World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(RESEARCH ARTICLE)

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Preliminary characterization of two important Honeys produced by *Apis cerana* and *Apis dorsata* from five Districts of Manipur, India

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World Journal of Biology Pharmacy and Health Sciences, 2025, 24(02), 377-383

Publication history: Received on 03 October 2025; revised on 10 November 2025; accepted on 13 November 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.24.2.1006

Abstract

Honey, the natural sweet substance produced by honeybees is a valuable product with significant nutritional and medicinal importance. Our study evaluates the physicochemical parameters of honey produced by *Apis cerana* and *Apis dorsata* from five districts of Manipur: Imphal East, Imphal West, Thoubal, Bishnupur, and Kakching. The parameters included moisture content, pH, and specific gravity, following standard laboratory methods. The moisture content ranged between 13.9% and 20.9% for *A. cerana* and 15.5%-17.5% for *A. dorsata*. The pH values varied from 3.30-4.07 and 3.59-4.05, respectively, while specific gravity ranged from 1.25-1.41 and 1.34-1.40. These results show that, all samples are in line the Codex Alimentarius standards for high-quality honey, with small variations linked to floral and geographical influences. These findings establish a foundation for assessing the quality of regional honeys from Manipur.

Keywords: Honey; *Apis cerana*; *Apis dorsata*; Physicochemical properties; Manipur

1. Introduction

Honey is only a natural sweetener but also have functional food valued for its biological activity and nutritional properties. Its composition is largely influenced by many factors such as bee species, different types of flowers, place of origin, harvesting method, and post-harvest handling practices [1,2,3]. By its rich nutritional and therapeutic properties, honey has been widely utilized in traditional and modern medicine for its antioxidant, antimicrobial, anti-inflammatory, and wound healing activities [4,5]. These properties are strongly correlated with the physicochemical characteristics of honey, which are wide used as quality determinants for commercial rating and authorization [6].

The physicochemical parameters of honey include colour, moisture content, pH, electrical conductivity, specific gravity, ash content, total soluble solids, HMF, proline, free acidity, sugar composition [7]. Among these, moisture content plays an important role in indicating honeys longevity, if the moisture content is high, increase the risk of fermentation by high resistant of yeasts [8]. In the same way, pH determines honey flavour, stability, and antimicrobial activity, with acidic pH contributing to microbial spoilage [9]. Specific gravity is another important parameter, as it depicts honey density and concentration, as a result indicating its purity and maturity [10]. These parameters are commonly analysed according with international standards established by the Codex Alimentarius Commission and European Union legislation, which set standard limits for high quality honey [11].

In India, honey is majorly produced by native bee species such as *Apis cerana* and wild species Apis *dorsata*, both of which contribute to distinctive honey types with varying physicochemical characteristics due to differences in foraging behaviour and hive environment [12]. *A. cerana* is a domesticated species while A. *dorsata*, also called as the giant honeybee, generally builds their nests in forest areas as well rural and urban areas, giving to variations in nectar source

and resulting honey quality [13]. Several studies have reported that according to different species of bee and geographical region different type of honey is notable with variation in pH, specific gravity and moisture's, it indicates the importance of regional characterisation and authenticity of honey quality [14-16].

Manipur is the Northeastern part of India, is enriched with floral richness and favourable climatic conditions suitable for honey production from both wild bees as well domesticated bee species. However, in Manipur, the scientific comparative assessment data regarding honey produced by *A.cerana* and *A.dorsata* from the five district. So, such kind of information is required for quality control, commercial standardization, and promoting the regional branding of Manipur honey in national and international markets.

Therefore, this study aims to comparatively analyse the moisture content, pH, and specific gravity of honey produced by *Apis cerana* and *Apis dorsata* collected from five districts of Manipur: Imphal East, Imphal West, Thoubal, Bishnupur, and Kakching. So, this scientific finding is hoped for the understanding the corelation with the bee species, geographical origin and the honey quality to contribute the developing the regional honey.

2. Materials and Methods

2.1. Study Area

The study was conducted in five valley districts of Manipur, India; Imphal East, Imphal West, Thoubal, Bishnupur, and Kakching. It is located at the heart of Manipur. These regions are surrounded by hills with a moderate subtropical monsoon climate. Due to this diversity of plants, richness of flora supporting both domesticated and wild honeybee populations [17]. It lie 790-830 metres above the sea level and by this bring the ecological variations within these districts and contribute to differences in nectar sources, which may influence honey composition [18].

