

## Comparative analyses of physico-chemical of *Apis mellifera* L. honey extracted from different floral resources and their health benefits

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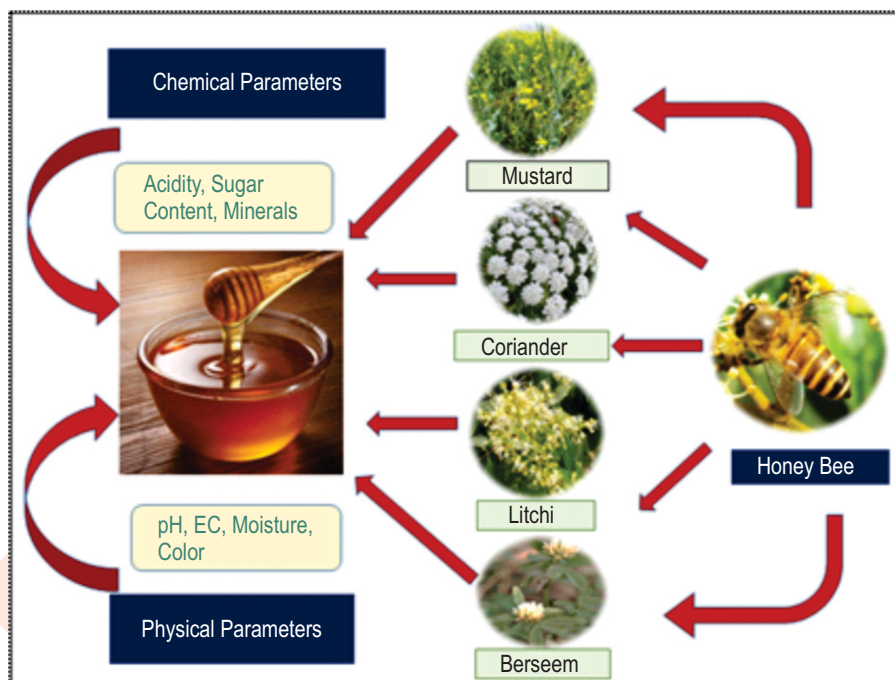
### Abstract

**Aim:** To analyze and compare the physico-chemical properties of *Apis mellifera* (L.) honey derived from major floral sources, including mustard, litchi, coriander and berseem.

**Methodology:** In this study physical parameters such as moisture content, color, pH, total soluble solids and electrical conductivity, were estimated along with chemical analysis of acidity, diastase activity, sugar composition and mineral contents.

**Results:** The results showed significant floral source variations in physico-chemical properties. The moisture content was highest in mustard honey and lowest in coriander honey. Litchi honey had the highest electrical conductivity, with pH ranging from 3.80 to 4.39. Color varied from amber (mustard) to extra white (litchi) and light amber (berseem).

**Interpretation:** The physico-chemical properties of honey, like moisture, pH and sugar content, reflect its quality and purity. Floral sources influence honey flavor, color and nutrition guiding consumer choices for health and culinary needs.



**Key words:** *Apis mellifera*, Flavour profiles, Floral sources, Honey, Nutritional benefits

## Introduction

Honey, often referred to as liquid gold, is a natural product of *Apis mellifera* (L.), resulting from the enzymatic transformation of nectar. The physico-chemical properties, of honey like color, flavor, viscosity and nutritional profile, are influenced by the floral sources of nectar. This study investigates the honey derived from Mustard (*Brassica* spp.), Litchi (*Litchi chinensis* Sonn.), Coriander (*Coriandrum sativum* L.) and Berseem (*Trifolium alexandrinum* L.), focusing on their unique flavors, aromas and nutritional attributes. By analyzing key parameters such as moisture content, pH, sugar concentration, electrical conductivity, and mineral contents etc., the research provides insights into the impact of floral origin on honey composition, contributing to understanding its quality, authenticity and potential applications. Beekeeping, integral to India's heritage, supports rural livelihoods by boosting income through bee flora management and diverse products. In the fiscal year 2023–24, the country exported 107,963.21 metric tonnes of natural honey, generating revenue of ₹1,470.84 crore (approximately USD 177.52 million) (APEDA, 2024).

