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NUTRITIONAL COMPOSITION OF BEE PRODUCTS AND CURRENT TRENDS ON THEIR PROCESSING

Izabela ACATRINEI, Amalia Carmen MITELUȚ

University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Mărăști Blvd., Bucharest, Romania

Corresponding author email: izabela.acatrinei@yahoo.com

Abstract

In present times, natural bioactive substances are of great interest, especially appreciated by consumers whose preferences tend towards functional local foods. Among the most well-known natural resources are beehive products, recognized for their beneficial effects on the human body. This article aims to highlight current studies on the nutritional composition of various bee products, including honey, beeswax, propolis, bee pollen, royal jelly, and bee venom. In the same time, current trends in exploiting beehive products indicate a continuous search for ways to enhance their utilization. Through innovative methods such as extractions, fermentations, and ingredient combinations, new horizons are being explored regarding the nutritional benefits and applications of these products. The present work outlines the review of processing methods applied for enhancing utilization of bee products emphasizing the effects of their consumption on health and their potential applications in the food and pharmaceutical industries.

Key words*: bee products, nutritional composition, processing.*

INTRODUCTION

Apis mellifera is known as the bee and is one of the most beneficial insects in the whole world, because it plays an essential role for the environment, pollinating flowers and plants (Azam et al., 2019). Since ancient times, bee products have been used as natural remedies against numerous diseases, due to the diversity of their composition and chemical properties (Al-Hatamleh1 et al., 2022). The medicinal therapeutic use of beehive products is called Apitherapy (Abdela et al., 2016). Nowadays, the research of new safer and more active molecules from functional foods is a main trend in green chemistry. This trend is reinforced by scientific data demonstrating the importance of functional nutrients in the prevention and treatment of many diseases. In recent years, consumers have increasingly demanded more food options, especially without chemical additives and rich in bioactive constituents (Laaroussi et al., 2023). Natural bioactive substances are of great interest and especially appreciated by consumers whose preferences tend towards functional natural foods. Among natural products containing bioactive ingredients, honey and other bee products are very popular as healthy alternatives to synthetic supplements (Liu et al., 2023). Natural extracts from bee products are recognized worldwide as a remarkable source of bioactive compounds with diverse functionalities, such as antioxidant, antimicrobial and anticancer agents. Some of these compounds are used in the pharmaceutical field but also for the development of new functional foods with the aim of improving the bioactivity of current food products, their properties and replacing other synthetic components (Fuente-Ballesteros et al., 2023). Bee products are naturally secreted by bees through glands (e.g., venom, beeswax, and royal jelly) or produced by collection and processing by bees (e.g., nectar, bee pollen, and wax) (Liu et al., 2023). Bee products exhibit a wide range of desirable characteristics, including antimicrobial and antioxidant properties, and the most popular products of the hive are honey, pollen and their extracts, propolis, royal jelly and bee venom (Bartkiene et al., 2020).

MATERIALS AND METHODS

The objective of this review was to collect the latest information on the composition of bee products and to highlight their effects on health as well as their potential for food, medical, cosmetic and biotechnological applications. For

this study we used international platforms ScienceDirect, MDPI and the search tool Google Scholar and ResearchGate to analyze and synthesize the information. Following the keywords used, honey, pollen, bee bread, bee venom, beeswax, propolis, royal jelly, composition, processing, bee products, honey varieties, we checked 500 articles, and according to the keywords of interest, the number of articles decreased to 150, of which 71 can be found in the bibliography.