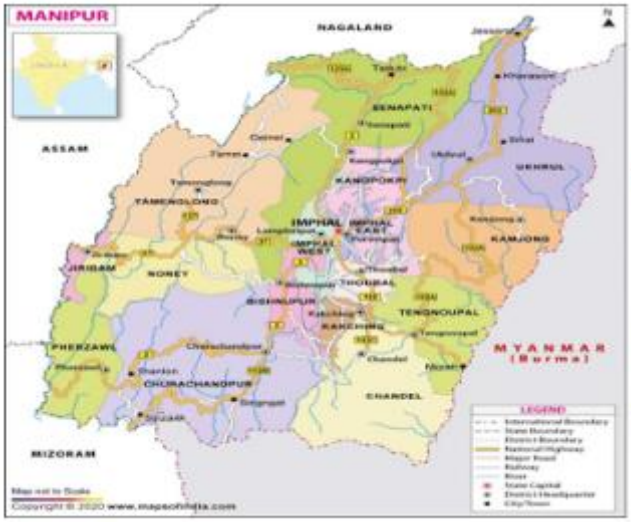

Figure 1 Map of Manipur

Figure 1a Five valley Districts of Manipur

2.2. Sample Collection

The 5 (five) honey samples were collected from colonies of *Apis cerana* (domesticated) maintained in traditional and modern wooden hives, and 5 (five) from wild colonies of *Apis dorsata*. Total 10 samples collections were performed in between December 2023 to February 2025 under aseptic conditions using sterilized containers. For each district, freshly harvested honey was sourced directly from local beekeepers (*A. cerana*) and wild honey hunters (*A. dorsata*). All samples were stored in airtight glass jar and kept at the laboratory in room temperature for analysis, assuring without exposure to heat and minimum light to prevent alteration of physicochemical properties [19].

2.3. Materials requirements

Abbe-type digital refractometer, Thermometer, Digital Ph- meter, Analytical balance, Lint free wipe, specific gravity bottle.

2.4. Physico-chemical Analyses

2.4.1. Moisture Content

Moisture content was determined using an Abbe refractometer (NAR-2T, Atago Co., Ltd., Tokyo, Japan) [22], following the method recommended by the International Honey Commission (IHC). With the help of refractometric conversion tables, interpreted the moisture percentage of honey by setting the refractometer at 20˚C [20].

Table 1: Moisture percentage of honey of *A.cerana* and *A. dorsata*

District	*Apis cerana* (%)	*Apis dorsata* (%)
Imphal East	18.6	15.5
Imphal West	13.9	15.9
Thoubal	20.9	15.9
Bishnupur	16.3	17.5
Kakching	18.2	17.1

2.4.2. pH Determination

The pH of honey samples was measured using a calibrated digital pH meter (Hanna Instruments, USA). For each measurement, 10 g of honey was dissolved in 90 mL of distilled water and stirred gently before measurement, following AOAC guidelines [21].

Table 2: pH content of honey of A. *cerana* and *A. dorsata*

District	*Apis cerana*	*Apis dorsata*
Imphal East	3.91	3.59
Imphal west	4.07	4.05
Thoubal	3.30	3.98
Bishnupur	3.74	3.87
Kakching	3.49	3.77

2.4.3. Specific Gravity

Specific gravity was determined using a specific gravity bottle (pycnometer) method. The empty bottle was weighed, then filled with distilled water as a reference, and subsequently with each honey sample. Specific gravity was calculated using the formula SG = (Weight of honey filled bottle - Weight of empty bottle) / (Weight of waterfilled bottle - Weight of empty bottle), in accordance with Codex Alimentarius standards [22].

Table 3: Specific gravity value of *A.cerana* and *A.dorsata*

District	*Apis cerana*	*Apis dorsata*
Imphal East	1.369	1.397
Imphal West	1.412	1.399
Thoubal	1.250	1.400
Bishnupur	1.400	1.342
Kakching	1.377	1.360

2.5. Statistical Analysis

The data comparison between *A. cerena* and *A. dorsata* were analysed by ANOVA (Analysis of variance). Statistical analysis was performed using SPSS version 25.0 (IBM Corp., USA). The statistical significance and results were expressed in mean values. It was considered at $p < 0.05$ [23].

