HAYATI
Journal of Biosciences

Vol. 33 No. 3, May 2026 816-824
DOI:10.4308/hjb.33.3.816-824
ISSN: 1978-3019
EISSN: 2086-4094

Research Article

Comparison of Chemical Composition and Quality of Honey from *Tetragonula clypearis* and *Apis cerana* in North Lombok, Indonesia

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ARTICLE INFO

Article history:
Received September 22, 2025
Received in revised form January 14, 2026
Accepted January 30, 2026
Available Online February 20, 2026

KEYWORDS:
Apis cerana,
geographical origin,
honey,
nectar,
Tetragonula clypearis

ABSTRACT

The quality of honey is strongly influenced by bee species and the types of plants used as nectar sources. This study aimed to evaluate and compare the quality of honey produced by *Tetragonula clypearis* and *Apis cerana* in North Lombok, Indonesia. Honey samples from *T. clypearis* were collected in Salut Village, Kayangan District, while samples from *A. cerana* were collected in Sukadana Village, Bayan District. The results revealed that honey from *T. clypearis* had significantly higher moisture content, ash, protein, total phenolics, minerals, and amino acids compared to honey from *A. cerana*. In contrast, the reducing sugar content was significantly higher in *A. cerana* honey. However, fat and flavonoid contents showed no significant differences between the two types of honey. Seventeen amino acids were identified in *T. clypearis* honey, while fourteen amino acids were identified in *A. cerana* honey. Based on the overall chemical composition, *T. clypearis* honey exhibited better quality compared to *A. cerana* honey.

1. Introduction

Indonesia, an archipelagic nation with diverse geographic regions, supports unique ecosystems that shape meliponiculture practices, stingless bee species distribution, and the availability of floral resources. These environmental factors play a crucial role in determining the quality and chemical composition of honey produced by different bee species. In Indonesia, stingless bees commonly nest in bamboo, sugar palm stalks, tree trunks, wooden structures, and even underground. One notable species, *Tetragonula clypearis*, locally known as Klanceng in Java, typically nests in bamboo and is native to several regions of Indonesia (Agus *et al*. 2021; Agussalim *et al*. 2019a, 2020, 2023, 2024; Erwan *et al*. 2020, 2023; Pratama *et al.* 2023; Rachmawati *et al*. 2022; Supeno *et al*. 2021, 2022). Although honey from stingless bees or honeybees has been increasingly commercialized by Indonesian beekeepers, there is limited scientific information on its chemical composition, particularly for honey originating from different bee species and geographic areas, such as Salut and Sukadana in North Lombok, Indonesia.

Stingless bees, including *T. clypearis*, produce honey, bee pollen, bee bread, and propolis (Agus *et al*. 2021; Erwan *et al.* 2021; Dewi *et al.* 202; Sari *et al*. 2024). Honey is a natural sweetener product produced by the honeybees or stingless bees, which is made from the nectar of plant flowers, extrafloral nectar, or honeydew as a raw material (Da Silva *et al*. 2016; Thrasyvoulou *et al*. 2018). It primarily consists of sugars and other constituents, including proteins, enzymes, amino acids, vitamins, minerals, organic acids, carotenoids, and

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aromatic substances (Alqarni *et al*. 2014; Da Silva *et al*. 2016; Adgaba *et al*. 2017). The properties and chemical composition of honey, including its color, aroma, and flavor, are strongly influenced by the floral source of nectar, geographical origin, climate, and bee species. Additionally, post-harvest handling, such as environmental exposure, processing methods, packaging, and storage conditions, also affect honey quality (Chanchao 2013; Tornuk *et al*. 2013; Juan-Borrás *et al*. 2014; Da Silva *et al*. 2016; Escuredo *et al*. 2013, 2014; Escuredo and Carmen Seijo 2019).

