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HONEY BEE (*Apis mellifera* L.) PRODUCTS AND COMPREHENSIVE USAGE AREAS

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Abstract:
Honeybees (*Apis mellifera L.*) play a crucial role in cross-pollination, enhancing genetic variation in plants and supporting their propagation through seed formation. This vital ecological function contributes to sustainable agriculture and global biodiversity. In addition to pollination, honeybees provide various products with significant applications in medicine, alternative therapy, and diverse industries. Honey, a nutrient-rich substance with antimicrobial and healing properties, has been used since ancient times for nutritional and therapeutic purposes. Propolis, composed of resins, wax, essential oils, and phenolic compounds, exhibits antimicrobial, antioxidant, and wound-healing properties and finds applications in pharmaceuticals, cosmetics, and food preservation. Royal jelly, rich in proteins, vitamins, and unique fatty acids like 10-HDA, demonstrates antimicrobial and anti-inflammatory effects and is widely used for health enhancement. Bee venom, containing bioactive peptides such as melittin and apamin, has therapeutic applications in conditions like arthritis and skin treatments but requires careful handling due to its allergenic potential. Beeswax, composed of complex organic compounds, is utilized in cosmetics, pharmaceuticals, and biofuel production due to its chemical stability and waterproofing properties. Lastly, bee pollen, a nutrient-dense superfood, is known for its high protein and vitamin content and is used in treating cardiovascular diseases, cancer, and diabetes. These diverse applications underscore the ecological and economic importance of honeybee products

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BAL ARISI (*Apis mellifera* L.) ÜRÜNLERİ VE YAYGIN KULLANIM ALANLARI

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Özet:
Bal arıları (*Apis mellifera* L.), yabancı tozlaşmada önemli bir rol oynar. Bitkilerdeki genetik çeşitliliği artırır ve tohum oluşumu yoluyla yayılmalarını destekler. Bu hayati ekolojik işlev, sürdürülebilir tarıma ve küresel biyoçeşitliliğe katkıda bulunur. Tozlaşmaya ek olarak, bal arıları tıp, alternatif terapi ve çeşitli endüstrilerde önemli uygulamalara sahip çeşitli ürünler sağlar. Antimikrobiyal ve iyileştirici özelliklere sahip besin açısından zengin bir madde olan bal, eski çağlardan beri beslenme ve tedavi amaçlı kullanılmaktadır. Reçineler, mum, uçucu yağlar ve fenolik bileşiklerden oluşan propolis, antimikrobiyal, antioksidan ve yara iyileştirici özellikler gösterir ve ilaçlarda, kozmetiklerde ve gıda korumada uygulamalar bulur. Proteinler, vitaminler ve 10-HDA gibi benzersiz yağ asitleri açısından zengin olan arı sütü, antimikrobiyal ve anti-inflamatuar etkiler gösterir ve tıpta kullanılması yanında alternatif tıp olarak için yaygın olarak kullanılmaktadır. Melittin ve apamin gibi biyoaktif peptitler içeren arı zehri, artrit ve cilt tedavileri gibi durumlarda terapötik uygulamalara sahiptir ancak alerjenik potansiyeli nedeniyle dikkatli bir şekilde kullanılması gerekir. Karmaşık organik bileşiklerden oluşan balmumu, kimyasal kararlılığı ve su geçirmezlik özellikleri nedeniyle kozmetik, ilaç ve biyoyakıt üretiminde kullanılır. Son olarak, besin açısından yoğun bir süper gıda olan arı poleni, yüksek protein ve vitamin içeriğiyle bilinir ve kardiyovasküler hastalıklar, kanser ve diyabet tedavisinde kullanılır. Bu çeşitli uygulamalar, bal arısı ürünlerinin ekolojik ve ekonomik önemini vurgular.