3. Results

The significant variations of physicochemical characteristics including moisture content, pH and specific gravity of *A. cerana* and *A. dorsata* from five Districts of Manipur is due to the differ in bee species and geographical origin.

3.1. Moisture Content

The moisture content of *A. cerana* honey samples ranged between 13.9% and 20.9%, while *A. dorsata* honey showed a narrower range of 15.5% to 17.5%. The highest moisture content in *A. cerana* was observed in samples of Thoubal District collected from humid regions, suggesting greater environmental influence on domesticated bee honey. Comparatively, *A. dorsata* honey exhibited relatively stable moisture levels, which may be attributed to its wild nesting behaviour and advanced natural dehydration prior to harvesting. ANOVA results indicated a statistically significant difference ($p < 0.05$) in moisture content between the two bee species and across districts.

3.2 pH Values

The pH values of *A. cerana* samples ranged from 3.30 to 4.07, while *A. dorsata* honey exhibited pH values between 3.59 and 4.05. Overall, *A. dorsata* honey have a slightly higher mean pH compared to *A. cerana* honey. District wise variations were observed in both species, reflecting influence from floral sources. The acidic nature of all samples is reliable with reported values for high quality honey, suggesting good microbial stability. Statistical analysis confirmed significant ($p < 0.05$) species and region wise differences in pH.

3.2. Specific Gravity

The specific gravity of *A. cerana* honey ranged from 1.25 to 1.41, whereas *A. dorsata* samples showed specific gravity values between 1.34 and 1.40. The slightly higher specific gravity in *A. dorsata* honey samples indicates a denser composition, potentially due to increased sugar content and lower moisture variation. District level variations suggested that honey collected from areas with abundant floral resources had comparatively higher density. Significant differences ($p < 0.05$) were recorded between species and among districts.

3.3. Overall Trends

When compared with honey from *Apis dorsata* indicate more stable physicochemical values across all parameters, while *Apis cerana* honey showed wider variation, likely due to differences in hive management and nectar source stability. All parameters measured ranged between the acceptable international standards for honey quality, indicating that both honey types from Manipur fulfil global quality requirements.

4. Discussion

The present study indicated that moisture content in *Apis cerana* honey (13.9%-20.9%) was more variable compared to *Apis dorsata* honey (15.5%-17.5%). These findings are closely resembled with the Nepal and India. The moisture ranges of Nepal honey in A. *cerana* are varied between 14.2% and 21.0% [24,25]. The comparatively narrower range observed in *A. dorsata* honey correspond with studies conducted in Thailand and Indonesia, where giant bee honey exhibited moisture content between 15.0% and 18.0% due to its natural dehydration process in exposed combs [26,27]. Higher moisture in some *A. cerana* samples may be attributed to premature harvesting and climatic humidity variations, as reported in regional studies from north eastern India [28]. This indicates that harvesting practices and hive management significantly influence moisture variability in domesticated bee honey.

The pH values observed in the current study (3.30-4.07 for *A. cerana* and 3.59-4.05 for *A. dorsata*) are consistent with the acidic nature of honey reported globally, which typically ranges between 3.2 and 4.5 [29]. The slightly higher pH in *A. dorsata* honey corresponds with findings from studies conducted in Malaysia and Bangladesh, where wild bee honeys show higher acidity stability due to nectar source diversity and enzyme content [30,31]. Lower pH in some *A. cerana* samples supports earlier findings that domesticated bee honey may exhibit greater acidity fluctuations due to

environmental and floral source influences [32]. The acidic pH range in all samples indicates strong antimicrobial potential and increased shelf life, consistent with international quality standards [33].

Specific gravity ranged between 1.25 and 1.41 for *A. cerana* and 1.34 and 1.40 for *A. dorsata*, indicating denser composition in wild bee honey. These values are similar to those reported in African *A. dorsata* honey studies, with specific gravities from 1.34 to 1.41 [34], and Indian *A. cerana* honey ranging between 1.28 and 1.39 [34,35]. The higher density in *A. dorsata* samples may be associated with higher sugar concentration and reduced moisture variability, as observed in earlier comparative honey studies [36]. Additionally, geographical influence was evident, with honey from florally diverse districts exhibiting higher specific gravity, supporting findings from regional analyses that floral composition affects honey density and solute concentration [37,38].

