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Review Article

From Hive to Hope: Honeybee and Apiculture Derived Products in Pakistan

Mahroo Munir[1], Sikandar Hayat[2], Zeshan Javaid[3], Muhammad Atif Irshad[4]*

[1] School of Zoology, Minhaj University, Township, Lahore, Pakistan
[2] Department of Zoology, The University of Lahore, 54000, Pakistan
[3] Department of Environmental Sciences, Government College University Faisalabad, 38000, Pakistan
[4] Department of Environmental Sciences, The University of Lahore, 54000, Pakistan
**Corresponding author`s email address: atif.irshad91@yahoo.com*

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Abstract: *Honeybees are vital for pollination, biodiversity, and the production of apicultural products. Their populations, however, are increasingly threatened by various environmental and biological stressors in Pakistan. Strengthening knowledge on their ecological and economic roles is crucial for sustainable conservation.* ***Objective:*** *To synthesize current evidence on honeybee species, apiculture development, economic potential of bee products, and the major threats to honeybee populations in Pakistan.* ***Methods:*** *This narrative review examined published literature, government reports, and apiculture data relevant to Pakistan. Sources were identified from major scientific databases and national records, with no time restrictions. Information on honeybee species distribution, apiculture production, export trends, and threats was extracted and descriptively analyzed to provide an updated overview for researchers and policymakers.* ***Results:*** *Pakistan hosts four honeybee species, with Apis mellifera being the predominant domesticated species. Despite growth in the apiculture sector, average honey yield remains below 12 kg per beekeeper, nearly half of the global average. Honey, pollen, propolis, beeswax, and royal jelly are produced, although honey remains the major export at approximately five million kilograms annually. Diverse biotic and abiotic pressures are causing significant declines in both wild and managed populations, while national data remain insufficient for informed conservation planning.* ***Conclusion:*** *Honeybees in Pakistan hold considerable ecological and economic value, yet their populations face multiple challenges that are inadequately documented. Strengthening research capacity, improving apicultural practices, and establishing targeted conservation strategies are essential to protecting honeybee diversity and ensuring sustainable resource use.*

Keywords: Apiculture, Biodiversity, Conservation, Honeybee, Pollination

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1. Introduction

Honeybees are integral to the health and productivity of natural and agricultural ecosystems, serving as primary pollinators for a vast range of flowering plants. Their activities support the pollination of nearly 70% of major food crops, making them indispensable for sustaining global food security and maintaining ecological balance (1, 2). Beyond their biological role, honeybees contribute significantly to environmental resilience by enabling plant reproduction, promoting genetic diversity, and helping restore degraded landscapes. In Pakistan, apiculture has deep historical and cultural roots, forming an essential Part of rural livelihoods, with many families depending on beekeeping for a steady income. Honeybee products, including honey, beeswax, and propolis, are not only economically profitable but also valued in traditional and modern medicine for their therapeutic properties. As environmental pressures continue to threaten honeybee populations, there is increasing recognition of the need for sustainable and scientifically informed apiculture practices to protect ecosystems and enhance socio-economic wellbeing across the country (3).

2. The Nexus of Honeybees, Pollination, and Biodiversity

The role of honeybees in pollination extends far beyond their contribution to fruit and seed production. They serve as essential agents of ecological stability by ensuring the reproduction of numerous flowering plants, many of which cannot propagate effectively in their absence (4). This process fosters rich genetic diversity and strengthens the resilience of plant communities against environmental stressors. Through their pollination activities, honeybees indirectly sustain diverse animal species that rely on flowering plants for food and habitat, creating a ripple effect that supports entire ecosystems (5). When declining bee populations disrupt pollination, the consequences can be severe, including reduced plant fertility, diminished food sources for wildlife, and long-term ecological imbalance. Such disruptions ultimately compromise ecosystem services that humans rely on, including food availability, soil conservation, and climate regulation. Maintaining healthy honeybee populations is therefore critical to preserving biodiversity, ensuring ecological sustainability, and supporting agricultural productivity at a national and global scale (6).

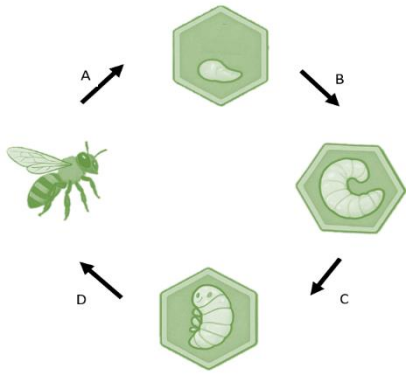

Figure 1: Lifecycle of a honeybee. A) The lifecycle starts with the queen laying a single, small, white, and oval-shaped egg in each hexagonal cell intended for brooding. **B)** A white, blind, and limbless larva hatches and stays curled into a C-shape at the bottom of the cell. **C)** The larvae transform into pupae inside the sealed cells. **D)** According to their pupal development, the new adults come out of their sealed cells.