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Introduction

The honeybee (*Apis mellifera* L.) contributes to cross-pollination in plants through sexual reproduction [1, 2, 3], thereby increasing genetic variation in plants and supporting the continuation of plant species by enabling the formation of new seeds. By ensuring sustainable agricultural production [4], honeybees maintain ecological balance and provide large-scale contributions to the economy. With their products and their role in pollination, they are regarded as the most important insect worldwide [5, 6, 7]. Honeybees are highly adaptable insects studied extensively by scientists, capable of thriving in a wide range of habitats—from semi-arid and arid regions to semi-temperate and temperate zones, from high mountains to rainforests. They also offer alternative medical solutions to people living in impoverished areas where modern medical facilities are inaccessible [8].

Honey

Honey generally consists of 15–17% water and contains 15 types of sugar carbohydrates, primarily fructose and glucose, making up 80–85% of its composition [9, 10, 11]. A honey sample typically includes nutrients such as magnesium (Mg), calcium (Ca), potassium (K), phosphorus (P), iron (Fe), copper (Cu), silicon (Si), aluminum (Al), cobalt (Co), nickel (Ni), and chromium (Cr). Additionally, honey contains 17 different amino acids, and the protein content varies between 0.4% and 1%, depending on the source of the honey [9, 10, 11]. The most valuable components of honey are its enzymes: diastase, invertase, and catalase. Honey also contains 13 different organic acids, including formic acid (CH_2O_2), malic acid (C4H6O5), oxalic acid ($C_2H_2O_4$), lactic acid ($C_3H_6O_3$), and citric acid ($C_6H_8O_7$). Moreover, honey is rich in vitamins, including K, E, C, B1, B4, B2, B3, B5, and B6 [10, 12, 13, 14, 15, 16, 17].

In a study by Chua et al. [18] using ICP-MS (Sciex Elan 6100, Perkin Elmer, USA), a honey sample was found to contain 26 nutrient elements: titanium (Ti), calcium (Ca), lead (Pb), cobalt (Co), vanadium (V), gallium (Ga), uranium (U), beryllium (Be), arsenic (As), lithium (Li), iron (Fe), barium (Ba), magnesium (Mg), cesium (Cs), aluminum (Al), indium (In), chromium (Cr), cadmium (Cd), manganese (Mn), silver (Ag), zinc (Zn), strontium (Sr), rubidium (Rb), arsenic (As), selenium (Se), and copper (Cu). Bogdanov [19] reported that an acceptable pH range for honey is between 3 and 4.

The use of honey by humans dates back approximately 5,500 years, making it as old as human history itself [20]. Throughout history, honey has been utilized for both nutrition and healing purposes. In regions where modern medical facilities are unavailable, honey has served as a healing agent, while in developed and developing countries, it is used as an alternative medicine to avoid the side effects of pharmaceutical drugs. Honey has been actively used in treating a wide range of ailments, including wound healing, cancer, eye diseases, stomach ulcers, eczema, hemorrhoids, hiccups, throat allergies, hepatitis, constipation, intestinal worms, tuberculosis, asthma, fatigue, thirst, dizziness, and stomach bloating [21].

Good-quality honey typically has a pH value between 3.2 and 4.5, contributing to its antibacterial properties [22]. James et al. [10] found that the pH of honey samples ranged from 3.0 to 4.0, while Meechai et al. [23] reported a pH range of 3.7 to 3.8. The energy value of honey is approximately 300 kcal per 100 grams. Kek et al. [24] recorded energy values between 266.7 and 327.5 kcal per 100 grams in honey samples, while Larson et al. [25] reported an energy value of 450 kcal per 100 grams for high-quality honey. Additionally, studies indicate that the low water content and hydrogen peroxide production in honey inhibit microbial activity [26, 27, 28].

Propolis

Types of propolis vary depending on the botanical composition of the pollens collected, the physical and chemical properties of the plants, and the geographical location [29].In medicine and the pharmaceutical industry, it is used for wound healing and skin protection, oral health, respiratory health, strengthening the immune system, treating stomach issues such as infections caused by *Helicobacter pylori*, as an antifungal and antibacterial agent, and in the treatment of chronic diseases [32,33].

Tablo 1. The content of propolis, its quantities, and the properties of these components.