The domestic honey market is also expanding. In 2023, it was valued at USD 815.6 million and is projected to reach USD 1,234.3 million by 2030, growing at a compound annual growth rate (CAGR) of 6.1% from 2024 to 2030 (Smith and Doe, 2023). India's beekeeping industry has experienced significant growth in recent years. As of 2018, the country had approximately 35 million bee colonies, a substantial increase from 8 million in 2005-2006 (Khan et al., 2007).

Beekeeping has seen significant growth in Uttarakhand, contributing to India's overall beekeeping industry, which includes approximately 250,000 units and an annual honey production of 94,500 metric tonnes (NBB, 2017). Of these, 8,700 beekeeping units are located in Uttarakhand, producing about 2,500 metric tonnes of honey in 2016-17 (Mishra and Rana, 2023). The primary economic output of honeybee colonies is honey, known for its distinct flavor, aroma and color. These characteristics are influenced by factors such as bee species, geographic origin, floral nectar availability, seasonal and climatic conditions, and the techniques used in honey extraction and storage (Castro et al., 2010). India's diverse agro-climatic zones support a wide variety of flowering plants crucial for honey production, with foraging preferences differing significantly among the bee species. These preferences are influenced by factors such as flower color, shape, scent, and nectar availability, and vary across species like *Apis dorsata* Fab., *Apis cerana* Fab., *A. mellifera*, *Apis florea* Fab., and stingless bee *Tetragonula* sp. According to Singh and Singh (2016), *A. cerana* and *A. mellifera* predominantly forage on crops like mustard (*Brassica* spp.), sunflower (*Helianthus annuus*), coriander (*C. sativum*), sesame (*Sesamum indicum*), and horticultural plants such as litchi (*L. chinensis*), guava (*Psidium guajava*), citrus (*Citrus* spp.), tulsi (*Ocimum sanctum*), and marigold (*Tagetes* spp.). In contrast, *A. dorsata*, a wild bee species, shows a preference for forest plants, including jamun

(*Syzygium cumini*), neem (*Azadirachta indica*), shisham (*Dalbergia sissoo*), acacia (*Acacia* spp.), and eucalyptus (*Eucalyptus* spp.). Recent studies (Tulu et al., 2023) highlight the reliance of *A. dorsata* on additional nectar sources such as *Prosopis juliflora*, *Punica granatum*, with monofloral sources like *Eucalyptus camaldulensis* contributing significantly to honey production. However, *A. florea*, the dwarf honey bee, forages primarily on citrus, litchi and guava (Bhusari et al., 2007). Similarly, stingless bees (*Tetragonula* sp.) forage across diverse plant families like Fabaceae and Asteraceae, exhibiting preference for economically important plants such as *Cocos nucifera* and *Musa paradisiaca* (Vijayakumar and Jeyaraaj, 2016).

The floral origin, closely tied to geographical location and climatic conditions, is a key factor influencing the physico-chemical variations in honey, due to differing chemical compositions and physical properties of plant nectars, secretions, and pollens (Mohammed, 2022). Honey is renowned for its nutritional and therapeutic properties, which vary depending on the botanical and geographical origins of its nectar. Several physico-chemical parameters, such as moisture content, acidity, and Hydroxymethylfurfural levels, have been identified as key indicators of honey quality (Mesele, 2020). These factors are shaped by the species of bees, the type of flowers they forage on, climate conditions, and the methods of honey processing (Thakur et al., 2022). Additionally, research by Al-Kafaween et al. (2023) highlighted the diverse biological activities of honey, including antibacterial, antifungal, antiviral, antioxidant, antidiabetic, antiobesity, anticancer, anti-inflammatory and wound-healing properties. Moreover, honey has demonstrated positive effects on cardiovascular, nervous and respiratory systems. These findings confirm that honey is not only a high-quality product but also a potent source of beneficial biological activity.