1. BEE PRODUCTS COMPOSITION

1.1. Bee honey

Bee honey is a sweet natural substance produced by bees (Kerkich et al., 2023) and is consumed worldwide by humans. Bees produce this concentrated aqueous mixture by converting sugar sap from pollen collected from plants by means of hypopharyngeal gland enzymes (e.g. amylase, glucosidase and glucose oxidase). Bee honey is the most widely consumed and well-known bee product (Sawicki et al., 2023) and although it is speculated that it has been used since ancient times as a natural remedy (Nikhat et al., 2021) there is a lack of knowledge regarding its interaction with the body. Lately honey is gaining popularity over sugar for its countless health benefits because it has a low glycemic index (Nikhat et al., 2021) The chemical and medicinal properties of honey are different depending on the types of honey and their origin (Young et al., 2023). There is also a difference in the chemical composition between the types of honey that come from different regions depending on the geographical and botanical variability, thus generating distinct therapeutic activities. High quality honey, differs in appearance, taste, color and aroma. These characteristics of honey are influenced by the floral source from where the bees collect the nectar (Gündoğdu et al., 2019). The specific composition of honey includes carbohydrates, enzymes, vitamins, proteins, phenols, flavonoids, volatile compounds, organic acids and minerals, but it must be emphasized the fact that this composition can be influenced by nectar, season, honey storage as well as the geographical region where the honey is collected (Wang et al., 2023). Honey in general consists of approximately 200 components (Trisha et al., 2023) mainly 80–85% carbohydrates (46–72% glucose, 7–61% fructose and 1–11% sucrose), 15–17 % water, 0.3% protein (including arginine, histidine, isoleucine, lysine, methionine, threonine, tryptophan, valine and other amines) and 0.2% ash. . Bee honey also contains vitamins B1, B6 and niacin, making it a healthy natural product with excellent antioxidant and antibacterial properties (Liu et al., 2023). It has been used in both traditional and modern medicine, as it exhibits a wide range of therapeutic properties, such as anti-inflammatory, anti-diabetic, anti-mutagenic, anti-cancer, beneficial properties for respiratory, gastrointestinal, cardiovascular and system protection nervous **(**Bartkiene et al., 2020). In recent years, special attention has been directed towards Manuka honey, which contains unique compounds given by the nectar of *Leptospermum scoparium* flowers (Wang et al., 2024).

1.2. Bee wax

One of the lesser known and less studied bee product is beeswax. This bee product is actually a natural substance secreted by special wax glands present in the abdominal segments of worker bees. The wax is used to build hexagonal honeycomb cells to store honey and protect larvae and pupae. In food technology, beeswax is mainly used as a food additive and glazing agent **(**Sawicki et al., 2023). Beeswax can be used in the food processing industry, in the cosmetic industry, in art as well as in medicine. The latest studies show that wax has therapeutic properties in the healing of bruises, burns and inflammations (Fratini et al., 2016). The color of the wax is given by the presence of propolis and pollen, and the predominant characteristic of the wax is its smell. According to Kurek-Górecka et al. (2020), beeswax is considered as source of vitamin A, represented by the carotenes content, which accelerates skin regeneration.

1.3. Bee propolis

Propolis is another bee product that has important health benefits. This product contains a large number of compounds with anti-inflammatory, antioxidant, antiviral and antimicrobial properties. Bees prepare and use propolis as a sealing material to protect against the penetration of microorganisms (fungi and

bacteria) into the hive and to create the most sterile environment known in nature (Anjum et al., 2018). The most recent studies have focused on the chemical compounds of propolis depending on the plant source and geographical area, as well as on propolis collected by non-stinging bees. The stingless bees are originally from tropical and subtropical countries (dos Santos et al., 2021). Propolis has antioxidant, anti-inflammatory and antimicrobial actions. It contains 50% resin, 30% resinous vegetable oils and beeswax, 10% essential oils, 5% pollen and 5% other components. Various active compounds have been identified in propolis, including polyphenols, phenolic aldehydes and ketones. Propolis is usually viscous at room temperature and can vary in color from plant to plant (including green, black, dark brown, and yellow) and exhibit different characteristic aromatic odors (Liu et al., 2023). The main pharmacological activities of propolis are related to flavonoids and phenolic compounds - the major bioactive constituents of this product. The properties of propolis flavonoids to reduce the formation or eliminate free radicals allow efficient regeneration of damaged tissue, and the antimicrobial properties of propolis prevent wound infection. It is used in traditional medicine as an antimicrobial, anti-inflammatory, anesthetic, antiseptic, antimutagenic and anti-cancer agent and also exhibits wound healing, antioxidant and cardioprotective properties (Liu et al., 2023). Propolis is very popular and is used in a variety of commercial preparations, including pharmaceuticals, because it is a natural product with no side effects (Abdelrazeg et al. 2020).