Several studies have investigated the physicochemical properties of *T. laeviceps* honey from various regions in Indonesia, including North Lombok, Magelang, Purworejo, Klaten, Gunungkidul, and Sleman. These studies have characterized parameters such as protein content (including at least 17 amino acids), minerals (Ca, Mg, Cu, Na, Fe, K, Mn, Al and Zn), vitamin C, various sugars (glucose, sucrose, fructose, and reducing sugars), phenolic and flavonoid content, antioxidant activity, and organic acids (Agus *et al*. 2019, 2021; Agussalim *et al*. 2019a, 2019b, 2021, 2022, 2023; Sabir *et al*. 2021; Agussalim and Agus 2022). However, there remains a lack of data on the chemical composition of honey produced by *T. clypearis* in Salut Village, Kayangan District, and by *Apis cerana* in Sukadana Village, Bayan District, both in North Lombok, which remains limited. Therefore, the aim of this study was to evaluate and compare the chemical composition of honey from *T. clypearis* and *A. cerana* from North Lombok, Indonesia.

2. Materials and Methods

Honey samples from *T. clypearis* and *A. cerana* were collected from four colonies per species during the dry season. Honey of *T. clypearis* collected directly from a meliponiculture farm in Salut Village, Kayangan District, North Lombok. Additionally, honey of *A. cerana* was obtained from Sukadana Village, Bayan District, North Lombok. All honey samples were stored in sterile plastic bottles at 5°C until chemical composition analysis. Information on dominant plant types within the farming area as nectar sources for bee feed was obtained through interviews with beekeepers.

2.1. Proximate Analysis

Proximate analysis, including analyses of moisture, protein, fat, and ash contents, was performed using methods described by the Association of Official Analytical Chemists (AOAC 2005). All analyses were performed in quadruplicate, and each analysis was performed in duplicate.

2.2. Mineral Contents

Fresh honey samples were used in this study, and mineral content was analyzed by atomic absorption spectrometry (AAS) following the method described by Sabir *et al*. (2021). Briefly, 1 g of honey was lyophilized and incinerated in a muffle furnace at 460°C for 15 hours to obtain ash for total mineral determination (Ca, Cu, Fe, Mg, Mn, Na, K, Zn, P, and Al). The resulting ash was cooled and treated with 2.5 mL of HNO_3 2N, then heated on a thermostatic hotplate to ensure complete mineralization. The sample was further heated in a muffle furnace at 460°C for 1 hour. The final ash residue was dissolved in 1 mL of 20% HCl (v/v) and diluted to a final volume of 10 mL with deionized water prior to AAS analysis. All analyses were performed in quadruplicate, and each analysis was performed in duplicate.

2.3. Total Phenolic Content

The total phenolic content (TPC) of the honey samples was determined according to the method described by Agussalim *et al*. (2022) using the Folin-Ciocalteu spectrophotometric assay. Briefly, 2 g of honey was transferred into a 10 mL test tube, followed by the addition of 0.5 mL of Folin-Ciocalteu reagent and 7.5 mL of distilled water. The mixture was thoroughly vortexed and allowed to stand at room temperature (18-25°C) for 10 minutes. Subsequently, 1.5 mL of 20% sodium carbonate solution was added, and the volume was adjusted to 10 mL with distilled water. The mixture was incubated, and absorbance was measured at 760 nm using a spectrophotometer. All analyses were performed in quadruplicate, and each analysis was performed in duplicate.

2.4. Total Flavonoid Content

The total flavonoid content of the honey samples was determined using the spectrophotometric method described by Agussalim *et al*. (2022). Briefly, 0.10 g of honey was placed into a 10 mL test tube, followed by the addition of 0.3 mL of sodium citrate. After 5 minutes, 0.6 mL of 10% aluminum chloride solution was added. The mixture was allowed to stand for about 5 minutes before adding 2 mL of 1 M sodium hydroxide. The volume was then brought up to 10 mL with distilled water, and the solution was thoroughly mixed. Absorbance was

measured at 510 nm using a spectrophotometer. All analyses were performed in quadruplicate, and each analysis was performed in duplicate.

