stingless bee honey typically contains lower levels of soluble solids, total sugars, and sucrose, often falling below the limit of quantification (LOQ). Furthermore, enzymatic activity, particularly diastase activity, is reduced, along with hydroxymethylfurfural (HMF) content, suggesting differences in honey aging and processing stability compared to Apis mellifera honey (Zaldivar-Ortega *et al*., 2024) [48]. Despite these variations, most samples maintain an appropriate pH and electrical conductivity, indicating a balanced mineral composition. Interestingly, stingless bee honey was identified in studies to contain comparable or even higher levels of cations than Apis mellifera honey, which may contribute to its bioactive potential and nutritional value (Avila *et al*., 2018).

These findings underscore the unique physicochemical profile of stingless bee honey, which is influenced by factors such as botanical origin, environmental conditions, and bee physiology. Understanding these properties is essential for establishing appropriate quality standards and promoting its functional applications in food and medicine.

Stingless bee honey exhibits superior flavonoid concentration and antioxidant capacity compared to *Apis mellifera* honey. A study by Alvarez-Suarez *et al*. (2018) assessed the antioxidant strength of *M. beecheii* honey, demonstrating an elevated antioxidant potential and a richer composition of phenolic compounds, flavonoids, carotenoids, ascorbic acid, free amino acids, and proteins relative to *A. mellifera* honey. Research by Oddo *et al*. (2008) on *Tetragonula carbonaria* honey in Australia confirmed its superior antioxidant activity compared to European floral honey, though its radical scavenging ability remained comparable to that of European honey samples.

These findings reinforce the traditional medicinal use of stingless bee honey, highlighting its functional properties similar to *Apis mellifera* honey in terms of antioxidant and bioactive potential. However, due to sample availability constraints, no direct correlations could be established between bee species, floral origin, and geographical location in this study.

7. Challenges in stingless bee honey utilization

The commercialization of stingless bee honey (SBH) faces several challenges, primarily due to its noncompliance with the honey quality standards established by Codex Alimentarius (2001) [11, 12], which are tailored for Apis mellifera honey. This limitation is especially relevant for species like *Tetragonula iridipennis*, whose honey exhibits distinct physicochemical traits not captured by existing regulations. One of the key quality parameters, free acidity, is used to assess honey fermentation. Unlike A. mellifera honey, SBH naturally undergoes fermentation, resulting in higher acidity levels that do not meet the regulatory requirements. Additionally, SBH differs in other critical parameters such as moisture content, reducing sugar levels, and diastase activity, making it difficult to standardize under existing global regulations.

Given these differences, there is an urgent need for specific quality standards for SBH to facilitate its commercialization and ensure product authenticity and safety for consumers. Some countries, such as Malaysia (Nordin *et al*., 2018) [36] and Brazil (de Souza *et al*., 2021) [15], have initiated efforts to establish regulatory frameworks for SBH. However, the diversity of stingless bee species and the limited knowledge of SBH composition pose significant challenges in defining comprehensive quality standards (Schvezov *et al*., 2020) [44]. This is particularly true for underrepresented species like *Tetragonula iridipennis*, for which comprehensive compositional data are still emerging.

Another major limitation is the lack of clinical trials validating the health benefits of SBH. Establishing SBH as a functional food with scientifically supported health claims would significantly enhance its market potential. Additionally, the lower production capacity of stingless bees compared to A. mellifera results in higher production costs, limiting its widespread availability. This limitation could be mitigated by employing artificial hive systems, especially for species like *Tetragonula iridipennis*, to optimize colony management and increase honey yield. This limitation could be mitigated by employing artificial hive systems to optimize colony management and increase honey yield.

Despite these challenges, SBH presents several advantages. Stingless bees are more adaptable in hive construction, exhibit lower rates of colony loss, and are less susceptible to diseases compared to A. mellifera. Moreover, SBH has been reported to possess a superior nutritional profile, characterized by higher concentrations of phenolic acids and antioxidant activity, making it a potential functional food. As awareness of the health benefits of SBH grows, health-conscious consumers may be willing to pay a premium price, thereby creating new opportunities for commercialization.