3. Apiculture-Derived Products

Apiculture in Pakistan provides a wide range of bee-derived products valued for their nutritional, medicinal, and commercial benefits. The key products include honey, beeswax, propolis, royal jelly, bee pollen, and bee venom, each contributing uniquely to health industries, agriculture, and household use. These products have gained increasing attention due to their natural origin, biochemical richness, and growing market demand. As consumers become more health-conscious, the use of natural bee products in food, pharmaceuticals, and cosmetics has expanded significantly. This diversification of bee products offers opportunities for income growth among beekeepers and rural households while also supporting the national economy. Understanding the unique roles and benefits of each product is essential for promoting sustainable production, improving quality standards, and meeting both domestic and international market needs.

3.1 Honey

Honey is one of the most widely consumed bee products and is renowned for its rich nutritional profile, including antioxidants, enzymes, vitamins, and various flavonoids (7). Its antimicrobial and anti-inflammatory properties make it valuable not only in culinary applications but also in traditional and modern medicine, where it is used to treat wounds, respiratory infections, and digestive issues (8). Honey has long been a Part of cultural and dietary practices in Pakistan, where it is used as both a natural sweetener and a therapeutic substance. Economically, honey production offers substantial potential, with increasing local demand and growing export opportunities. The global shift toward natural health products has further boosted interest in Pakistani honey varieties, some of which come from rich floral regions with unique taste profiles and medicinal qualities (9). Strengthening quality control measures and promoting sustainable harvesting practices can enable beekeepers to tap into larger international markets and enhance national revenue.

3.2 Bee Venom

Bee venom is a bioactive substance produced by worker bees and contains various peptides and enzymes known for their therapeutic potential. Research has demonstrated that bee venom exhibits strong anti-inflammatory, neuroprotective, and immunomodulatory effects, making it a promising candidate for the treatment of chronic inflammatory conditions and certain types of pain (10). Furthermore, studies indicate that bee venom components possess cytotoxic properties against cancer cell lines, which has spurred interest in its potential as a complementary cancer therapy (11). As consumers increasingly seek natural and holistic treatment options, apitherapy has gained recognition, contributing to the rising commercial demand for bee venom–based products. The appeal of bee venom lies not only in its pharmacological benefits but also in its minimal processing and natural origin, aligning with global trends favoring herbal and alternative medicine (12). Expanding research and ensuring safety standards can enhance its successful integration into clinical and wellness markets.

3.3 Propolis

Propolis, often referred to as bee glue, is a resinous substance collected by bees from tree buds and plant exudates. It is widely known for its strong antimicrobial, antioxidant, and anti-inflammatory properties, making it valuable for medicinal and cosmetic applications (13). Its role in natural preservation has made it an ingredient of interest in the organic food and skincare industries, where consumers favour chemical-free and eco-friendly alternatives. Propolis is incorporated into nutritional supplements, throat sprays, ointments, and several topical products due to its ability to inhibit bacterial growth and promote wound healing (14). In Pakistan, propolis production has significant potential due to the country's diverse flora, which contributes to varying chemical compositions and unique therapeutic properties. Enhanced research, standardized extraction processes, and improved marketing strategies could substantially increase its appeal in both domestic and international markets.

3.4 Beeswax

Beeswax is a natural secretion produced by bees and is commonly used in skincare, cosmetics, candle making, and food preservation. Its environmentally friendly nature and versatility have increased its appeal among consumers and industries seeking sustainable alternatives to synthetic waxes (15). Beeswax is used in lotions, balms, creams, and medicinal formulations due to its moisturizing, protective, and anti-inflammatory properties. Additionally, its role in organic food storage and in biodegradable packaging has gained attention amid global concerns about plastic pollution. Increased commercial demand for beeswax presents income opportunities for beekeepers in Pakistan, particularly when integrated with value-added market products.

3.5 Bee Pollen

Bee pollen is considered a nutrient-dense superfood and contains proteins, essential amino acids, antioxidants, vitamins, and minerals. It is widely consumed for its potential health benefits, including improved immunity, enhanced metabolism, and increased energy levels (16). Bee pollen is incorporated into dietary supplements, smoothies, and other health products marketed to individuals seeking natural, nutrient-rich alternatives. Its increasing popularity in the health and wellness sector has significantly raised its commercial value. In Pakistan, the diversity of flowering plants contributes to the production of pollen with unique nutritional profiles, offering an opportunity to promote locally produced pollen to global markets. Strengthening quality assurance and packaging strategies can enhance consumer confidence and market growth.