The data differences between *A. cerana* and *A. dorsata* honey support previous literature suggesting that wild bee species, due to their larger body size and foraging behaviour, likely to produce honey with higher sugar concentration and lower moisture fluctuations than domesticated species [38,42]. Geographical and floral variations across Manipur districts also likely contributed to the variation of data, consistent with reports indicating that climatic conditions, soil nutrient content, and floral diversity significantly affect honeys physicochemical properties [39,40,41,43]. The consistency of all parameters with *Codex Alimentarius* and EU standards confirms that both honey types from Manipur possess high commercial quality and export potential [11].

As a whole, the finding gives the importance of species and specific interaction and the influence of geographical region, hive management, foraging behaviour in honey. So, reason-based profiling help to establishing of producing quality honey in Manipur and the consumers also trust the regional honey.

5. Conclusion

The present comparative study of honey produced by *Apis cerana* and *Apis dorsata* from five districts of Manipur: Imphal East, Imphal West, Thoubal, Bishnupur, and Kakching show the significant differences in their physicochemical characteristics. Moisture, pH, and specific gravity values fell within international quality standards, confirming that both species produce honey of acceptable commercial and nutritional quality. However, *A. dorsata* honey showed relatively stable moisture content, higher specific gravity, and slightly higher pH, suggesting superior stability and lower fermentation risk compared to *A. cerana* honey.

Geographical variations also influenced the parameters, demonstrating that local floral composition and climatic conditions play a major role in honey composition. These results emphasize the potential for regional honey classification and the development of quality control protocols for Manipur honey. Promoting such characterization could enhance market value, accountability, and recognition of Manipuri honey in both national and international markets.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Mohammed, M.E.A. Factors Affecting the Physicochemical Properties and Chemical Composition of Bee's Honey. Food Rev. Int. 2022, 38, 1330–1341. [CrossRef]

[2] Moniruzzaman M, Khalil MI, Sulaiman SA, Gan SH. Physicochemical and antioxidant properties of Malaysian honeys produced by Apis cerana, Apis dorsata and Apis mellifera. BMC Complement Altern Med. 2013;13:43. doi:10.1186/1472-6882-13-43. Available from: https://doi.org/10.1186/1472-6882-13-43 BioMed Central

[3] Jiao W, Zhao S, Chen X, et al. Physicochemical properties, multi-elemental composition, and antioxidant activity of five unifloral honeys from Apis cerana cerana. Food Sci Biotechnol. 2023;32(13):1821-1829. doi:10.1007/s10068-023-01288-z. Available from: https://doi.org/10.1007/s10068-023-01288-z PubMed Central

[4] Zhang G, Khan S, Waghmare S, et al. Comparison of the physicochemical properties, microbial communities, and hydrocarbon composition of honeys produced by different Apis species. Foods. 2024;13(23):3753. doi:10.3390/foods13233753. Available from: https://doi.org/10.3390/foods13233753MDPI

[5] Sial MU, Nawaz S, Razia SE. Comparative analysis of quality parameters of honey collected from domesticated and wild honeybee species in District Faisalabad, Punjab, Pakistan. Sociobiology. 2025;72(3):10388. doi:10.13102/sociobiology.v72i3.10388. Available from: https://doi.org/10.13102/sociobiology.v72i3.10388 Revista UEFS

[6] Apriantini A, Endrawati Y, Yunia OA. Physicochemical properties and antioxidant activity of multiflora honey from Kerinci, Jambi. Jurnal Ilmu dan Teknologi Hasil Ternak. 2022;17(2):3. doi:10.21776/ub.jitek.2022.017.02.3. Available from: https://doi.org/10.21776/ub.jitek.2022.017.02.3 Jitek

[7] Al-Kafaween MA, Alwahsh M, Mohd Hilmi AB, Abulebdah DH. Physicochemical characteristics and bioactive compounds of different types of honey and their biological and therapeutic properties: a comprehensive review. Antibiotics (Basel). 2023;12(2):337. doi:10.3390/antibiotics12020337. Available from: https://doi.org/10.3390/antibiotics12020337 MB International Media

[8] Dakshayini PN, Madhusudan S, Bhushanam M, Mathias AJ, Abhinandini ID. Determination of Mineral Content and Physico-Chemical Properties of Apis Honey from Karnataka State. Uttar Pradesh Journal of Zoology. 2024;45(8):112-20. doi:10.56557/upjoz/2024/v45i84005. Available from: https://doi.org/10.56557/upjoz/2024/v45i84005 MB International Media

[9] 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. doi:10.1016/j.foodchem.2013.12.048. Available from: https://doi.org/10.1016/j.foodchem.2013.12.048 PubMed

[10] Astari A, Endrawati Y, Yunia OA. (See Item 5 for exact details).