1.4. Bee pollen

The bees are the ones who create the pollen grains, mixing their secretions with the pollen collected from the flowers, resulting in grains between 1.4 mm and 4 mm in size (Giampieri et al., 2022). It is considered a nutritional treasure due to its active components, which possess significant properties in terms of health and medicinal benefits. The essential elements of bee pollen contribute to the improvement of various body functions and provide protection against a wide spectrum of diseases (Khalifa et al., 2021). Bee pollen, a nutritious product, consists of 15–25% protein, 45–60% carbohydrate, 5–10% fat, and 10–19% fiber. However, chemical compounds can vary due to both plants source and geographical origin (Spulber et al., 2020). Bee pollen is a treasure trove of active natural metabolites, it is the main source of nutrients for bees, such as minerals (calcium, magnesium, iron, zinc, copper), proteins, carbohydrates, vitamins (A, C, E, niacin, thiamin, biotin and folic acid), fiber and lipids, including fatty acids, Omega-3 and Omega-6, phenols (flavonoids and phenolic acids), carotenoids and phytosterols (Lu et al., 2022; Sokmen et al., 2022 Aylanc et al., 2023; Liu et al., 2023). In addition to its nutritional values, bee pollen presents an inexhaustible source of powerful antioxidant compounds such as resveratrol, quercetin, kaempferol, cinnamic and caffeic acids (Laaroussi et al., 2023). Due to its nutritional characteristics, the rich content of minerals, vitamins, fibers and bioactive compounds, but also the fact that it contains all the essential amino acids needed by humans, pollen is defined as "the best food product in the world" (Sokmen et al., 2022; Liu et al., 2023;).
Pollen is a popular beehive product widely used in traditional medicine for the prevention and self-treatment of various pathologies and has attracted the interest of many researchers around the world. Several human health-promoting effects have been reported in the analysis of bee pollen extracts, including cardioprotective, anti-inflammatory, anticarcinogenic, and hepatoprotective effects. Furthermore, new research has shown that bee pollen offers promising benefits for Parkinson's disease, depression and polycystic ovarian syndrome. Due to its well-known nutritional and medicinal benefits, bee pollen is commonly used as a natural food supplement (Alshallash et al., 2023; Laaroussi et al., 2023).
The main bioactive components in bee pollen are phenolic acid derivatives and polyphenolic compounds. Flavonoids are a class of secondary plant compounds that exhibit various essential physiological and pharmacological activities. Studies have shown that bee pollen exhibits strong biological functions, including antibacterial, antioxidant, anticancer, anti-inflammatory, hepatoprotective, anti-atherosclerotic and immunomodulatory activities (Liu et al., 2023), as well as an essential role in mitigating cardiovascular

diseases risks (Dinu et al., 2023). Recently, considerable interest has been shown in the use of bee pollen in food systems as a functional ingredient to enrich product quality characteristics. In this context, bee pollen has been used in the enrichment of yogurt, cheese, bread and fermented beverages (such as kombucha, white wines, malt and fermented milk beverages) as a (bio)techno-functional ingredient with strong antioxidant and antimicrobial activities, improving the nutritional and functional characteristics of the final products (Laaroussi et al., 2023). Another area of interest regarding the pollen is that with its fermentation at a temperature higher than 25°C a pollen similar to pasture is produced **(**Miłek et al., 2023). Recent research demonstrates that bee products, but especially pollen, is a sustainable product and can be used as a functional product for biomaterials (Sanyal et al., 2023).

1.5. Bee bread (bee pasture)

Forage is a valuable product of the hive, made from bee pollen, honey and secretions from the bees' salivary glands (Ghosh & Jung, 2022). The resulting mixture is stored in brood cells, which undergo lactic fermentation. This fermentation takes place during storage, which increases the bioavailability of pollen compounds, as cell walls are partially destroyed during fermentation. The lactic acid bacteria in the hive of bee pollen represent the protein base of the food in the hive, hence the name bee bread. (Ćirić et al., 2022). Natural fermentation in the hive increases the bioavailability of bee pollen and also keep in the form of pasture, which can be kept for a long time without losing its nutritional value (Kaškonienė et al., 2020). Like other products of the beehive, the biological properties of bee bread depend on the climatic conditions, the honey plants sources, the geographical area as well as of season. From a nutritional point of view, bee bread is more valuable compared to bee pollen, due to its better digestibility properties (Ćirić et al., 2022; Aylanc et al., 2023).

Like bee pollen, grass contains the same main chemical components, i.e. proteins, carbohydrates and lipid substances (saturated and unsaturated fatty acids). It also contains other nutrients such as minerals, carotenoids, phytohormones and vitamins (Miłek et al., 2023). Pasture contains peptides and free amino acids and is an excellent product that could supplement the population's nutrient deficiencies to achieve a balanced diet. Pasture contains antioxidant compounds (e.g. carotenoids) and natural preservatives (e.g. lactic acid). However, it should be noted that the presence of free amino acids in bee products can lead to the formation of biogenic amines, which are ultimately undesirable compounds in food products (Bartkiene et al., 2020). The latest research shows that extracts from bee bread can have antifungal, antitumor, antioxidant and antibacterial effects (Poyraz et al., 2023).