3.6 Royal Jelly

Royal jelly is a highly nutritious substance produced by worker bees to feed larvae and the queen bee. Rich in proteins, vitamins, amino acids, and specific bioactive compounds, royal jelly is widely used in nutritional supplements to boost immunity, improve reproductive health, and enhance overall wellbeing (17). Its anti-inflammatory and antioxidant properties have further increased its appeal among health-conscious consumers. International demand for royal jelly has grown steadily, offering promising opportunities for commercial expansion in Pakistan. Improved processing methods, proper storage techniques, and stricter quality control measures are essential to maintaining its therapeutic potential and increasing its market competitiveness.

4. API-Based Environmental Health Monitoring

The use of Application Programming Interface technologies has emerged as a transformative approach to monitoring environmental factors that influence honeybee health. By integrating sensors and cloud-based systems, APIs provide real-time data on temperature, humidity, atmospheric pollutants, hive weight, and bee activity, enabling beekeepers to make informed management decisions (18). This technology enables early detection of colony stress, enabling timely interventions that can prevent colony losses. Additionally, data gathered through these systems contribute to broader environmental monitoring, helping researchers evaluate climate trends, pollution levels, and ecological changes impacting bees. With the advancement of digital agriculture in Pakistan, incorporating such monitoring tools can enhance precision apiculture, increase productivity, and support sustainable beekeeping practices.

5. Evolution of Apiculture in Pakistan

Apiculture in Pakistan has undergone a significant transformation, evolving from traditional, subsistence-based practices to more structured, commercialized methods. Historically, beekeeping was limited to rural communities that relied on indigenous bee species and simple hive designs. Over time, increasing awareness of the economic value of honey and other bee products led to the adoption of modern hive technologies and the development of structured training programs for beekeepers (19). Government initiatives, research institutions, and international development programs have played important roles in advancing the apiculture sector. Today, commercial beekeeping contributes to income generation, employment creation, and rural development. As global demand for natural products rises, Pakistan has the potential to expand its honey exports and strengthen its position in regional markets. Continued investment in beekeeper education, quality control, and sustainable

practices is essential to enhancing productivity and promoting long-term ecological and economic resilience (20).

6. Challenges to Honeybee Biodiversity

Honeybee biodiversity faces numerous environmental and anthropogenic threats, and understanding these challenges is essential to developing effective conservation strategies. These threats vary in intensity and impact but collectively contribute to declining bee populations and reduced colony productivity. Key categories of threats include climate change, agricultural intensification, chemical pollutants, biological hazards, and emerging technological disruptions. Without timely interventions, these factors may lead to long-term ecological imbalance and loss of critical ecosystem services provided by honeybees. Strengthening monitoring, research, sustainable land-use practices, and policy frameworks is vital to safeguarding honeybee diversity and ensuring resilient apiculture.

6.1 Climate Change

Climate change presents one of the most significant challenges to honeybee health worldwide. Rising temperatures, altered precipitation patterns, and shifts in seasonal cycles disrupt the availability of floral resources essential for bee foraging and colony development (21). Changes in blooming periods can lead to mismatches between bee activity and food availability, causing nutritional stress and reduced honey production. Additionally, extreme weather events such as heatwaves, droughts, and floods can damage natural habitats and increase colony mortality. In Pakistan, where climate variability is pronounced, these effects are already being observed, impacting both wild and managed bee populations. Ensuring climate-resilient apiculture practices and promoting diverse, bee-friendly ecosystems are increasingly important for sustaining honeybee populations under evolving climate conditions.

6.2 Agricultural Practices

Intensive agricultural systems pose major threats to honeybee survival through monoculture cropping practices, habitat loss, and the extensive use of chemical pesticides. Monoculture reduces floral diversity, limiting bees' access to varied, nutrient-rich pollen sources essential to colony health (22). Pesticides, especially neonicotinoids and other systemic chemicals, can cause both acute toxicity and chronic sub-lethal effects, such as impaired navigation, weakened immunity, and reduced reproductive success. These impacts not only threaten bee populations but also undermine pollination services, which are crucial to agriculture. Promoting sustainable farming practices, integrated pest management, and the establishment of pollinator-friendly habitats can significantly reduce the harmful effects of agricultural intensification on bees (23).