This study investigates the influence of floral origin on the physico-chemical properties of honey. The findings aim to provide scientific insights into the relationship between floral sources and honey characteristics, contributing to a better understanding of its quality attributes. This research seeks to enhance knowledge on the unique properties of honey from different floral origins.

## Materials and Methods

*A. mellifera* colonies were placed in separate locations (Table 1) to prevent cross-pollination and managed during specific flowering seasons to ensure targeted foraging. Honey samples from mustard, coriander, litchi and berseem were collected in sterilized glass bottles, blended, filtered, and stored at 10–16°C with <65% relative humidity. Samples, named by floral source, were analyzed for physico-chemical parameters like moisture, pH, sugars, electrical conductivity, HMF, diastase activity location, acidity etc. The physico-chemical analyses of honey was estimated as per the methods established by AOAC (2012) and Bogdanov et al. (1997). The analyses were carried out in triplicate.

**Table 1:** Floral resource for different honey at different location

Common name	Scientific name	Flowering period	Source*	Location of bee colonies
Mustard	<i>Brassica</i> spp.	Dec-Jan	N,P	Crop Research Centre
Litchi	<i>Litchi chinensis</i> Sonn.	Feb-Mar	N,P	Horticulture Research Centre
Coriander	<i>Coriandrum sativum</i> L.	March-April	N,P	Vegetable Research and Training centre
Berseem	<i>Trifolium alexandrinum</i> L.	April-May	N,P	Livestock Research Centre/ Instructional Dairy farm

\*N=Nectar, P=Pollen

**Table 2:** Colour index scale

Colour	Pfund scale (mm)
Water white	< 08
Extra white	09–17
White	18–34
Extra light amber	35–50
Light amber	51–85
Amber	86–114
Dark amber	>114

### Physical parameters

Moisture content was determined from the refractive index of honey. A digital refractometer (BioGEN Scientific), that can be thermostated at 20°C, regularly calibrated with distilled water or with another certified reference material (Bogdanov *et al.*, 2002). The appearance of honey was assessed using the color index scale (mm) from the National Bee Board (2017) and the Pfund classifier. Homogeneous, bubble-free samples were measured in a 10 mm cuvette using a color photometer. Results, expressed in mm Pfund grades against a glycerol standard, were obtained in triplicate per sample, following the approved standards (Table 2).

The pH meter was calibrated with pH buffer, where 10 g of honey was taken in a beaker and placed under a pH probe tube and then the pH of honey sample was determined by pressing the pH button of Digital pH meter (Bogdanov *et al.*, 2002). Total soluble solids was measured using a hand refractometer (ERMA Japan) ranging between 58 to 92° Brix. Thereafter, the prism was washed off with distilled water, dried with a cotton, thereafter, a drop of honey was placed in the prism and the readings were noted. The electrical conductivity at 1/5 was determined according to the method described by Bogdanov *et al.* (2002) using a conductometer (Systronics conductivity meter 308). The measurements were carried out at 20°C in a 20% aqueous solution with respect to dry matter of honey. The conductivity value was directly determined by the cell in the solution after immersion. The results were expressed in  $\mu\text{S cm}^{-1}$ .

### Chemical parameters

Titrate acidity of honey samples was determined according to AOAC (2012). Ten gram of honey sample was dissolved in 75 ml of CO<sub>2</sub> free distilled water in a 250 ml beaker and stirred with a magnetic stirrer. The solution was titrated with 0.1M NaOH solution to a final pH of 8.5. Diastase activity was estimated by dissolving a 5 g of sample in water and buffer solution, incubating with starch at 40°C, and analyzing photometrically (Bogdanov *et al.*, 2002) to determine diastase number (DN). The results were expressed in Schade units per gram of honey and termed Diastase Number (DN).

The reducing sugar content in honey sample was determined by the modified procedure of Lane and Eynon (1923). The procedure involved reduction of Soxhlet's modification of Fehling's solution by titrating with copper sulphate at 60°C against a solution of reducing sugars in honey, using methylene blue as an internal indicator. The sucrose content of the honey samples was determined according to Pearson (1971). Titration was done following a procedure similar to that for estimating reducing sugars. Non-reducing sugars were determined by subtracting the reducing sugars from the total sugars. Hydroxymethylfurfural content in honey samples was determined following the method outlined by Bogdanov *et al.* (2002).