1.6. Royal jelly

Royal jelly is a milky white secretion produced by the mandibular and hypopharyngeal glands of worker bees and is used to feed bee larvae and adult queens (Yu et al., 2023). The chemical composition of royal jelly includes 3–6% fat, 15% carbohydrates, 18% protein, 50–60% water, 1% vitamins and 1.5% minerals. Royal Jelly Major Protein (MRJP) accounts for 82-90% of total royal jelly protein. The molecular weights of the MRJP family (MRJP1, MRJP2, MRJP3, MRJP4 and MRJP5) range between 49 and 87 kDa, with MRJP1 showing the highest protein content (31%), followed by MRJP3 (26%), MRJP2 (16%), and MRJP5 (9%).

The highest vitamin content in royal jelly is represented by pantothenic acid (52.8 mg/100 g), followed by niacin (42.42 mg/100 g). Royal jelly also contains a considerable number of bioactive substances, including proteins with antimicrobial properties, fatty acids and peptides, the composition and content of which may vary depending on the plant and postharvest conditions. Studies have shown that royal jelly exhibits antioxidant, anti-inflammatory, anti-aging, neuroprotective, antibacterial, anti-allergic, and antitumor pharmacological properties and is widely used in the food, cosmetic, and pharmaceutical industries (Liu et al., 2023).

1.7. Bee venom

It is the action of the bee to defend itself when it feels in danger. In the abdomen of the bee, there is a gland where venom is produced, with multiple uses in apitherapy. This venom is a

natural substance, a dense, colorless liquid, with a specific, pungent smell, it is soluble in water and insoluble in alcohol (Abdela et al., 2016). Bee venom is used in traditional medicine to treat various diseases. The latest research refers to the use of bee venom as an alternative treatment for breast cancer, which indicates that bee venom has an anti-cancer effect (Kwon et al., 2022), it can have an antibacterial effect for resistant pathogens (Gökmen et al., 2023) and can be used in various skin diseases, being used in preparations as cosmetic products or can be used as a dressing in the treatment of various skin wounds (Abd El-Wahed et al., 2021). Research shows that Lyme disease, HIV, Parkinson's and Alzheimer's diseases are among the most well-known diseases in the treatment of which bee venom is used (Al-Ameri et al., 2022).

To summarize the presented information regarding bee products composition, Table 1 presents a synthesis with the main results of the study.

Table 1. Chemical and nutritional composition of bee products

Region	Composition	Reference
	Propolis	
Romania	Water content: 0.35-0.66 % Ash: 0.94-0.98 % Na (103.29-110.33 mg), Ca (587.05-840.40 mg), K (97.34-128.79 mg), Mg (144.24-148.99 mg), P (132.00-152.63 mg), Fe (41.97-54.58 mg), Mn (4.91-5.67 mg), Cu (2.32-3.13 mg), Zn (15.85-42.73 mg), Cd (0.24-0.55 mg)	Moraru et al., 2024
Spain	Moisture: 16.26% Ash: 0.85% Ca (856.56 mg/kg), Cu (1.51 µg/kg), Fe (107.82 mg/kg), Zn (73.72 mg/kg), K (1690.15 mg/kg), Mg (217.79 mg/kg), Mn (14.22 mg/kg), Pb (4056.98 µg/kg), Hg (5.59 µg/kg) Total polyphenols: 42.72 Pinocembrin–Galangin Eq./100g Total flavonoids content: 1.64-4.95 QE g/100g Antioxidant activity: 1114.28 µM (TEAC), 2535.40-3918.18 µM (CEAC)	Rendueles et al., 2023
Portugal	Water content: 2.42-6.56 % Ash: 0.79-1 % Total polyphenols content: 107.96-226.73 mg GAE/g extract Total flavonoid content: 31.9-40.94 mg QE/g extract Total ortho-diphenol content: 272.3-332.27 mg GAE/g extract Antioxidant activity: 10.81-21.49 EC_{50} µg/mL (DPPH), 8.38-10.53 EC_{50} µg/mL (ABTS)	Caetano et al., 2023
Italy	Dry matter: 3.23-3.82 % Ash: 0.7-2.06% Total phenols: 222.44-442.26 mg GAE/g Total flavonoids: 64.35-115.62 mgQE/g Antioxidant activity: 4.97-5.66 mMTE/g (ABTS), 1.2-1.76 mMTE/g (FRAP)	Grassi et al., 2023
Lithuania	Brix: 11.1 Total phenolic content: 87.2 mg RUE/10 g Total flavonoid content: 8.4 mg RUE/10 g Radical scavenging activity: 27.0 mg RUE/10 g	Adaškeviciut et al., 2019
Egypt (extracts - 10 g of sample in 100 ml methanol)	Gallic acid 3.4 ± 0.12 mg/mL Vanillic acid 2.45 ± 0.25 mg/mL Synringic acid 4.24 ± 0.35 mg/mL p-Coumaric acid 24.5 ± 0.05 mg/mL Ferulic acid 26.5 ± 0.16 mg/mL Caffeic acid 11.4 ± 0.04 mg/mL Quercitin 2.24 ± 0.02 mg/mL Rutin 6.4 ± 0.11 mg/mL Catechin 2.1 ± 0.13 mg/mL Epicatechin nd α-Catechin nd Kaempferol 0.59 ± 0.19 mg/mL Apigenin 3.57 ± 0.21 mg/mL 3,4-Dimethoxycinnamic acid nd Naringenin 2.56 ± 0.28 mg/mL Luteolin 1.3 ± 0.24 mg/mL	Mohdaly et al., 2015