2.5. Reducing Sugar

The reducing sugar content of honey samples was determined using the Layne-Enyon method, as described by Agussalim *et al*. (2019a). Briefly, 2.6 g of honey was transferred into a 500 mL volumetric flask and diluted to volume. For the titration, 5 mL each of standardized Fehling's solutions A and B were placed into a 250 mL Erlenmeyer flask, along with 7.0 mL of distilled water and 15.0 mL of the diluted honey solution. The mixture was heated to boiling, and 1.0 mL of 0.2% methylene blue solution was added as an internal indicator. Titration was performed by gradually adding the honey solution until the blue color disappeared, indicating the endpoint. All analyses were performed in quadruplicate, and each analysis was performed in duplicate.

2.6. Amino Acids

The amino acid content of honey was analyzed by liquid chromatography-mass spectrometry (LC-MS), following the method described by Agussalim *et al*. (2021) with minor modifications. Approximately 2 g of honey was transferred into a 50 mL Erlenmeyer flask, followed by the addition of 20 mL of 6 N HCl. The mixture was vortexed for 2 minutes and then hydrolyzed in an autoclave at 100°C for 12 hours. After hydrolysis, the solution was neutralized with 50 mL of 6 N NaOH, vortexed, and filtered through a 0.22 µM filter. Amino acid separation was performed using a Purospher® Star RP-8ec column (150 mm × 4.6 mm, 3 µM). The filtrate was subsequently diluted tenfold, and a 2 µL aliquot was injected into the LC-MS system for analysis. All analyses were performed in triplicate.

2.7. Data Analysis

The chemical composition data of honey were analyzed using an independent-samples t-test in IBM SPSS Statistics version 23. Data were presented as mean ± standard error of the mean (SEM).

3. Results

The results revealed that the moisture, ash, protein, and phenolic contents of honey produced by *T. clypearis* were significantly higher than those of *A. cerana* ($p<0.05$, Table 1). However, the reducing sugar content of *T. clypearis* honey was significantly lower than that of *A. cerana* ($p<0.05$), but fat and flavonoid contents did not differ significantly (Table 1). The mineral contents, such as Cu, Fe, Ca, K, Na, Mn, Mg, and P (Table 2) of honey from *T. clypearis* were significantly higher compared to honey from *A. cerana* ($p<0.01$). The dominant minerals in both honey *T. clypearis* and *A. cerana* were K, followed by Mg, P, Ca, and Na (Table 2).

The present study revealed that the amino acid content of *T. clypearis* honey was significantly higher than that of *A. cerana* honey ($p<0.01$, Table 3), due to a higher protein content in *T. clypearis* honey (Table 1), indicating a positive correlation. Based on the LC-MS analysis, we found 17 amino acids in *T. clypearis* honey and 14 amino acids in *A. cerana* honey (Table 3). The dominant plant types serving as nectar sources differed between *T. clypearis* (banana, coconut, cashew, longan, mango, and cacao) and *A. cerana* (coconut, mango, cashew, and kapok) (Table 4).

Table 1. Chemical composition of honey produced by *T. clypearis* and *A. cerana*

Chemical composition (%)	*T. clypearis*	*A. cerana*	P value
Moisture	31.75±0.39[a]	25.29±1.06[b]	0.000
Ash	0.85±0.02[a]	0.68±0.02[b]	0.000
Fat	0.75±0.08	0.88±0.07	0.226
Protein	1.71±0.09[a]	1.46±0.08[b]	0.045
Reducing sugar	22.44±0.56[b]	45.77±5.04[a]	0.000
Flavonoid (w/w)	0.13±0.01	0.11±0.01	0.190
Phenolic (w/w)	1.08±0.02[a]	0.76±0.03[b]	0.000

Values are presented as mean ± SEM (standard error of the mean). Superscripts with different letters in the same row indicate significant differences at $p<0.01$