Absorbance was read at 284 nm on a UV Spectrophotometer (Eppendorf India). Fiehe's test, as described by Phadke (1967), was also employed as a preliminary qualitative assessment to underscore the importance of monitoring levels for ensuring honey quality. The mineral content was determined using an atomic absorption spectroscopy (AOAC, 2012). This method was employed to quantify essential minerals like calcium, iron, manganese, zinc, copper, magnesium, nickel and chromium.

**Statistical analysis:** Analysis of variance (ANOVA) was employed to compare the quantified variables among the honey samples. The analyses were performed using SPSS Statistics software, and treatment means were compared by Duncan's Multiple Range Test at a 5% significance level ( $P < 0.05$ ).

## Results and Discussion

The results of physico-chemical analysis of honey obtained from various floral origins are presented in Table 3 and 4. The acidic nature of honey attributed to the presence of organic acids which is a key factor for its stability, texture, shelf life and flavor. In this study, the pH levels of honey samples from different floral sources were analyzed, revealing subtle differences in flavor profiles. Coriander honey exhibited the highest pH of 4.39, resulting in a milder and smoother taste. Litchi honey (pH 4.13) and Mustard honey (pH 4.01) provided balanced acidity, while Berseem honey, with the lowest pH of 3.80, had a strong flavor. Although the pH variations were not statistically significant ( $p > 0.05$ ), the range of 3.80–4.39 offered diverse flavor options for consumers. These findings are consistent with the previous studies. Dobrinas *et al.* (2022) found pH levels ranging between 4.10–5.0 in honey obtained from beekeepers, local markets, and organic sources, all within the acceptable range. Raweh *et al.* (2023) documented a wider pH range of 3.5–7.1 in Saudi Arabian honey, with three Sidr honey samples exceeding the typical range of 3.4–6.1. Similarly, Adalina *et al.* (2024) found that monofloral honey had a pH range of 4.1–4.5 (average 4.3), while in multifloral honey the pH ranged between 3.5–4.5 (average 4.0). These results highlight the influence of floral origin, geography, and environmental factors on honey's pH, contributing to its sensory attributes and consumer appeal. Albu *et al.* (2021) reported pH values ranging between 3.675 in acacia honey samples and 5.398 in linden honey samples.

Electrical conductivity (EC) is a critical indicator of honey quality, reflecting its mineral content, which influences flavor and texture. In this study, EC values ranged from 0.27 to 0.58  $\text{mS cm}^{-1}$ , aligning with European standards ( $< 0.80 \text{ mS cm}^{-1}$  for blossom honey). Litchi honey exhibited the highest EC (0.58  $\text{mS cm}^{-1}$ ), providing a robust flavor, while Mustard honey had the lowest EC (0.27  $\text{mS cm}^{-1}$ ), offering a subtler taste. Coriander and Berseem honeys had EC values of 0.33 and 0.57  $\text{mS cm}^{-1}$ , respectively, indicating balanced flavor profiles. These results align with previous research of Krishna and Hasani (2015), who reported EC values of 0.35  $\text{mS cm}^{-1}$  for natural honey and 0.27  $\text{mS cm}^{-1}$  for industrial honey, demonstrating a range suited to various preferences. Similarly, Beykaya (2021) observed EC values of 0.21–1.16  $\text{mS cm}^{-1}$  in honey from different Turkish regions, while Lim *et al.* (2022) recorded EC values of 0.35–1.08  $\text{mS cm}^{-1}$  in Peninsular Malaysian honey, emphasizing regional variability. Notably, secretion honeys tend to exhibit higher EC values than floral honeys, underscoring the link between EC and honey's floral origin, which influences its sensory characteristics and consumer appeal.