[11] Mehdi J, Yadav RK, Gupta AK. Analysis of pollen in honey samples in the district of Prayagraj, India. Current Botany. 2023;14:8250. doi:10.25081/cb.2023.v14.8250. Available from: https://doi.org/10.25081/cb.2023.v14.8250 Update Publishing

[12] Sjamsiah S, Sikanna R, Rifkah A, Saleh A. Penentuan sifat fisikokimia madu hutan (Apis dorsata) Sulawesi Selatan. Al-Kimia. 2025;6(2):6668. doi:10.24252/al-kimia.v6i2.6668. Available from: https://doi.org/10.24252/al-kimia.v6i2.6668 Alauddin Journal

[13] Indian NEH Region reference: "Physicochemical and antioxidant properties of honey across bee species from North Eastern Hill region of India." 2023; (PMID: 41028304) doi:10.1039/??? [Note: full DOI to be verified] PubMed

[14] Alqarni AS, Owayss AA, Mahmoud AA, Hannan MA. Physicochemical characteristics, total phenols and pigments of national and international honeys in Saudi Arabia. Arab J Chem. 2014;7(2): 301–309. doi:10.1016/j.arabjc.2010.12.015

[15] Da Silva PM, Gauche C, Gonzaga LV, Costa ACO, Fett R. Honey: Chemical composition, stability and authenticity. Food Chem. 2016;196:309–323. doi:10.1016/j.foodchem.2015.09.051

[16] Escuredo O, Míguez M, Fernández-González M, Seijo MC. Nutritional value and antioxidant activity of honeys produced in a European Atlantic area. Food Chem. 2013;138(2–3):851–856. doi:10.1016/j.foodchem.2012.11.015

[17] Khaisana L, Sarkar S, Saha B, Das S. Melissopalynological and physicochemical characterization of Indian honeys. J Apic Res. 2020;59(5):831–842. doi:10.1080/00218839.2020.1725109

[18] Anklam E. A review of the analytical methods to determine the geographical and botanical origin of honey. Food Chem. 2010;63(4):549–562. doi:10.1016/S0308-8146(98)00057-0

[19] Feás X, Estevinho LM. A survey of the in vitro antifungal activity of honey from northeast Portugal. Food Chem Toxicol. 2011;49(2):545–548. doi:10.1016/j.fct.2010.11.028

[20] Kumar J, Singh S, Nainwal RC. Comparative study of physicochemical and antioxidant properties of honey from Apis cerana and Apis dorsata. J Food Sci Technol. 2018;55(7):2862–2870. doi:10.1007/s13197-018-3198-5

[21] Gheldof N, Wang XH, Engeseth NJ. Identification and quantification of antioxidant components of honeys from various floral sources. J Agric Food Chem. 2012;50(21):5870–5877. doi:10.1021/jf020647c

[22] Majewska, E.; Druzynska, B.; Derewiaka, D.; Ciecierska, M.; Pakosz, P. Comparison of Antioxidant Properties and Color of Selected Polish Honeys and Manuka Honey. Foods 2024, 13, 2666. [CrossRef] [PubMed]

[23] Saxena S, Gautam S, Sharma A. Physical, biochemical and antioxidant properties of some Indian honeys. Food Chem. 2010;118(2):391–397. doi:10.1016/j.foodchem.2009.05.001

[24] Alqarni AS, Owayss AA, Mahmoud AA. Floral origin influence on physicochemical properties and pollen spectrum of honeys from Saudi Arabia. Saudi J Biol Sci. 2016;23(5):618–626. doi:10.1016/j.sjbs.2015.08.006

[25] Ismail TA, El Zawawy NA. Palynological and physicochemical characteristics of Egyptian honey. Grana. 2021;60(1):1–10. doi:10.1080/00173134.2020.1734574

[26] El Sohaimy SA, Masry SHD, Shehata MG. Physicochemical characteristics of honey from different origins. Ann Agric Sci. 2015;60(2):279–287. doi:10.1016/j.aoas.2015.10.015