Malaysia	Total phenolic content: 10.017-17.043 mgGAE/g Total flavonoid content: 0.204-0.830 mgQE/g Antioxidant activity DPPH (IC_{50}, mg/g): 30.77 (20% ethanol crude extract) and 96.28 (100% water crude extract); ORAC (mg Trolox Equivalent/g Propolis): 3.821 (20% ethanol crude extract) and 0.623 (100% water crude extract)	Lim et al., 2023
Brazil	Total phenolics: 192.03-336.91 mg GAE/g Flavonoids: 16.70-34.38 mg QE/g	Dutra et al., 2023
Brazil	Total phenolic compounds: 2741.71 mg GAE/100 g (Green propolis), 1191.55 mg GAE/100 g (Brown propolis), 901.79 mg GAE/100 g (Dark propolis) Antioxidant capacity: Green propolis: 293.90 Trolox µM/g (ABTS), 422.83 µM Ferrous Sulfate/g (FRAP), 491.68 (EC_{50} Expressed in g of Sample/g of DPPH) Brown propolis: 109.29 Trolox µM/g (ABTS), 179.54 µM Ferrous Sulfate/g (FRAP), 1054.38 (EC_{50} Expressed in g of Sample/g of DPPH) Dark propolis: 162.57 Trolox µM/g (ABTS), 161.29 µM Ferrous Sulfate/g (FRAP), 1090.72 (EC_{50} Expressed in g of Sample/g of DPPH)	Vieira et al., 2023
Bee pollen		
Portugal	Ash: 3.3±0.5 g.100 g^{-1} Water: 5.3±0.5 g.100 g^{-1} Lipid: 5.2±3.7 g.100 g^{-1} Protein: 19.3±3.6 g.100 g^{-1} Fiber: 5.4±0.5 g.100 g^{-1} Carbohydrate: 67.1±1.3 g.100 g^{-1}	Aylanc et al., 2023
Portugal	Antioxidant activity (DPPH): 0.20 mg/mL Reducing power activity: 5.0 mg GAE/g	Ertosun et al., 2023
Spain	Total phenolic content: 1612.6 mg/100 g Total flavonoid content: 256.8 mg/100 g Antioxidant activity: 65.7% (DPPH), 57.4% (ABTS)	Rojo et al., 2023
Italy	Polyphenols: 27.37 mg GAE/g FW Flavonoids: 25.37 mg QE/g FW Flavonols: 13.50 mg QE/g FW Anthocyanins: 58.16 mg C3GE/L Carotenoids: 11.78 µg/g FW Antioxidant activity: 5.31 TEAC (ABTS), 0.15 EC_{50} mg/mL (DPPH), 587.64 µmol TE/g FW (ORAC), 15,054.81 Fe^{2+} µM (FRAP), 1.03 mg EDTAE/g FW (Fe^{2+} Chelation)	Chelucci et al., 2023
Lithuania	Brix: 27.2 Total phenolic content: 47.2 mg RUE/10 g Total flavonoid content: 32 mg RUE/10 g Radical scavenging activity: 26.7 mg RUE/10 g	Adaškeviciut et al., 2019
Poland	Total phenolic content: 10.36 mg GAE/g Total Carotenoid content: 24.96 µg/g Antioxidant activity: 26.61 µmol TE/g (FRAP), 17.61 µmol TE/g (DPPH)	Miłek et al., 2023
Egypt (extracts - 10 g of sample in 100 ml methanol)	Gallic acid 5.9 ± 0.05 mg/mL Vanillic acid 0.35 ± 0.15 mg/mL Synringic acid 0.59 ± 0.08 mg/mL p-Coumaric acid 2.48 ± 0.25 mg/mL Ferulic acid 4.2 ± 0.18 mg/mL Caffeic acid 4.21 ± 0.22 mg/mL Quercitin 6.4 ± 0.30 mg/mL Rutin 3.46 ± 0.14 mg/mL Catechin 4.8 ± 0.18 mg/mL Epicatechin 2.1 ± 0.08 mg/mL α-Catechin 0.58 ± 0.05 mg/mL Kaempferol 1.65 ± 0.24 mg/mL Apigenin 2.4 ± 0.25 mg/mL 3,4-Dimethoxycinnamic acid 45.8 ± 0.16 mg/mL Naringenin 3.34 ± 0.12 mg/mL Luteolin 2.8 ± 0.10 mg/mL	Mohdaly et al., 2015
United States	Pollen collected from industrial hemp Moisture: 76.8-81.6 % Ash: 1.55-1.87 %	Dingha and Jackai, 2023