Moisture content plays a pivotal role in determining honey's quality, influencing both texture and flavor. In this study, honey from different floral sources exhibited variability in moisture content. Mustard honey had the highest moisture content at 19.56%, resulting in a smooth texture favored by some consumers. Litchi honey followed at 18.56%, offering a slightly

thicker consistency, while Berseem and Coriander honeys had lower moisture contents of 17.74% and 17.45%, respectively, creating a denser and richer flavor profile. These differences, statistically significant ( $p > 0.05$ ), are influenced by factors such as floral origin, ripeness, weather conditions, and extraction methods. Supporting these findings, Raweh *et al.* (2023) reported differences in moisture content between local and imported honey samples. Imported honey exhibited a higher average moisture content ( $17.2 \pm 0.3\%$ ) compared to local honey ( $14.9 \pm 0.2\%$ ), though both remained within the acceptable limit of 20%. Similarly, Adalina *et al.* (2024) observed water content ranging between 22.0 to 28.0% in honey samples, emphasizing the influence of geographical and environmental factors on honey composition. These results highlight the importance of maintaining moisture levels within regulatory standards to ensure quality and consumer satisfaction.

Total soluble solids (TSS) serve as a critical indicator of sugar content in honey, directly influencing its sweetness and consumer preference. In this study, TSS values varied across floral sources. Coriander honey exhibited the highest TSS (82.55°Brix), offering a rich, concentrated sweetness. Berseem honey followed at 82.26°Brix, while Litchi and Mustard honeys recorded slightly lower values of 81.44° and 80.44°Brix, respectively, appealing to consumers who prefer milder sweetness. Although the differences in TSS were not statistically significant ( $p > 0.05$ ), these variations underscore diverse flavor profiles among honey types. These findings partially align with earlier studies. Abdi *et al.* (2024) reported TSS values ranging from 75.9 to 77.5°Brix, with an average of 76.5°Brix. The study noted significantly higher TSS levels ( $p < 0.05$ ) in samples from local retailers as compared to local producers, suggesting possible adulteration or aging. Similarly, Albu *et al.* (2021) found TSS values ranging between 79.23 to 84.80%, with significant differences ( $p < 0.05$ ) between acacia and linden honeys. Linden honey showed the highest TSS (up to 83.26°Brix), while acacia honey had the lowest (as low as 77.83°Brix). The range of TSS values observed in this study reaffirms natural sweetness and quality of honey, emphasizing the need for regular monitoring to prevent adulteration and ensure product authenticity.

Honey color, a key determinant of consumer appeal, exhibited significant variation across floral sources in this study, ranging from extra white to amber. Mustard honey displayed an amber hue (86–114 mm Pfund), while Litchi honey was extra white (9–17 mm). Coriander honey was classified as extra light amber (35–50 mm), and Berseem honey fell into the light amber category (51–85 mm). These variations cater to diverse consumer preferences, offering a spectrum from light to rich tones. The findings align with Beykaya (2021), who reported color values ranging from 20.0 to 110 mm Pfund in honey samples from different Turkish regions, with chestnut honey showing a value of 88.3 mm Pfund. Similarly, Adalina *et al.* (2024) noted that monofloral honey exhibited intensity values between 47 and 143 mm Pfund whereas multifloral honey ranged from 74 to 100 mm Pfund. These differences are primarily influenced by the floral