Content of propolis	Quantities (%)	Properties of these components
Resins and Balsams	50-60%	Antibacterial, antifungal, and wound-healing properties [30,31]
Pollen	5%	Nutritional value and low allergenicity [30,31]
Essential Oils	5-10%	Antimicrobial and aromatic effects [30,31]
Beeswax	30-40%	Structural functionality and protective barrier roles [30,31]
Phenolic Compounds	10-20%	Strong antioxidants (flavonoids, phenolic acids, etc.)
Flavonoids	5-10%	Antioxidant, antimicrobial, and anti-inflammatory properties
Aromatic Acids	5%	Plays a role in antimicrobial activities
Amino Acids	in trace amounts	Building blocks of proteins
Vitamins	in trace amounts	B-derivatives, Vitamin C, and Vitamin E
Minerals	in trace amounts	Zinc, iron, magnesium, calcium, etc.

In cosmetics and personal care, it is utilized in anti-aging products, acne treatments, moisturizers, and lip protection [34,35].In the food and beverage industry, it is employed for the development of dietary products, the production of functional foods, and extending shelf life by protecting foods against bacteria and fungi [36,37].In the livestock sector, it aids in wound healing in animals, promotes bee health, and is used in alternative medicine practices such as apitherapy and aromatherapy [29,38].In agriculture, it prevents diseases and pests from damaging plants [39,40], while in the wood industry, it is used for protective purposes [41].Additionally, it plays a role in cancer research [42] and in combating certain antibiotic-resistant bacteria [43,44].

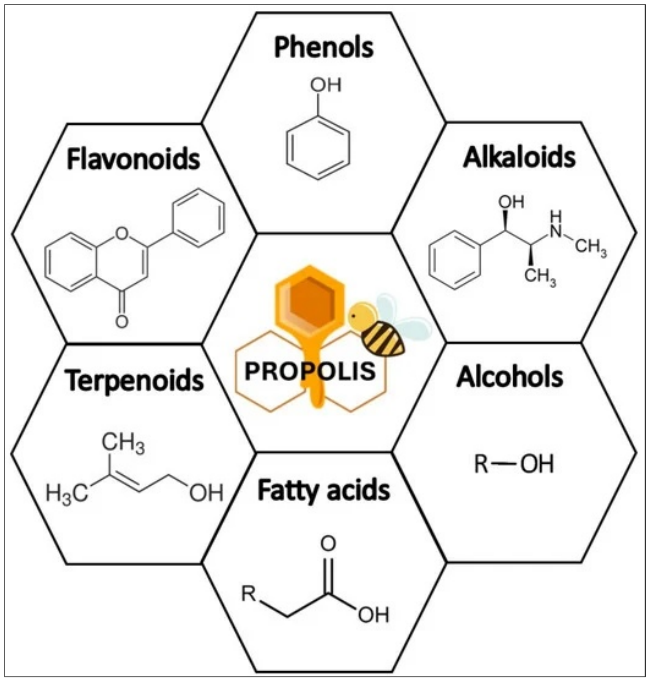

Figure 1. The chemical composition of a propolis sample and the chemical structures of components [45].