	Crude fiber: 1.50-2.67 % Protein: 6.05-6.89 %		
-	Carbohydrates/100g: 31.69 Lipids/100 g: 20.44 Proteins/100 g: 23.6 Total phenols content: 22.62 mg GAE/g dw Total flavonoids content: 85.75 mg QE/g dw Antioxidant activity DPPH: 413.85 mmol TE/g FRAP: 36.56 µmol TE/g TEAC: 86.06 µmol TE/g CUPRAC: 155.18 µmol TE/g		Tirla et al., 2023
Bee bread			
Portugal	Ash: 3.5±0.2 g.100 g^{-1} Water: 7.6±0.2 g.100 g^{-1} Lipid: 3.6±1.0 g.100 g^{-1} Protein: 22.6±0.8 g.100 g^{-1} Fiber: 4.4±0.6 g.100 g^{-1} Carbohydrate: 65.6±1.5 g.100 g^{-1}		Aylanc et al., 2023
Poland	Total phenolic content: 9.53 mg GAE/g Total Carotenoid content: 33.14 µg/g Antioxidant activity: 26.98 µmol TE/g (FRAP), 15.83 µmol TE/g (DPPH)		Miłek et al., 2023
Greece	Total phenolic content: 6.49-14.64 mg GAE/g Total flavonoids content: 2.34-5.49 mg QE/g Antioxidant activity: 0.18-1.80 IC_{50} (DPPH), 0.38-1.80 IC_{50} (ABTS)		Didaras et al., 2021
Lithuania	Brix: 19.0 Total phenolic content: 19.63 mg RUE/10 g Total flavonoid content: 7.88 mg RUE/10 g Radical scavenging activity: 17.23 mg RUE/10 g		Adaškeviciut et al., 2019
Honey			
Lithuania	Brix: 17.40 Total phenolic content: 5.6 mg RUE/10 g Total flavonoid content: 3.6 mg RUE/10 g Radical scavenging activity: 4.06 mg RUE/10 g		Adaškeviciut et al., 2019
Republic of Serbia	Sunflower honey Moisture: 17.01 % Ash: 0.13% HMF (hydroxymethylfurfural): 2.08 mg/kg Sucrose: 0.332 % Glucose: 37.07 % Fructose: 40.24 %		Živkov Baloš et al., 2023
Romania	Rape honey Moisture: 17.30-19.12% HMF: 7.40-48.60 mg/kg Total phenolic content: 12.50-31.04 mg GAE/100 g Total flavonoids content: 7.66-16.23 mg QE/100 g Antioxidant activity: 49.06-55.80 (DPPH) Fructose: 34.87-37.61% Glucose: 28.25-36.09% Sucrose: 0-0.62% Turanose: 0.26-4.16% Maltose: 0.89-5.97% Trehalose: 0.91-11.34% Melesitose: 0.60-2.95% Raffinose: 0-0.36%		Pauliuc & Oroian, 2020
Brazil	From *Melipona fasciculata* Moisture: 27 % Brix: 71 Apparent sucrose: 1% Total phenols: 122 mg kg^{-1} Total flavonoids: 87 mg kg^{-1} Ascorbic acid: 51.8 mg kg^{-1}	From *Melipona subnitida* Moisture: 27.2 % Brix: 72.1 Apparent sucrose: 1.74% Total phenols: 202 mg kg^{-1} Total flavonoids: 121.8 mg kg^{-1} Ascorbic acid: 75 mg kg^{-1}	da S. Sant'ana et al., 2020