Conclusion

Stingless bee honey (SBH) is emerging as a valuable natural product with notable therapeutic and nutraceutical potential, yet research remains skewed toward a few dominant species. Among the underrepresented varieties, *Tetragonula iridipennis* (dammar bee) honey stands out for its traditional use and promising antioxidant and antimicrobial properties. Despite its bioactive richness, scientific data on dammar bee honey are still limited. Strengthening research on its unique composition and health effects, through *in vivo* studies and clinical trials, will be crucial to validate its medicinal applications and promote its inclusion in functional food markets. Unlocking the potential of dammar bee honey can enrich both scientific understanding and sustainable meliponiculture practices.

Reference

1. Abd Jalil MA, Kasmuri AR, Hadi H. Stingless bee honey, the natural wound healer: A review. Skin Pharmacol Physiol,2017:30(2):66-75.
2. Ali H, Abu Bakar MF, Majid M, Muhammad N, Lim SY. *In vitro* anti-diabetic activity of stingless bee honey from different botanical origins. Food Research,2020:4(5):1421-6.
3. Álvarez-Suarez JM, Giampieri F, Brenciani A, Mazzoni L, Gasparrini M, González-Paramás AM, Santos-Buelga C, Morroni G, Simoni S, Forbes-Hernández TY, Afrin S. Apis mellifera vs Melipona beecheii Cuban polifloral honeys: A comparison based on their physicochemical parameters, chemical composition and biological properties. LWT,2018:87:272-9.
4. Ávila S, Beux MR, Ribani RH, Zambiazi RC. Stingless bee honey: Quality parameters, bioactive compounds, health-promotion properties and modification detection strategies. Trends Food Sci Technol,2018:45(4):147-55.
5. Aziz MSA, Giribabu N, Rao PV, Salleh N. Pancreatoprotective effects of Geniotrigona thoracica stingless bee honey in streptozotocin-nicotinamide-induced male diabetic rats. Biomed Pharmacother,2017:89:135-45.
6. Biluca FC, Braghini F, Gonzaga LV, Costa ACO, Fett R. Physicochemical profiles, minerals and bioactive compounds of stingless bee honey (Meliponinae). J Food Compos Anal,2016:50:61-9.
7. Biluca FC, de Gois JS, Schulz M, Braghini F, Gonzaga LV, Maltez HF, Rodrigues E, Vitali L, Micke GA, Borges DL, Costa ACO. Phenolic compounds, antioxidant capacity and bioaccessibility of minerals of stingless bee honey (Meliponinae). J Food Compos Anal,2017:63:89-97.
8. Biluca FC, da Silva B, Caon T, Mohr ETB, Vieira GN, Gonzaga LV, Vitali L, Micke G, Fett R, Dalmarco EM, Costa ACO. Investigation of phenolic compounds, antioxidant and anti-inflammatory activities in stingless bee honey (Meliponinae). Food Res Int,2020:129:108756.
9. Can Z, Yildiz O, Sahin H, Turumtay EA, Silici S, Kolayli S. An investigation of Turkish honeys: Their physico-chemical properties, antioxidant capacities and phenolic profiles. Food Chem,2015:180:133-41.
10. Chuttong B, Chanbang Y, Sringarm K, Burgett M. Physicochemical profiles of stingless bee (Apidae: Meliponini) honey from South East Asia (Thailand). Food Chem,2016:192:149-55.
