THE CHEMICAL COMPOSITION OF HONEY – THE COMPLEXITY OF A NATURAL FOOD

Elena Daniela BRATOSIN[1], Maria GITEA[2], Marc GHITEA[2], Lavinia PURZA[3], Delia Mirela ȚIȚ[3]

[1] University of Oradea, Doctoral School of Biomedical Sciences, Department of Pharmacy , 410087, Oradea, Romania
[2]Faculty of Medicine and Pharmacy, University of Oradea, 1st December Square 10, 410028 Oradea, Romania;
[3]Department of Pharmacy, Faculty of Medicine and Pharmacy, University of Oradea, 1st Decembrie Street, 410073 Oradea, Romania.

REVIEW ARTICLE

Abstract

Honey, a natural product derived from floral nectar by Apis mellifera, represents one of the most complex functional foods of natural origin. Recent research has highlighted a wide spectrum of biological activities, including anti-inflammatory, antibacterial, antifungal, antihypertensive, hypoglycemic, and hepatoprotective effects. The chemical composition of honey is dominated by sugars—monosaccharides, disaccharides, oligosaccharides, and polysaccharides—but also includes enzymes (catalase, peroxidase, diastase, invertase, glucose oxidase), organic acids, amino acids, proteins, vitamins, trace elements, and Maillard reaction products. Bioactive phenolic compounds, particularly flavonoids such as chrysin, kaempferol, quercetin, pinobanksin, pinocembrin, luteolin, apigenin, genistein, naringenin, and hesperetin, play an essential role, contributing significantly to the therapeutic potential of honey.
The aim of this paper is to provide an updated overview of the chemical composition of honey and to highlight its beneficial health properties, emphasizing the complexity and medical relevance of this natural product.

Keywords*:* Honey, chemical composition, phenolic compounds, volatile compounds, antioxidants.

INTRODUCTION

Apiculture is the knowledge and art of utilizing hive products—such as honey, royal jelly, propolis, bee venom, and bee bread—for the maintenance and support of health. In recent years, these natural products have attracted growing interest due to their applicability in both traditional and modern medicine, with numerous studies highlighting their pharmacological effects and health benefits (Pasupuleti et al., 2017).

Apitherapy, a branch of traditional medicine, employs bee products in the treatment of various conditions, with honey standing out as one of the oldest and most valuable products, renowned for its medicinal and health-promoting properties (Badolato et al., 2017). Honey is a sweet and viscous substance produced by Apis mellifera from floral or extrafloral nectar, with a complex composition that determines the variability of its color, consistency, and aroma (Chen et al., 2019; Jaganathan & Mandal, 2009). In general, darker honey exhibits a stronger taste and a higher content of bioactive compounds (Jaganathan & Mandal, 2009). It is commonly consumed in its natural state—liquid, crystallized, or in the comb—and is used both as a food and as a medicine (Olaitan et al., 2007).

According to European Community legislation, honey is defined as "the natural sweet substance produced by bees from the nectar of plants or from secretions of living parts of plants, which bees collect, transform, dehydrate, and store in honeycombs for maturation" (Hills et al., 2019). Before the scientific basis of its composition was understood, honey was empirically used in the treatment of a wide range of ailments. Today, modern research confirms its antioxidant, antimicrobial, anti-inflammatory, and even antitumor effects, as well as its beneficial role in cardiovascular, metabolic, and digestive health (Khan et al., 2017; Miguel et al., 2017).

Honey is also recognized for its applicability both orally and topically, in conditions such as laryngitis, gastrointestinal ulcers, constipation, eczema, burns, infected wounds, and scars (Fakhlaei et al., 2020).

The aim of this presentation, entitled "The Chemical Composition of Honey – The Complexity of a Natural Food", is to provide an updated overview of honey's chemical composition and its multiple implications for human health, emphasizing both the complexity of this natural product and its value as a food and therapeutic adjuvant.

MATERIAL AND METHOD

A literature review was conducted to synthesize recent scientific data regarding the chemical composition of honey and its therapeutic potential. The search was restricted to articles published in English and indexed in online databases such as PubMed, Elsevier, Wiley, and Google Scholar. Relevant keywords—including honey, chemical composition, phenolic compounds, volatile compounds, antioxidants.— were used to identify suitable studies.

The initial search yielded 1,074 results. After applying inclusion and exclusion criteria, approximately 250 articles were selected for detailed evaluation. Abstracts and full texts were analyzed, classified, and interpreted to determine the relevance, validity, and therapeutic applicability of the reported findings. Subsequently, the data were synthesized to provide an updated overview of the chemical composition of honey and its beneficial health effects.

RESULTS AND DISCUSSIONS

Honey is a natural food of remarkable chemical complexity, containing more than 200 identified compounds. Its main components are sugars and water, along with vitamins (particularly B-group vitamins and vitamin C), minerals (K, Na, Ca, Mg, Zn, Fe, Cu, Mn, P), proteins (including enzymes), organic acids, pigments, phenolic compounds, volatile compounds, and lipids, as well as low levels of hydroxymethylfurfural (HMF) (Magazù et al., 2008).