**Table 3:** Physico-chemical properties of honey collected from different bee flora

Honey parameters	Honey obtained from different bee flora				SE (±)	CD at 5%
	Mustard	Litchi	Coriander	Berseem		
pH	4.01 <sup>a</sup>	4.13 <sup>b</sup>	4.39 <sup>a</sup>	3.80 <sup>c</sup>	0.066	0.823
EC (mS cm <sup>-1</sup> )	0.27 <sup>bb</sup>	0.58 <sup>a</sup>	0.33 <sup>bb</sup>	0.57 <sup>a</sup>	0.041	0.112
Moisture (%)	19.56 <sup>a</sup>	18.56 <sup>b</sup>	17.45 <sup>c</sup>	17.74 <sup>d</sup>	0.248	0.089
TSS (°Brix)	80.44 <sup>b</sup>	81.44 <sup>b</sup>	82.55 <sup>bc</sup>	82.26 <sup>a</sup>	0.346	0.113
Free acidity (meq kg <sup>-1</sup> )	20.45 <sup>c</sup>	24.56 <sup>b</sup>	16.50 <sup>d</sup>	32.22 <sup>a</sup>	2.942	1.240
Lactone acidity (meq kg <sup>-1</sup> )	5.07 <sup>d</sup>	7.98 <sup>c</sup>	6.56 <sup>b</sup>	8.16 <sup>a</sup>	0.518	0.121
Total acidity (meq kg <sup>-1</sup> )	25.52 <sup>c</sup>	32.54 <sup>b</sup>	23.06 <sup>d</sup>	40.38 <sup>a</sup>	3.163	0.214
HMF (mg kg <sup>-1</sup> )	8.45 <sup>d</sup>	16.91 <sup>a</sup>	10.97 <sup>c</sup>	14.76 <sup>b</sup>	0.991	0.041
Diastase (Schade)	19.45 <sup>b</sup>	15.54 <sup>c</sup>	14.54 <sup>d</sup>	25.86 <sup>a</sup>	1.344	0.117
Reducing sugar (%)	56.21 <sup>c</sup>	57.33 <sup>a</sup>	52.36 <sup>d</sup>	56.85 <sup>b</sup>	0.592	0.049
Non-reducing sugar (%)	6.56 <sup>d</sup>	11.26 <sup>a</sup>	9.21 <sup>b</sup>	7.74 <sup>c</sup>	0.529	0.023
Total Sugar (%)	62.77 <sup>c</sup>	68.59 <sup>a</sup>	61.57 <sup>d</sup>	64.59 <sup>b</sup>	0.804	0.123

Values are mean ± S.E.; Treatment means were compared with Duncan's Multiple Range Test at 5% level of significance.

**Table 4:** Mineral content in the honey collected from different bee floras

Minerals	Mustard (ppm)	Litchi (ppm)	Coriander (ppm)	Berseem (ppm)	SE (±)
Ca	8.54 <sup>a</sup>	6.72 <sup>b</sup>	4.33 <sup>c</sup>	4.74 <sup>c</sup>	1.27
Fe	2.67 <sup>a</sup>	0.81 <sup>c</sup>	0.24 <sup>d</sup>	1.56 <sup>b</sup>	0.55
Mn	2.08 <sup>b</sup>	2.68 <sup>a</sup>	2.18 <sup>b</sup>	0.29 <sup>c</sup>	0.52
Zn	0.36 <sup>b</sup>	0.20 <sup>c</sup>	1.10 <sup>a</sup>	0.22 <sup>c</sup>	0.20
Cu	0.04 <sup>a</sup>	0.23 <sup>a</sup>	0.30 <sup>a</sup>	0.16 <sup>a</sup>	0.03
Mg	2.01 <sup>b</sup>	2.63 <sup>a</sup>	0.78 <sup>c</sup>	2.31 <sup>b</sup>	0.30
Ni	0.06 <sup>a</sup>	0.18 <sup>a</sup>	0.09 <sup>a</sup>	0.11 <sup>a</sup>	0.01
Cr	0.31 <sup>a</sup>	0.22 <sup>a</sup>	0.42 <sup>a</sup>	0.50 <sup>a</sup>	0.02

Treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance (p<0.05).

source, nectar, pollen pigments, and non-enzymatic browning reactions during honey storage and processing.

Acidity is a vital chemical property of honey that affects its flavor, preservation and overall quality, playing a key role in consumer preferences. In this study, the total acidity of four floral honey types—Mustard, Litchi, Coriander and Berseem—was evaluated, revealing significant variations ( $p > 0.05$ ). Mustard honey exhibited a total acidity of 25.25 meq kg<sup>-1</sup>, Litchi honey 39.54 meq kg<sup>-1</sup>, Coriander honey 21.56 meq kg<sup>-1</sup> and Berseem honey 47.40 meq kg<sup>-1</sup>, with the highest acidity was observed in Berseem honey and the lowest in Coriander honey. These values, ranging from 21.56 to 47.40 meq kg<sup>-1</sup>, comply with the maximum permissible limit of 50 meq kg<sup>-1</sup> set by Bogdanov *et al.* (2002), and Codex Alimentarius standards (2019). The findings align with Albu *et al.* (2021) who reported the lowest free acidity in acacia honey (8.6 meq kg<sup>-1</sup>) and the highest in multifloral honey (27.1 meq kg<sup>-1</sup>). Similarly, Sharma *et al.* (2024) reported high acidity in Yemeni and Egyptian honey samples compared to honey samples from Saudi Arabia and Kashmir. Raweh *et al.* (2023) observed a wide acidity range for local honey (11 to 110 meq kg<sup>-1</sup>, mean = 61 ±