11. Codex Alimentarius. Alinorm 41/0: Revised standard for honey. Alinorm,2001:1:19-26.
12. Codex Alimentarius Commission. Codex Standard 12: Revised Codex Standard for Honey. Standards and Standard Methods,2001:11.
13. da Silva PM, Gauche C, Gonzaga LV, Costa ACO, Fett R. Honey: Chemical composition, stability and authenticity. Food Chem,2016:196:309-23.
14. de Sousa JMB, de Souza EL, Marques G, de Toledo Benassi M, Gullón B, Pintado MM, Magnani M. Sugar profile, physicochemical and sensory aspects of monofloral honeys produced by different stingless bee species in Brazilian semi-arid region. LWT - Food Science and Technology,2016:65:645-51.
15. de Souza APF, Rodrigues NR, Reyes FGR. Glyphosate and aminomethylphosphonic acid (AMPA) residues in Brazilian honey. Food Addit Contam Part B,2021:14(1):40-7.
16. Esa NEF, Ansari MNM, Razak SIA, Ismail NI, Jusoh N, Zawawi NA, Jamaludin MI, Sagadevan S, Nayan NHM. A review on recent progress of stingless bee honey and its hydrogel-based compound for wound care management. Molecules,2022:27(10):3080.
17. Fletcher MT, Hungerford NL, Webber D, De Jesus MC, Zhang J, Stone ISJ, Blanchfield JT, Zawawi N. Stingless bee honey, a novel source of trehalulose: A biologically active disaccharide with health benefits. Sci Rep,2020:10:1-8.
18. Habib HM, Al Meqbali FT, Kamal H, Souka UD, Ibrahim WH. Physicochemical and biochemical properties of honeys from arid regions. Food Chem,2014:153:35-43.
19. Iglesias A, Feás X, Rodrigues S, Seijas JA, Vázquez-Tato MP, Dias LG, *et al*. Comprehensive study of honey with protected denomination of origin and contribution to the enhancement of legal specifications. Molecules,2012:17:8561-77.
20. Jimenez M, Beristain CI, Azuara E, Mendoza MR, Pascual LA. Physicochemical and antioxidant properties of honey from Scaptotrigona mexicana bee. J Apic Res,2016:55(2):151-60.
21. Kaškonienė V, Venskutonis PR. Floral markers in honey of various botanical and geographic origins: A review. Compr Rev Food Sci Food Saf,2010:9(6):620-34.
22. Kek SP, Chin NL, Yusof YA, Tan SW, Chua LS. Classification of entomological origin of honey based on its physicochemical and antioxidant properties. Int J Food Prop,2017:20(3):2723-38.
23. Kek SP, Chin NL, Yusof YA, Tan SW, Chua LS. Total phenolic contents and colour intensity of Malaysian honeys from the Apis spp. and Trigona spp. bees. Agriculture and Agricultural Science Procedia,2014:2:150-5.
24. Khalil MI, Motallib MA, Anisuzzaman ASM, Sathi ZS, Hye MA, Shahjahan M. Biochemical analysis of different brands of unifloral honey available at the Northern region of Bangladesh. J Med Sci,2001:1:385-8.
25. Krishnasree V, Mary Ukkuru P. *In vitro* antidiabetic activity and glycemic index of bee honeys. Indian J Tradit Knowl,2017:16(1):134-40.
26. Kulkarni SR, Gurve SS, Chormule AJ. Effect of different indigenous bee attractants in onion (Allium cepa L.) crop. Ann Plant Prot Sci,2017:25:78-82.