The molecular composition of honey varies depending on botanical and geographical origin, climatic conditions, and processing methods (Manyi-Loh et al., 2011; Viuda-Martos et al., 2008). Among the amino acids present are glycine, methionine, arginine, and especially proline, considered a quality marker (Giusto et al., 2017). Proteins include enzymes such as glucose oxidase, invertase, diastase, peroxidase, and catalase, as well as non-enzymatic proteins (Erejuwa et al., 2012; Machado De-Melo et al., 2018).

Carbohydrates account for approximately 95% of the dry matter, the most important being fructose (≈41%), glucose (≈34%), and sucrose (1–2%), along with more than 45 oligosaccharides (Machado De-Melo et al., 2018). Organic acids, particularly gluconic acid (70–90%), contribute to taste, aroma, and antimicrobial properties (Machado De-Melo et al., 2018; Santos-Buelga & González-Paramás, 2017). Vitamins occur in small amounts, with vitamin C and B-group vitamins (B1, B2, B5, B6, B8, B9) being predominant (Machado De-Melo et al., 2018; da Silva et al., 2016). Minerals, especially potassium, are more abundant in darker honeys (Machado De-Melo et al., 2018; Santos-Buelga & González-Paramás, 2017).

Phenolic compounds and flavonoids (quercetin, kaempferol, chrysin, luteolin, apigenin, naringenin, pinocembrin) are responsible for antioxidant and anti-inflammatory properties (Machado De-Melo et al., 2018; da Silva et al., 2016). Over 600 volatile compounds (aldehydes, ketones, esters, terpenes, hydrocarbons) contribute to the specific aroma (Machado De-Melo et al., 2018; Tafere, 2021; Santos-Buelga & González-Paramás, 2017). Other constituents include pigments (carotenoids, xanthophylls, anthocyanins), lipids (≈0.04%), and essential oils (thymol, bisabolol, farnesol, cineole) (Machado De-Melo et al., 2018). Hydroxymethylfurfural (HMF) is present only in traces in fresh honey, increasing during processing and storage (Machado De-Melo et al., 2018; Tafere, 2021; Bogdanov, 2016). The water content (15–21%) influences crystallization, viscosity, and stability, with lower levels (<14%) indicating superior quality (Tafere, 2021; da Silva et al., 2016).

The findings confirm that honey is a food with an extremely complex chemical composition, consisting of more than 200 bioactive compounds. This diversity explains the variability of its organoleptic and therapeutic properties, as well as the growing interest in its use as a functional food and nutraceutical agent (Magazù et al., 2008). The composition of honey is not uniform but depends largely on botanical origin, climate, and geographical factors, leading to significant differences in sugar, amino acid, mineral, and phenolic content (Manyi-Loh et al., 2011; Viuda-Martos et al., 2008). The identification of proline as a quality marker is particularly important for detecting adulteration and assessing authenticity (Giusto et al., 2017).

Carbohydrates, which constitute the majority of the dry matter, provide not only energy value but also physicochemical properties such as hygroscopicity and crystallization, which influence preservation and market acceptability (Machado De-Melo et al., 2018). Organic acids, vitamins, and minerals, although present in smaller amounts, contribute to honey's biological activity, particularly its antimicrobial and antioxidant properties

(Machado De-Melo et al., 2018; Santos-Buelga & González-Paramás, 2017; da Silva et al., 2016). The predominance of potassium and the higher mineral content in darker honeys highlight the significance of botanical and chromatic origin for nutritional value (Machado De-Melo et al., 2018; Santos-Buelga & González-Paramás, 2017).

Phenolic compounds and flavonoids (such as quercetin, kaempferol, or chrysin) play a major role in anti-inflammatory and antioxidant properties, explaining both the traditional and modern therapeutic uses of honey (Machado De-Melo et al., 2018; da Silva et al., 2016). At the same time, volatile compounds and pigments provide honey with unique organoleptic characteristics that enhance consumer acceptance (Machado De-Melo et al., 2018; Santos-Buelga & González-Paramás, 2017).

The presence of hydroxymethylfurfural (HMF) as an indicator of freshness and the impact of water content on stability and quality underline the need for rigorous processing and storage methods (Machado De-Melo et al., 2018; Tafere, 2021; da Silva et al., 2016; Bogdanov, 2016).

Overall, the complex composition of honey supports both its nutritional value and therapeutic potential. However, the wide variability determined by environmental and processing factors suggests the need for further research aimed at standardizing quality parameters and establishing stronger correlations between chemical composition and biological effects.

CONCLUSIONS

Honey represents a complex natural food, with a highly diverse chemical composition that includes more than 200 bioactive compounds. This diversity accounts for its nutritional and organoleptic properties as well as its demonstrated therapeutic effects.

The reviewed findings confirm that sugars, amino acids, organic acids, vitamins, minerals, phenolic compounds, pigments, and volatile compounds act synergistically to contribute to honey's biological activity, providing antioxidant, antimicrobial, anti-inflammatory, and cardioprotective effects.