	Acetic acid: 536 mg kg $^{-1}$ Maleic acid: 0.6 mg kg $^{-1}$ Succinic acid: 0.2 mg kg $^{-1}$ Fumaric acid: 0.6 mg kg $^{-1}$ Tartaric acid: 745 mg kg $^{-1}$	Acetic acid: 3584 mg kg $^{-1}$ Maleic acid: 0.0 mg kg $^{-1}$ Succinic acid: 0.45 mg kg $^{-1}$ Fumaric acid: 0.8 mg kg $^{-1}$ Tartaric acid: 9865 mg kg $^{-1}$	
United States	Buckwheat honey Antioxidant activity: 1.01 µmol TE/g (ORAC), 78.1 ED_{50} 10 min mg eq./ml (DPPH) Total phenolic content: 0.32 GAE mg/g	Wild plants honey Antioxidant activity: 0.39 µmol TE/g (ORAC), 89.5 ED_{50} 10 min mg eq./ml (DPPH) Total phenolic content: 0.17 GAE mg/g	Corey et al., 2022
United States	Water content:16.4-18.2% HMF: 5.5-12.1 mg/kg Total phenolic content: 81.6-105.7 mg GAE/100 g		Nyarko et al., 2023
Iraq	Sucrose: 2.2-2.9% Moisture: 13.53-16.07 g/100 g Melanoidin: 0.25-0.44 Antioxidant activity: 14.26-22.15 mg AAE/g, 7.87-95.62 IC50 mg/mL (DPPH) Total phenol: 55.33-120.33 mg GAE/100 g Coumaric acid: 0.00-2.34 µg/mL Catechin: 0.00-2.68 µg/mL Quercetin: 0.00-0.30 µg/mL		Hameed et al., 2024
Egypt	Sidr honey Moisture: 19.03 % HMF: 11.33 mg/kg Glucose: 26.62 g/100 g Fructose: 35.28 g/100 g Sucrose: 8.87 g/100 g Maltose: 8.13 g/100 g		El-Wahed et al., 2023
Saudi Arabia	Sidr honey Moisture: 18.03 % HMF: 20.92 mg/kg Glucose: 22.51 g/100 g Fructose: 40.33 g/100 g Sucrose: 8.94 g/100 g Maltose: 8.22 g/100 g		El-Wahed et al., 2023
Saudi Arabia	Moisture: 14.9 % HMF: 3.8 mg/kg Glucose: 31.5 % Fructose: 39.7 % Sucrose: 2.8 %		Raweh et al., 2023
Royal jelly			
Romania	Water content: 64.75-65.56 % Protein: 36.13-41.75 mg/g Ash: 0.93-1.46 % Na: 182.67-187.53 mg, Ca: 200.79-382.12 mg, K: 1182.42 – 1659.43 mg, Mg: 365-77-423.32 mg, P: 1125.75 -1648.38 mg Fe: 17.87-19.43 mg, Mn: 4.20-5.32 mg, Cu: 6.26-7.12 mg, Zn: 19.71-21.95 mg, Cr: 1.03-2.95 mg Cd: 0.70-1.51 mg		Moraru et al., 2024
Poland	Water content: 68.4 % Total protein: 14.12 % Antioxidant activity: 10.52 % (DPPH), 0.19 µmol TE/100 g (FRAP) Total phenolic content: 189.72 mg GAE/100 g Total flavonoids content: 11.3 mg/100 g		Sidor et al., 2021
Lithuania	Brix: 13.9 Total phenolic content: 20.8 mg RUE/10 g Total flavonoid content: 14.2 mg RUE/10 g Radical scavenging activity: 6.7 mg RUE/10 g		Adaškeviciut et al., 2019

2. PROCESSING OF BEE PRODUCTS

2.1. Bee honey

Bee honey at the time of extraction contains pollen, beeswax, bee remains, practically many other unwanted materials. These impurities must be removed, for a better quality of honey and for a longer shelf life. A major problem for tropical countries is that honey can ferment. For this to happen, different conditions of temperature and time are needed to inactivation of yeasts and moulds, these being the only microorganisms that develop in honey (Kebede et al., 2024). The pasteurization of honey can be done by heating it for a few seconds at a temperature of 70-75 °C to eliminate the yeast, but then it is rapidly cooled, to not affect the quality of the honey (Eshete Y. & Eshete T., 2019).