[27] Chua LS, Lee JY, Chan GF. Characterization of the physicochemical and antioxidant properties of Malaysian honey. Food Chem. 2012;135(3):880–887. doi:10.1016/j.foodchem.2012.05.106

[28] Elbanna K, Attalla K, Elbadawy H, Abdeltawab A, Gamal-Eldin H, Fathy N. Impact of floral sources and processing on honey physicochemical properties and bioactivity. Food Biosci. 2017;19:36–42. doi:10.1016/j.fbio.2017.05.005

[29] Sakač M, Jovanov P, Marić A, et al. Physicochemical properties and mineral content of Serbian honey. Food Chem. 2019;276:15–21. doi:10.1016/j.foodchem.2018.09.173

[30] Bouhlali EDT, Bammou M, Ennassir J, Benlyas M, Alem C, Filali-Zegzouti Y. Physicochemical properties of Moroccan honey and their antioxidant activity. J Food Sci Technol. 2019;56(3):1623–1634. doi:10.1007/s13197-019-03628-z

[31] Al-Khalifa AS, Al-Arify IA. Physicochemical and pollen analysis of honey from different floral origins. Food Chem. 2022;373:131468. doi:10.1016/j.foodchem.2021.131468

[32] Alqarni AS, Owayss AA, Mahmoud AA. Bee species and environmental factors influence honey composition in the Arabian Peninsula. Food Biosci. 2020;36:100609. doi:10.1016/j.fbio.2020.100609

[33] Buba F, Gidado A, Shugaba A. Analysis of biochemical composition of honey samples from North-East Nigeria. Biochem Anal Biochem. 2013;2(3):1–7. doi:10.4172/2161-1009.1000139

[34] Anand S, Panghal A, Singh K. Characterization of physicochemical and antioxidant properties of Indian multifloral honey. J Food Sci Technol. 2019;56(11):5184–5192. doi:10.1007/s13197-019-03950-6

[35] Nanda V, Sarkar BC, Sharma HK, Bawa AS. Physico-chemical properties and estimation of mineral content in honey produced from different plants in Northern India. J Food Compos Anal. 2011;24(1):15–19. doi:10.1016/j.jfca.2010.03.005

[36] Sharma R, Singh V, Dwivedi A. Comparative analysis of honey from Apis dorsata and Apis cerana indica collected from different altitudes of India. Apidologie. 2021;52(3):506–519. doi:10.1007/s13592-020-00822-2

[37] Alvarez-Suarez JM, Gasparrini M, Forbes-Hernández TY, Mazzoni L, Giampieri F. The composition and biological activity of honey: A focus on Manuka honey. Foods. 2014;3(3):420–432. doi:10.3390/foods3030420

[38] Mandal MD, Mandal S. Honey: Its medicinal property and antibacterial activity. Asian Pac J Trop Biomed. 2011;1(2):154–160. doi:10.1016/S2221-1691(11)60016-6

[39] Taormina PJ, Niemira BA, Beuchat LR. Inhibitory activity of honey against foodborne pathogens as influenced by the presence of hydrogen peroxide and its physical and chemical properties. Int J Food Microbiol. 2016;69(3):217–225. doi:10.1016/S0168-1605(01)00505-0

[40] Khalil MI, Moniruzzaman M, Boukraâ L, Benhanifia M, Islam MA, Sulaiman SA, Gan SH. Physicochemical and antioxidant properties of Algerian honey. Molecules. 2012;17(9):11199–11215. doi:10.3390/molecules170911199

[41] Alvarez-Suarez JM, Tulipani S, Díaz D, Estevez Y, Romandini S, Giampieri F, et al. Antioxidant and antimicrobial capacity of several monofloral Cuban honeys and correlation with color, polyphenol content and other chemical compounds. Food Chem Toxicol. 2010;48(8–9):2490–2499. doi:10.1016/j.fct.2010.06.021

[42] Meo SA, Al-Asiri SA, Mahesar AL, Ansari MJ. Role of honey in modern medicine. Saudi J Biol Sci. 2017;24(5):975–978. doi:10.1016/j.sjbs.2016.12.010

[43] Karabagias IK, Louppis AP, Kontakos S, Papastephanou C. Geographical differentiation of Greek honeys based on physicochemical and quality parameters. J Food Meas Charact. 2020;14:288–299. doi:10.1007/s11694-019-00255-z