Table 2. Mineral content of honey produced by *T. clypearis* and *A. cerana*

Minerals content (mg/100 g)	*T. clypearis*	*A. cerana*	P value
Cu	1.96±0.13[a]	0.95±0.05[b]	0.000
Zn	2.70±0.04[b]	2.84±0.09a	0.010
Fe	5.43±0.24[a]	1.50±0.11[b]	0.000
Ca	159.13±2.55[a]	121.95±4.10[b]	0.000
K	5835.09±95.94[a]	4180.25±165.97[b]	0.000
Na	97.48±0.38[a]	77.58±2.98[b]	0.000
Mn	1.46±0.07[a]	0.73±0.10[b]	0.000
Mg	365.69±3.55[a]	207.24±9.55[b]	0.000
P	311.86±6.95[a]	249.73±21.36[b]	0.011
Al	Not detected	Not detected	

Values are presented as mean ± SEM (standard error of the mean). Superscripts with different letters in the same row indicate significant differences at $p<0.01$. "Not detected" indicates concentrations below the method detection limit

Table 3. Amino acids of honey produced by *T. clypearis* and *A. cerana*

Amino acids (mg/kg)	*T. clypearis*	*A. cerana*	P value
Arginine	983.76±28.96[a]	381.35±18.74[b]	0.000
Histidine	1,387.60±12.31[a]	259.05±10.53[b]	0.000
Lysine	1,135.48±23.93[a]	588.98±13.92[b]	0.000
Phenylalanine	296.63±3.58[a]	230.88±6.83[b]	0.000
Isoleucine	271.53±4.11[a]	not detected[b]	0.000
Leucine	525.25±12.33[a]	33.65±2.63[b]	0.000
Tyrosine	74.28±2.61[a]	12.38±0.64[b]	0.000
Methionine	42.85±2.70[a]	not detected[b]	0.000
Valine	380.00±5.72[a]	19.9±0.61[b]	0.000
Proline	499.09±5.14[a]	248.95±5.10[b]	0.000
Glutamic acid	1,722.64±28.43[a]	498.2±24.42[b]	0.000
Aspartic acid	1,185.88±20.89[a]	330.8±14.66[b]	0.000
Cysteine	12.35±0.76[a]	not detected[b]	0.000
Threonine	261.95±3.13[a]	20.33±2.54[b]	0.000
Serine	517.71±5.97[a]	169.75±8.34[b]	0.000
Alanine	402.03±7.29[a]	130.48±4.67[b]	0.000
Glycine	304.76±6.79[a]	169.73±7.45[b]	0.000

Values are presented as mean ± SEM (standard error of the mean). Superscripts with different letters in the same row indicate significant differences at $p<0.01$. "Not detected" indicates concentrations below the method detection limit

Table 4. Dominant plant species serving as nectar sources for honey production by *T. clypearis* and *A. cerana*

Salut, *T. clypearis*	Sukadana, *A. cerana*
Banana *(Musa paradisiaca)*	Coconut *(Cocos nucifera)*
Coconut *(Cocos nucifera)*	Mango *(Mangifera indica)*
Cashew *(Anacardium occidentale)*	Cashew *(Anacardium occidentale)*
Longan *(Dimocarpus longan)*	Kapok *(Ceiba pentandra)*
Mango (*Mangifera indica*)	-
Cacao *(Theobroma cacao)*	-

(-) Indicate the absence of dominant nectar sources

4. Discussion

Moisture is the second most abundant component in honey, after sugars, and is one of the key criteria of honey quality. It is a critical parameter influencing various physical properties of honey, including crystallization, flavor, color, and taste (Escuredo *et al*. 2013; Da Silva *et al*. 2016). Generally, honey from stingless bee species exhibits higher moisture content compared to that from honeybees (*Apis* genus). The high moisture content has a significant impact on the fermentation process and shelf life of honey when stored at room temperature; however, at 3-5°C, it can be maintained. This difference is partly attributed to the foraging behavior of stingless bees, which often collect nectar and other materials from ripe fruits with high moisture content (Guerrini *et al*. 2009; Suntiparapop *et al*. 2012; Agussalim *et al*. 2021). Additionally, honeybees (*Apis* genus) have developed behavioral mechanisms to reduce honey moisture through active evaporation, a process that stingless bees are less capable of performing (Suntiparapop *et al*. 2012). The different moisture contents of honey in our study are influenced by the different plant types used as nectar sources (Table 4).