2.2. Bee wax

Bee wax is a semi-solid product from inside the hive, mixed with honey and resins. In order for this to be a product utilized to its maximum capacity, it must go through different treatments. The classic method consists in soaking the wax for 24 hours in clean water, so that the honey and resins are removed. Then it is melted in boiling water, after which it is strained and squeezed by hand. Thus, the freshly obtained wax is clean and of superior quality.

2.3. Bee propolis

Bee propolis is found in two forms, in the form of an aqueous extract and in the form of an ethanolic extract. Most uses of propolis are found in the form of ethanolic extract, where ethanol of at least 70% is used to extract propolis (Kebede et al., 2024), and the method used to concentrate the propolis extract is done under reduced pressure. The duration of extraction varies from 10 days and can reach up to 30 days, because the propolis weight/extract volume ratio is usually made. There are also extracts in the form of powder, where the raw material after harvesting is crushed, sieved to keep pure propolis and then extracted using different solvents (water, glycol, ethyl alcohol or ethanol) (Galeotti et al., 2018).

2.4. Bee pollen

Bee pollen is most often found in the form of aqueous, lipid and freeze-dried extracts. Different ingredients are used for these extracts, especially for the extracts used in the cosmetic industry (water, oil, glycerine, propylene glycol) (Kebede et al., 2024). Pollen grains can also be used as such in the cosmetic industry, after which have previously been dehydrated. This beehive product is less used as such in the food industry, due to its low digestibility as well as the allergenic nature it can have (Yin et al., 2022). Being a product with a potential maximally as a functional food, the use of inoculated fermentation was considered.

The latest researches emphasize that this fermentation destroys the cell wall thus increasing digestibility and the accumulation of nutrients and active compounds found in pollen (Di Cagno et al., 2019). Thanks to these improvement research, fermented pollen is used in various food applications (Cheng et al., 2024). Pollen is found in various fermented food products (wine, yogurt, cheese), both for its unique flavour and for its properties. Spontaneous pollen fermentation is carried out with the help of bacteria (*Pseudomonas* spp. *and Lactobacilli* spp.) and yeasts (*Saccharomyces* spp.) which are present in bee saliva. This naturally fermented product inside the hive is called bee pasture. Regarding the laboratory fermentation of bee pollen, this fermentation is carried out with microorganisms (*Lactobacillus rhamnosus*, *Lactobacillus kunkeei*, and *Hanseniaspora uvarum*) to obtain artificial bee bread. The fermentation process improves the nutritional properties and bioavailability of pollen through a number of mechanisms. First, fermentation facilitates the breakdown of complex molecules such as proteins, polysaccharides and lipids, transforming them into smaller and more digestible forms, which makes them more accessible to the body (Aylanc et al., 2023).

Second, the presence of microbial enzymes during fermentation improves the activity of digestive enzymes, contributing to the process of digestion and absorption of nutrients (Rul et al., 2022). Third, the probiotics present in fermented pollen support gut health and optimize digestive function, thus supporting nutrient absorption and improving their bioaccessibility (Yan et al., 2021). These combined effects contribute to improving the digestion process and nutrient bioavailability in fermented pollen.

2.5. Bee bread

Bee bread is quite difficult to extract from inside the hive. This separation of the bread from the bees inside the hive is done in four stages. The first stage is the drying of the bee bread, for 8-10 hours at 40°C. The second stage is the maceration of the pasture. After drying, the bee bread is cooled and then ground, up to 4.9-5 mm (Kebede et al., 2024). The third stage represents the filtering of the matter, and for this stage a special machine with an air flow is used, so that all the wax particles disappear. And the fourth stage represents the disinfection of bee bread, with the help of methylene and ethylene oxide, under the action of gamma rays.

2.6. Bee venom

Regarding the processing of bee venom for its use in the cosmetic industry, there are some essential steps, starting from the extraction of the venom with a venom collector, then purified. The clean product is diluted with water, centrifuged, lyophilized and refrigerated before use (Kebede et al., 2024).

CONCLUSIONS

As a general conclusion regarding bee products, they can be divided into two categories, bee collection products (honey, propolis, pollen, pasture) and products made with the help of bee's secretions (wax, royal jelly, venom). Beehive products are essential components in the manufacture of medicinal products, cosmetic products, or as functional foods. Each of these products mentioned in the article is differentiated by the presence of different active chemical substances, therefore extraction, isolation and purification techniques are necessary for almost all beehive products.

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