27. Kumar D, Hazra K, Prasad PVV, Bulleddu R. Honey: an important nutrient and adjuvant for maintenance of health and management of diseases. J Ethn Foods,2024:11(1):28.
28. Kwakman PH, Velde AAT, de Boer L, Speijer D, Vandenbroucke-Grauls MJC, Zaat SA. How honey kills bacteria. FASEB J,2010:24(7):2576-82.
29. Lavinas FC, Gomes BA, Silva MV, Nunes RM, Leitão SG, Moura MR, Simas RC, Carneiro CS, Rodrigues IA. Discriminant analysis of Brazilian stingless bee honey reveals an iron-based biogeographical origin. Foods,2023:12(1):180.
30. Malaysian Standard. MS 2683: Kelulut (Stingless Bee) Honey – Specification: Quality requirements. Selangor, Malaysia,2017.
31. Massaro CF, Shelley D, Heard TA, Brooks P. *In vitro* antibacterial phenolic extracts from “sugarbag” pot-honeys of Australian stingless bees (Tetragonula carbonaria). J Agric Food Chem,2014:62(50):12209-17.
32. Michener CD. The bees of the world. The Johns Hopkins University press,2007.
33. Michener CD. The meliponini. In: Pot-honey: a legacy of stingless bees. New York, NY: Springer New York, 2012. p. 3-17.
34. Mohd Fadzelly AB, Shuaibu BS, Fazleen IAB, Ong JC. Physicochemical and antioxidant potential of raw unprocessed honey from Malaysian stingless bees. Pak J Nutr,2017:16:888-94.
35. Nishio EK, Ribeiro JM, Oliveira AG, Andrade CGTJ, Proni EA, Kobayashi RKT, Nakazato G. Antibacterial synergic effect of honey from two stingless bees: Scaptotrigona bipunctata Lepeletier, 1836, and S. postica Latreille, 1807. Sci Rep,2016:6(1):21641.
36. Nordin A, Sainik NQAV, Chowdhury SR, Saim AB, Idrus RBH. Physicochemical properties of stingless bee honey from around the globe: A comprehensive review. J Food Compos Anal,2018:73:91-102.
37. Noiset P, Héger M, Salmon C, Kwapong P, Combey R, Thevan K, Warrit N, Rojas-Oropeza M, Cabirol N, Zaragoza-Trello C, Rasmussen C. Ecological and evolutionary drivers of stingless bee honey variation at the global scale. Sci Total Environ,2025:969:178945.
38. Patricia V. Effect of stingless bee honey in selenite induced cataracts. Apiacta,2002:3:1-2.
39. Pimentel TC, Rosset M, de Sousa JMB, de Oliveira LIG, Mafaldo IM, Pintado MME, Magnani M. Stingless bee honey: An overview of health benefits and main market challenges. J Food Biochem,2022:46(3):13883.
40. Pote CL, Shirsat DV, Mahadule PA, Gade KA, Pandit TR, Soumia PS, Thangasamy A, Kumar S, Mahajan V, Karuppaiah V. Biochemical, antioxidants, and mineral constituents of stingless bee honey. Front Sustain Food Syst,2025:9:1546843.
41. Ramón-Sierra J, Ruíz-Ruíz J, Ortiz-Vázquez E. Electrophoresis characterisation of protein as a method to establish the entomological origin of stingless bee honeys. Food Chem,2015:183:43-8.
42. Ranneh Y, Ali F, Zarei M, Akim AM, Hamid HA, Khazaai H. Malaysian stingless bee and Tualang honeys: A comparative characterization of total antioxidant capacity and phenolic profile using liquid chromatography-mass spectrometry. LWT,2018:89:1-9.
43. Rao PV, Krishnan KT, Salleh N, Gan SH. Biological and therapeutic effects of honey produced by honey bees and stingless bees: A comparative review. Rev Bras Farmacogn,2016:26:657-64.
44. Schvezov N, Pucciarelli AB, Valdes B, Dallagnol AM. Characterization of yateí (Tetragonisca fiebrigi) honey and preservation treatments: Dehumidification, pasteurization and refrigeration. Food Control,2020:111:107080.
45. Vit P, Bankova V, Ramírez-Arriaga E, Moreno E, Zamudio F. Pharmaceutical stingless bees. In: Stingless Bee Nest Cerumen and Propolis, Volume 1. Cham: Springer International Publishing, 2024, 345-85.
46. Wongsa K, Meemongkolkiat T, Duangphakdee O, Prasongsuk S, Rattanawannee A. Physicochemical properties, phenolic, flavonoid contents and antioxidant potential of stingless bee (Heterotrigona itama) honey from Thailand. Curr Res Nutr Food Sci,2023:11(1).
47. Xolalpa-Aroche A, Hernandez-Mena DI, Moguel-Chin WI, Contreras-Peruyero H, Rivero-Cruz BE, Ortiz-Vazquez E, Rivero-Cruz JF, M RA V, Delgado-Suarez EJ. Physicochemical properties of two Mexican stingless bee honeys to strengthen their biocultural value. Rev Bras Farmacogn,2024:34(5):1129-39.
48. Zaldivar-Ortega AK, Cenobio-Galindo ADJ, Morfin N, Aguirre-Álvarez G, Campos-Montiel RG, Esturau-Escofet N, Garduño-García A, Angeles-Hernandez JC. The physicochemical parameters, phenolic content, and antioxidant activity of honey from stingless bees and Apis mellifera: A systematic review and meta-analysis. Antioxidants,2024:13(12):1539.
49. Zulkhairi Amin FA, Sabri S, Mohammad SM, Ismail M, Chan KW, Ismail N, Norhaizan ME, Zawawi N. Therapeutic properties of stingless bee honey in comparison with European bee honey. Adv Pharmacol Pharm Sci,2018:2018:6179596.
50. Zulkifli NA, Hassan Z, Mustafa MZ, Azman WNW, Hadie SNH, Ghani N, Mat Zin AA. The potential neuroprotective effects of stingless bee honey. Front Aging Neurosci,2023:14:1048028.