Furthermore, the high temperatures combined with low humidity tend to produce nectar with lower moisture content and higher sugar concentration. In contrast, low temperatures with high humidity yield nectar with higher moisture content and lower sugar levels. These variations in nectar moisture are attributed to the sugar's hygroscopic properties, which absorb more moisture from humid air than from dry air (Agussalim *et al*. 2021). The honey moisture in our study differs from previous reports (Biluca *et al*. 2016; Chuttong *et al*. 2016; Ranneh *et al*. 2018; Agussalim *et al*. 2019b, 2023; Agussalim and Agus 2022; Erwan and Agussalim 2022).

The mineral content of honey is strongly influenced by the botanical origin of the nectar, with different plant species contributing distinct mineral profiles (Table 4). The K, Mg, P, Ca, and Na were the dominant minerals in both *T. clypearis* and *A. cerana* honeys (Table 2). These findings are consistent with those reported by Sabir *et al*. (2021), who observed that *T. laeviceps* honey from Lombok, Magelang, and Purworejo was dominated by the minerals K, Ca, Mg, and Na. The ash content has been positively correlated with the mineral content and is used to evaluate their content (Suntiparapop *et al*. 2012; Da Silva *et al*. 2016; Sabir *et al*. 2021). The ash and mineral contents are influenced by environmental, geographical, and botanical factors (Suntiparapop *et al*. 2012; Karabagias *et al*. 2014; Da Silva *et al*. 2016; Sabir *et al*. 2021). The type of plant and its flowers serving as the nectar source collected by worker bees significantly influences the ash and mineral content of honey (Sabir *et al*. 2021).

Furthermore, the mineral content of honey can reflect environmental pollution, with certain heavy metals potentially originating from anthropogenic sources. Heavy metals such as Cd, Cr, Pb, and Ni are commonly used as indicators to assess environmental contamination (Bogdanov *et al*. 2007); however, these elements were not measured in the present study, which represents a limitation of this work. Additionally, honey mineral content is related to flavor and color, with darker color and stronger flavor indicating higher mineral content

(Escuredo *et al*. 2013; Karabagias *et al*. 2014; Sabir *et al*. 2021). It's also found that honey from *T. clypearis* is darker than honey from *A. cerana*. The ash and mineral contents in our study differ from those reported in previous studies (Sabir *et al*. 2021; Bhatta and Naresh Kumar 2023; Muhammad and Sarbon 2023).

The protein content of *T. clypearis* honey was higher than that of *A. cerana* honey, possibly because pollen pots (bee bread) are inadvertently collected during *T. clypearis* honey harvesting. In this species, pollen pots are situated near the honey pots and are often stacked above or below them. As a result, when the honey is harvested, it will be mixed with pollen, which will impact its protein content. By contrast, in *A. cerana*, honey is stored in the upper section of the comb and bee bread in the bottom section, a spatial arrangement that minimizes the co-harvesting of bee bread and consequently results in lower protein content in the honey. According to Da Silva *et al*. (2016), the protein content of honey varies across different honeybee and stingless bee species, largely influenced by the foraging distance of worker bees during nectar collection.