At the same time, honey's chemical composition is influenced by factors such as botanical origin, geographical location, and processing methods, which explain the variability observed among different types of honey. Indicators such as proline and hydroxymethylfurfural (HMF) prove to be useful for assessing product quality and authenticity.

Considering these aspects, honey emerges as a valuable nutraceutical, with potential for integration into the prevention and support of treatment for chronic diseases. Nevertheless, further studies are required to standardize composition and to establish clear correlations between chemical content and clinical effects.

REFERENCES

Badolato, M.; Carullo, G.; Cione, E.; Aiello, F.; Caroleo, M.C. From the hive: Honey, a novel weapon against cancer. *European Journal of Medicinal Chemistry* 2017, *142*, 290-299, doi:https://doi.org/10.1016/j.ejmech.2017.07.064.

Bogdanov, S. Honey Composition. *Bee Product Science* 2016.

Chen, C.-T.; Chen, B.-Y.; Nai, Y.-S.; Chang, Y.-M.; Chen, K.-H.; Chen, Y.-W. Novel inspection of sugar residue and origin in honey based on the 13C/12C isotopic ratio and protein content. *Journal of Food and Drug Analysis* 2019, *27*, 175-183, doi:https://doi.org/10.1016/j.jfda.2018.08.004

da Silva, P.M.; Gauche, C.; Gonzaga, L.V.; Costa, A.C.; Fett, R. Honey: Chemical composition, stability and authenticity. *Food Chem* 2016, *196*, 309-323, doi:10.1016/j.foodchem.2015.09.051.

Erejuwa, O.O.; Sulaiman, S.A.; Ab Wahab, M.S. Honey: a novel antioxidant. *Molecules* 2012, *17*, 4400-4423.

Fakhlaei, R.; Selamat, J.; Khatib, A.; Razis, A.F.A.; Sukor, R.; Ahmad, S.; Babadi, A.A. The Toxic Impact of Honey Adulteration: A Review. *Foods* 2020, *9*, doi:10.3390/foods9111538.

Giusto, G.; Vercelli, C.; Comino, F.; Caramello, V.; Tursi, M.; Gandini, M. A new, easy-to-make pectin-honey hydrogel enhances wound healing in rats. *BMC Complement Altern Med* 2017, *17*, 266, doi:10.1186/s12906-017-1769-1.

Hills, S.P.; Mitchell, P.; Wells, C.; Russell, M. Honey supplementation and exercise: a systematic review. *Nutrients* 2019, *11*, 1586.

Jaganathan, S.K.; Mandal, M. Antiproliferative effects of honey and of its polyphenols: a review. *J Biomed Biotechnol* 2009, *2009*, 830616, doi:10.1155/2009/830616.

Khan, R.U.; Naz, S.; Abudabos, A.M. Towards a better understanding of the therapeutic applications and corresponding mechanisms of action of honey. *Environ Sci Pollut Res Int* 2017, *24*, 27755-27766, doi:10.1007/s11356-017-0567-0.

Machado De-Melo, A.A.; Almeida-Muradian, L.B.d.; Sancho, M.T.; Pascual-Maté, A. Composition and properties of Apis mellifera honey: A review. *Journal of Apicultural Research* 2018, *57*, 5-37, doi:10.1080/00218839.2017.1338444.

Magazù, S.; Migliardo, F.; Telling, M. Structural and dynamical properties of water in sugar mixtures. *Food Chem* 2008, *106*, 1460-1466.

Manyi-Loh, C.E.; Ndip, R.N.; Clarke, A.M. Volatile compounds in honey: a review on their involvement in aroma, botanical origin determination and potential biomedical

activities. *International Journal of Molecular Sciences* 2011, *12*, 9514-9532.

Miguel, M.G.; Antunes, M.D.; Faleiro, M.L. Honey as a Complementary Medicine. *Integr Med Insights* 2017, *12*, 1178633717702869, doi:10.1177/1178633717702869.

Olaitan, P.B.; Adeleke, O.E.; Ola, I.O. Honey: a reservoir for microorganisms and an inhibitory agent for microbes. *Afr Health Sci* 2007, *7*, 159-165, doi:10.5555/afhs.2007.7.3.159.

Pasupuleti, V.R.; Sammugam, L.; Ramesh, N.; Gan, S.H. Honey, Propolis, and Royal Jelly: A Comprehensive Review of Their Biological Actions and Health Benefits. *Oxidative Medicine and Cellular Longevity* 2017, *2017*, 1259510, doi:10.1155/2017/1259510.

Santos-Buelga, C.; González-Paramás, A.M. Chemical Composition of Honey. In *Bee Products - Chemical and Biological Properties*, Alvarez-Suarez, J.M., Ed.; Springer International Publishing: Cham, 2017; pp. 43-82.

Tafere, D.A. Chemical composition and uses of Honey: A Review. *Journal of Food Science and Nutrition Research* 2021, *4*, 194-201.

Viuda-Martos, M.; Ruiz-Navajas, Y.; Fernández-López, J.; Pérez-Alvarez, J.A. Functional properties of honey, propolis, and royal jelly. *Journal of food science* 2008, *73*, R117-124, doi:10.1111/j.1750-3841.2008.00966.x.