8.3 meq kg<sup>-1</sup>), significantly higher than imported honey (7 to 37 meq kg<sup>-1</sup>, mean = 18 ± 2.1 meq kg<sup>-1</sup>). Adalina *et al.* (2024) reported honey acidity between 1.83 and 7.5 ml of NaOH 0.1N kg<sup>-1</sup>, with monofloral honey showing a mean value of 4.93 ml NaOH 0.1N kg<sup>-1</sup> and multifloral honey a mean of 2.79 ml NaOH 0.1N kg<sup>-1</sup>. These findings collectively underscore the importance of monitoring honey acidity, ensuring adherence to quality standards and offering products that meet diverse consumer expectations.

Hydroxymethylfurfural is a vital quality parameter in honey, as its concentration rises during processing and storage, affecting flavor and consumer preference. In this study, Hydroxymethylfurfural levels varied significantly among the analyzed floral honey types ( $p > 0.05$ ). Litchi honey exhibited the highest Hydroxymethylfurfural content (16.91 mg kg<sup>-1</sup>), followed by Berseem (14.76 mg kg<sup>-1</sup>), Coriander (10.97 mg kg<sup>-1</sup>), and Mustard (8.45 mg kg<sup>-1</sup>) honeys. The lower Hydroxymethylfurfural content in Mustard honey compared to Litchi honey highlights the role of floral origin, processing and storage conditions. These findings partially align with Abera and Alemu (2023), who reported

higher Hydroxymethylfurfural levels (22.66–65.94 mg kg<sup>-1</sup>) in honey samples from Ethiopian lowland, midland and market sources. In contrast, Adalina *et al.* (2024) observed lower Hydroxymethylfurfural contents in monofloral honey (0.47–0.64 mg kg<sup>-1</sup>) and multifloral honey (0.43–0.55 mg kg<sup>-1</sup>), emphasizing the influence of floral source and regional differences on Hydroxymethylfurfural levels.

Freshly harvested honey contains small amounts of HMF, typically around 0.06–0.2 mg 100 g<sup>-1</sup>, which can increase during storage due to factors such as temperature and time. These results underscore the need for proper handling and storage practices to maintain honey quality and meet consumer expectations. Diastase enzyme (amylase) activity is a crucial factor in honey, as it breaks down starch into simpler sugars, contributing to its sweetness and health benefits. Proper heating and storage are essential for preserving diastase activity, which is vital for maintaining nutritional and market value of honey. In this study, diastase activity varied across different floral sources, with Mustard honey showing an average of 19.45 DN, Litchi honey at 15.54 DN, Coriander honey 14.50 DN and Berseem honey exhibiting the highest activity 25.86 DN. These differences were statistically significant ( $p > 0.05$ ). Berseem honey, with the highest diastase activity, stands out as particularly beneficial for health-conscious consumers due to its natural enzymatic properties. These results are consistent with the findings of Raweh *et al.* (2023) who reported a range of diastase values for local honey samples from 5.2 to 29.0 DN, with a mean of 11.9 DN, falling within the Codex Alimentarius standard ( $\geq 8$  DN). Abdi *et al.* (2024) also noted a significant reduction in diastase activity ( $p < 0.05$ ) in adulterated honey, where addition of sugar syrup led to a decreased the DN value from 14 to 4. This reduction suggests that heat exposure or adulteration may lead to enzyme denaturation, emphasizing the importance of maintaining diastase activity for authentic honey.