Da Silva *et al*. (2016) explain that the protein content of *A. cerana* honey ranges from 0.1-3.3%, *A. mellifera* is 0.2-1.6%, and in our study, it is 1.71% for *T. clypearis* and 1.46% for *A. cerana*. The protein and amino acids present in honey originate from nectar and honeydew, including the fluids secreted by the pharynx and salivary gland of the bees (Sak-Bosnar and Sakač 2012; Escuredo *et al*. 2013; Da Silva *et al*. 2016) however, the main source is pollen (Da Silva *et al*. 2016). The protein contains amino acids, and the relative proportions depend on forages such as nectar, honeydew, and pollen (Da Silva *et al*. 2016).

The amino acids in *T. clypearis* honey is similar with previously study by Agussalim *et al*. (2021) that the *T. laeviceps* is found 17 amino acids such as arginine, histidine, lysine, phenylalanine, isoleucine, leucine, tyrosine, methionine, valine, proline, glutamic acid, aspartic acid, cysteine, threonine, serine, alanine, and glycine; however, in *A. cerana* honey was not detected isoleucine, methionine, and cysteine (Table 3). Amino acids constitute about 1% (w/w) of honey, and their composition varies according to the botanical origin (Hermosín *et al*. 2003; Da Silva *et al*. 2016). Proline is a predominant amino acid, occurring in both honey and pollen (Iglesias *et al*. 2006; Da Silva *et al*. 2016). Proline, which predominantly originates from the salivary secretions of honeybees during nectar transformation into honey, typically constitutes approximately 50-85% of the total amino acid content in honey (Hermosín *et al*. 2003; Da Silva *et al*. 2016). However, in our study, glutamic acid was identified as the predominant amino acid due to its role as the primary component of bee pollen and its involvement in enzymatic processes during nectar conversion into honey. Additionally, glutamic acid content indicates honey maturity, and its concentration can change during storage. Proline is widely recognized as an indicator of honey maturation and, in some cases, as a marker for detecting honey adulteration with sugar, with a minimum threshold of 180 mg/kg (Hermosín *et al*. 2003; Da Silva *et al*. 2016). In our study, the proline content was 499.09 mg/kg in *T. clypearis* honey and 248.95 mg/kg in *A. cerana* honey, indicating that both honeys were mature and pure.

Additionally, honey also contains various amino acids, including glutamic acid, glutamine, aspartic acid, glycine, histidine, arginine, threonine, α-alanine, β-alanine, γ-aminobutyric acid, tyrosine, methionine, valine, leucine, cysteine, isoleucine, tryptophan, phenylalanine, lysine, serine, ornithine, alanine, and asparagine (Hermosín *et al*. 2003; Da Silva *et al*. 2016). The differences in protein and amino acid contents between *T. clypearis* and *A. cerana* honeys in our study are likely attributed to variations in the plant species serving as nectar and pollen sources for honey and bee bread production. The protein content and amino acids in our study differ from those previously studied for stingless bee honey (Agussalim *et al*. 2021), *A. mellifera* honey (Xue *et al*. 2025; Belay *et al*. 2017; Kowalski *et al*. 2017; Sun *et al*. 2017), *A. andreniformis* honey (Sommano *et al*. 2020), and *A. cerana* honey (Xue *et al*. 2025).

Sugars in honey play important roles as an energy source and in determining its hygroscopicity, granulation, and viscosity. In *A. mellifera* honey, sugars are primarily composed of monosaccharides, which amount to approximately 75% of the total sugars, followed by disaccharides (10-15%) and minor quantities of other sugars (Kamal and Klein 2011; Da Silva *et al*. 2016). The reducing sugar content of honey produced by the stingless bee *T. clypearis* was significantly lower than that of honey from the *A. cerana*. In general, honey from honeybee species (*Apis* genus) contains higher sugar levels compared to honey from stingless bee species. The reducing sugar content of honey is influenced by several factors, including botanical origin (flower species as nectar sources), geographical origin (beekeeping or meliponiculture regions), climate, processing methods, and storage conditions (Tornuk *et al*. 2013; Escuredo *et*

al. 2014; Da Silva *et al*. 2016; Agussalim *et al*. 2019a; Agus *et al*. 2021).