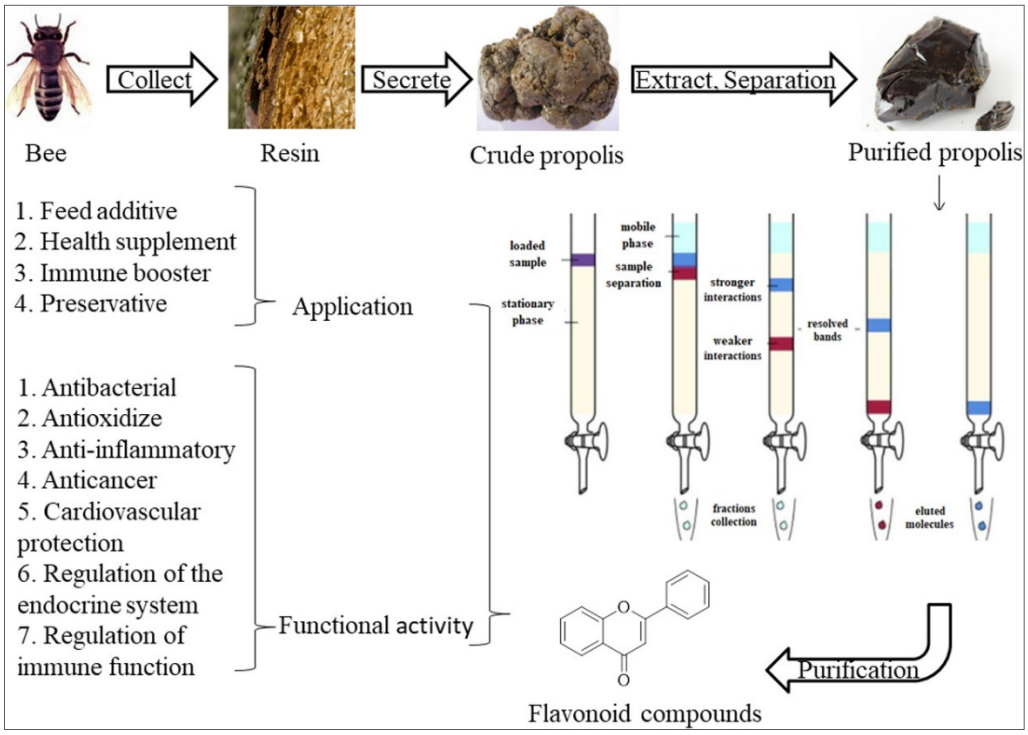

Figure 2. Stages of propolis production [46].

Royal Jelly

Royal jelly is a highly important bee product obtained from bees. It has the ability to provide energy to the consumer, with natural sugars like fructose and galactose ranging from 2.3% to 7.8% and 3.4% to 7.7% respectively [48]. It contains unique fatty acid 10-HDA, which has antimicrobial and anti-inflammatory properties [48], a water content of 60-70% [48], and a protein content of 9-18% [48]. It also contains trace amounts of vitamins B1, B2, B3, B5, B6, B7, B9, B12, and some vitamin C [48, 50, 51]. The amino acid content, which forms the building blocks of proteins, is 7.9% [48, 52, 53]. Additionally, it contains trace amounts of minerals such as Calcium (Ca), Magnesium (Mg), Potassium (K), Sodium (Na), and Zinc (Zn); phenolic compounds in trace amounts; and both RNA and DNA nucleotides and enzymes [48, 51, 54, 55, 56].

Bee Venom

Melittin, dry honey bee venom is composed of 40-60% of the main 26 amino acid peptides, which have anti-inflammatory and antimicrobial properties but can also cause pain and inflammation [57]. The hyaluronidase enzyme found in bee venom is used in various medical fields, including dermatology, oncology, surgery, internal medicine, orthopedics, ophthalmology, and gynecology [58]. Additionally, the phospholipase A2 enzyme, which makes up 10-12% of the venom, can break down cell membranes and trigger allergic reactions [59,60]. Apamin, which constitutes 2-3% of dry honey bee venom, contains 18 amino acids of a neurotoxin peptide [61,62]. The anti-inflammatory and analgesic effects of Adolapin are present at levels of 1-2%, while the mast cell degranulation peptide (MCDP) is also found at 1-2% and can activate histamine release, triggering allergic reactions [63,64,65,66]. Bee venom also contains trace amounts of carbohydrates, lipids, and amino acids, with histamine, a component that causes nausea, itching, and swelling, present at 0.1% [67,68].

Bee venom has a neutral to slightly acidic pH range (pH: 4.5-5.5) [69,70]. Despite being present in very small amounts, it has toxicity due to its more than 40 bioactive components and can affect the immune and nervous vascular systems, ranging from mild pain to allergic reactions. It is also used in apitherapy applications, and bee venom has been shown to treat diseases like arthritis, rheumatism,

and multiple sclerosis. Additionally, it improves skin elasticity and reduces wrinkles in skin treatments. Bee venom can act both as a potent therapeutic agent and an allergenic factor [71,72,73].