The reducing sugar content is a crucial factor in determining quality of honey, sweetness, and nutritional value. In this study, the reducing sugar concentrations in Mustard, Litchi, Coriander and Berseem honey were 62.77, 68.59, 61.57 and 64.59%, respectively. The differences in reducing sugar levels between the honey types were statistically significant ( $p > 0.05$ ), indicating that the floral source plays a significant role in the composition of honey. These findings are consistent with previous research on honey from various botanical sources. For example, Sharma *et al.* (2021) analyzed Italian honey and reported combined glucose and fructose content at 72.3%, with sucrose levels at 5.55%. Similarly, Adalina *et al.* (2024) found that the reducing sugar content in honey ranged from 79.03 to 94.88%, with variation attributed to floral source and geographical location. These differences in sugar content highlight the impact of nectar sources on honey composition, also noted by Lan *et al.* (2021). Mongi and Ruhembe (2024) observed variability in sugar content across different honey samples, reporting TSC values ranging from 72.6 to 75.8%. Their findings indicate that while honey from monofloral and multifloral sources generally adheres to the minimum sugar content (65%). Maintaining optimal levels of reducing

sugars is critical for ensuring quality and marketability of honey. Higher reducing sugar content enhances its natural sweetness, appealing to consumers who prioritize taste and health benefits.

When evaluating health benefits of honey, analyzing its mineral content provides insight into its nutritional value and quality. The mineral content of honey varied significantly based on its floral sources (Table 4), contributing to its unique characteristic. In this study, Mustard honey exhibited the highest calcium content (8.54 ppm), which is beneficial for bone and dental health. Coriander honey was rich in zinc (1.10 ppm), an essential mineral required for immune function and cell repair. Litchi honey showed the highest concentrations of manganese (2.68 ppm) and magnesium (2.63 ppm), both of which play vital roles in antioxidant defense, muscle function and cardiovascular health. Each type of honey in this study provides distinct mineral advantages, though all types are universally recognized for their health-promoting properties. They supply essential trace elements, natural sugars, and bioactive compounds that contribute to energy metabolism, immune defense, and overall well-being. These findings are consistent with previous studies on mineral content of honey. Linkon *et al.* (2015) observed significant variations in calcium levels across honey types, with concentrations ranging between 75.4 to 1710.499 ppm.

Barreiros *et al.* (2024) highlighted the role of honey in contributing to daily mineral intake, noting that consuming 20 g of honey daily could provide approximately 15% of the recommended intake of manganese, 5% selenium, 3.5% zinc and 1% copper. Bogdanov *et al.* (2007) highlighted the presence of key minerals, including potassium, calcium, magnesium, iron, manganese, zinc and copper, contributing to honey's therapeutic properties, such as antioxidant and immune-supporting effects. Similarly, Al-Kafaween *et al.* (2023) elucidated that honey contain approximately 180 distinct compounds, including amino acids, vitamins, minerals and enzymes. The composition of honey varies significantly depending on its floral source and geographical origin. Among the major and minor elements, potassium is typically found in high concentrations, followed by sodium, calcium and magnesium. Research shows that honey possess diverse biological activities, including antimicrobial, antioxidant, antidiabetic, anticancer, anti-inflammatory and wound-healing effects, while benefiting cardiovascular, nervous and respiratory systems.

This study underscores honey as a nutrient-rich natural food, aligning with dietary trends that emphasize reduced sugar intake and increased antioxidants. Analyzing honey from four floral sources—Mustard, Litchi, Coriander and Berseem—produced by *A. mellifera*, the research reveals that botanical origin significantly affects its properties. Mustard honey had higher acidity and moisture, Litchi honey was rich in fructose, Coriander honey exhibited a balanced sugar profile and Berseem honey was notable for its mineral content and electrical conductivity. The findings highlight the diverse nutritional and health benefits of different honey types, suggesting that incorporating a variety into

the diet can provide complementary advantages. This information will benefit consumers, beekeepers, and honey industry, while future studies would explore seasonal and geographical impacts on honey composition.

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