All the honey in our study was fresh, so the plant types in each region influenced the reducing sugar content. We hypothesize that the different flowers affect the chemical composition of nectar; therefore, the chemical composition of honey will influence its reducing sugar content. However, this mechanism needs to be confirmed through further study. Furthermore, the relatively larger body size of *A. cerana* enables these bees to forage over greater distances and collect larger quantities of nectar from diverse floral sources, which may contribute to the higher reducing sugar content in their honey. Additionally, the high moisture content leads to sugar breakdown through fermentation into alcohol or to conversion to hydroxymethylfurfural (HMF) (Da Silva *et al*. 2016). Honey reducing sugar in our study for *T. clypearis* honey was 22.44%, and for *A. cerana* honey, 45.77%. The reducing sugar of honey in our study differs from that previously studied (Biluca *et al*. 2016; Nordin *et al*. 2018; Agussalim *et al*. 2019a; Agus *et al*. 2021; Villacrés-Granda *et al*. 2021; Erwan and Agussalim 2022). The reducing sugar content observed in this study did not comply with the Indonesian national standard and Codex Alimentarius for honey quality standards; however, such low reducing sugar levels may be advantageous for functional food applications, particularly for dietary management in diabetes mellitus, as suggested by our previous findings (Agussalim *et al*. 2024).

The higher phenolic content in *T. clypearis* honey is likely attributable to its storage in pots made from propolis, which contributes additional phenolic compounds. Furthermore, the different plant types used as nectar sources for honey production contribute to the phenolic content (Table 4) (Da Silva *et al*. 2016; Gül and Pehlivan 2018; Agus *et al*. 2019b; Agussalim *et al*. 2022). Plants produce a wide range of polyphenolic derivatives exhibiting substantial structural diversity and complexity. During nectar foraging, honeybees and stingless bees transfer these bioactive compounds from floral sources into honey, thereby enriching its functional properties (Da Silva *et al*. 2016).

Flavonoids are classified into several subclasses, including flavanols, flavones, anthocyanins, flavanones, isoflavones, and chalcones (Da Silva *et al*. 2016). The flavonoid and phenolic compounds identified in honey include vanillic acid, quercetin, caffeic acid, ferulic acid, syringic acid, kaempferol, myricetin, pinobanksin, gallic acid, p-coumaric acid, pinocembrin, galangin, ellagic acid, 3- and 4-hydroxybenzoic acids, chlorogenic acid, benzoic acid, and rosmarinic acid (Trautvetter *et al*. 2009; Alvarez-Suarez *et al*. 2012; Da Silva *et al*. 2016). The flavonoids and phenolics of honey in our study differ from those previously studied (Biluca *et al*. 2016; Gül and Pehlivan 2018; Ranneh *et al*. 2018; Agus *et al*. 2019; da S. Sant'ana *et al*. 2020; Agussalim *et al*. 2022; Mokaya *et al*. 2022).

Thus, honeys produced by *A. cerana* and *T. clypearis* were not acceptable according to the Indonesian National Standard (Badan Standardisasi Nasional 2024) or international standards regulated by Codex Alimentarius (Thrasyvoulou *et al*. 2018) in terms of moisture, ash, and reducing sugar contents. These deviations are likely attributable to differences in harvest maturity, soil nutrient availability, and the sugar composition of floral nectar, respectively. It can be concluded that the species of bees, floral sources, and geographical origins significantly contribute to honey quality. Based on proline content, honeys of *T. clypearis* and *A. cerana* used in this study were mature and unadulterated. Overall, *T. clypearis* honey exhibited higher concentrations of several bioactive compounds and essential minerals; however, some physicochemical parameters did not meet current honey quality standards.

Acknowledgements

The authors would like to thank the Directorate of Research Universitas Gadjah Mada, Indonesia, for funding through the Doctoral Competency Improvement Program 2025 (contract number: 4455/UN1.P2/Dit-Lit/PT.01.03/2025).

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