Beeswax

The chemical composition of beeswax includes over 300 components, including fatty acid esters, hydrocarbons, alcohols, and free fatty acids, as well as complex organic compounds [74, 75]. Beeswax also plays a key role in the honeybee colony, helping to recognize nestmates, establish characteristic chemical content, and facilitate chemical communication among bees in the hive [76, 77, 78]. Beeswax is used in the food industry as the additive E901, and due to its melting temperature of 70-90°C, it is also utilized in the cosmetic and pharmaceutical industries [79, 80, 81]. Hydrocarbons, responsible for the water-repellent properties of beeswax, make up 12.3-17.8% of its composition [82]. The most abundant hydrocarbon in Amellifera beeswax is C27 alkane (heptacosane), which constitutes 6.2% of the total components of the wax (Aichholz and Lorbeer [83]). Subsequent analyses by Maia and Nunes [84] revealed a higher presence of heptacosane, with the C27 content in the total beeswax reaching 13%. They also found the proportions of nonacosane (C29) and hentriacontane (C31) hydrocarbons to range between 9.9% and 16.8%. In content analysis of European honeybee beeswax, Tulloch [85] identified 11 major components: 14% hydrocarbons, 35% monoesters, 14% diesters, 3% triesters, 8% hydroxyl polyesters, 1% acid esters, 1% acid polyesters, 12% free acids, 1% free alcohols, and 6% unidentified components. Beeswax in nature is categorized into three types: plant-based, animal-based, and mellifera bee species (which is typically honeybee wax). Its structure primarily consists of long ester chains formed between fatty alcohols and fatty acids. These long ester chains can be converted into fatty acid methyl esters (FAMEs) through the transesterification process, enabling the production of biodiesel fuel [86, 87].

Pollen

Bee pollen is a very powerful and healthy food source, often referred to as a superfood. It has been shown that bee pollen can meet 60-70% of daily nutritional requirements due to its high fiber and protein content [88]. Bee pollen generally contains 10-40% protein, 13-55% carbohydrates, 1-13% lipids, 0.3-20% crude fiber, and 2-6% ash [89]. It also contains B1, B2, B3, B5, B6, B9, B12 vitamins, as well as C, D, E, and K vitamins, essential minerals, all essential amino acids and fatty acids, free amino acids, carotenoids, and flavonoids [90, 91]. The main sugars in bee pollen are fructose, glucose, and sucrose, while the remaining sugars make up 1% and include turanose, trehalose, ribose, melizitose, isomaltose, and arabinose [92, 93]. Additionally, it is a product with a very powerful nutritional content that strengthens the immune system and provides natural energy. This high nutritional value is used in dietary applications to help individuals lose weight [94]. Bee pollen is used in the treatment of diseases such as cardiovascular diseases, infectious diseases, cancer, and diabetes. Bee pollen, which consists of flower nectar, enzymes, flower pollens, and honeybee secretions, contains secondary metabolites including proteins, carbohydrates, fatty acids, vitamins, polyphenols, phytosterols, co-enzymes, enzymes, and carotenoid pigments. These components give bee pollen antibacterial, antioxidant, anticancer, antiallergic, antifungal, immunomodulatory, hepatoprotective, and chemopreventive effects [96].

Conclusion and Recommendations

While honeybees collect pollen from plants to produce honey and other bee products, they also facilitate cross-pollination. As bees land on most plants, they drop both the foreign pollen they carry and the plant's own pollen, ensuring fertilization. This enables the plant to benefit from both cross-pollination and self-pollination. The greatest source of variation desired by plant breeders comes from honeybees. Through functions such as cross-pollination and seed formation, plants play an active role in maintaining ecological balance and supporting sustainable agricultural practices.

As a result of this study, it has been found that bee products such as honey, propolis, royal jelly, bee venom, beeswax, and pollen have very high nutritional values. In addition to their use in industries like medicine, food, and cosmetics, they are also utilized as alternative medicine in regions where modern medical facilities are not available.

It is recommended to reduce the use of agricultural chemicals harmful to honeybees, combat natural

enemies that threaten bees, protect bee populations and their habitats, and increase their populations and genetic diversity. Furthermore, efforts should be made to standardize the use of bee products in alternative medicine, enhance genetic diversity in plant cover, protect clean water sources, and conduct research to uncover the therapeutic effects and biological properties of bee products.

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