6.3 Chemical Hazards

Honeybees are exposed to a multitude of chemical hazards, including heavy metals, industrial pollutants, and microplastics, all of which can accumulate in hive products. These contaminants may enter the environment through industrial emissions, agricultural runoff, and polluted water sources, posing health risks not only to bees but also to consumers of bee products (24). Microplastics have recently emerged as a concerning pollutant, capable of disrupting the bee gut microbiota and increasing susceptibility to infections. Heavy metals such as lead, cadmium, and mercury can impair bee physiology and reduce colony resilience. Enhanced environmental regulations, widespread monitoring, and targeted research are essential to mitigate these risks and ensure the safety of bee-derived products. (Figure 2)

6.4 Biological Hazards

Honeybee colonies are susceptible to various biological threats, including bacterial infections, fungal diseases, viral pathogens, and parasitic mites. Varroa mites pose a serious challenge by feeding on bee larvae and spreading debilitating viruses that can weaken entire colonies (25). Fungal infections such as chalkbrood and stonebrood, along with viral diseases, can significantly reduce colony productivity and survival. Addressing these hazards requires integrated pest management strategies, improved hive hygiene practices, and increased access to diagnostic tools. Research on disease-resistant bee strains and advanced treatment methods is crucial for long-term colony health.

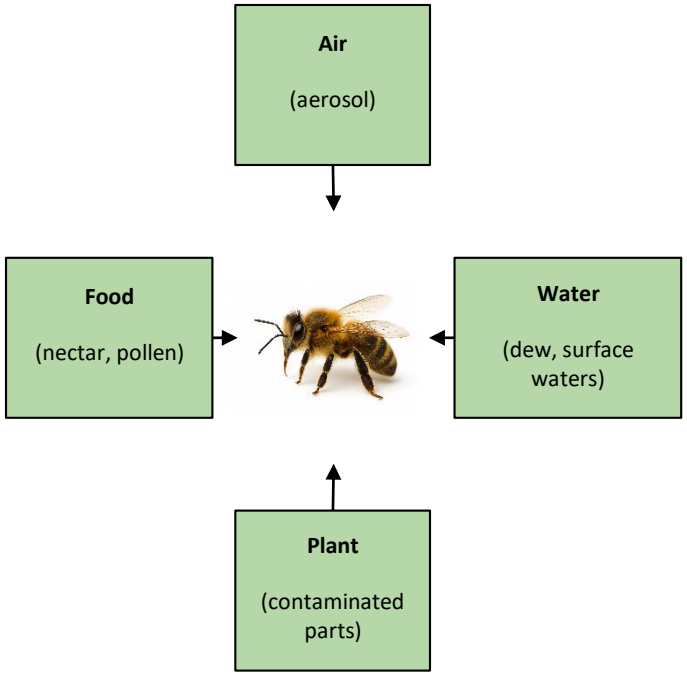

Figure 2: Sources of chemical exposure to honeybees

6.5 Colony Collapse Disorder

Colony Collapse Disorder remains a significant global concern, characterised by the sudden disappearance of worker bees from the hive while the queen and immature bees remain. The exact causes of CCD are still being studied, but evidence suggests that it results from a combination of factors, including pesticide exposure, nutritional stress, microbial infections, and habitat loss (26). CCD poses a severe threat to beekeepers and agricultural systems reliant on pollination services. Continued research is vital to understanding its underlying mechanisms and developing effective mitigation strategies. Establishing diverse forage landscapes, reducing harmful pesticide use, and enhancing hive management techniques can help reduce the incidence of CCD (27).

6.6 Electromagnetic Signals

Emerging evidence suggests that electromagnetic signals emitted from devices such as mobile phones, wireless networks, and communication towers may interfere with honeybee orientation, communication, and navigation. These signals may disrupt bees' ability to return to the hive, potentially contributing to population decline (28). As technological infrastructure expands across urban and rural landscapes, studying the long-term effects of electromagnetic exposure on bee behaviour and colony health becomes increasingly important. Implementing precautionary measures and conducting region-specific research could help mitigate potential risks and support the preservation of healthy bee populations.

7. Conclusion

Honeybees play a foundational role in supporting both natural ecosystems and agricultural productivity. Their contributions as pollinators and producers of valuable natural products underscore their importance to environmental sustainability and socio-economic development. In Pakistan and around the world, honeybees continue to face mounting challenges from climate change, agricultural intensification, chemical pollutants, and biological threats. Sustainable apiculture practices, supported by technological innovations, policy reforms, and environmental stewardship, are essential for strengthening honeybee resilience. By promoting awareness, investing in research, and implementing comprehensive conservation strategies, societies can safeguard honeybee populations and ensure the continued health of the ecosystems that depend on them. The protection of honeybees ultimately

reflects a broader commitment to environmental responsibility, food security, and the wellbeing of future generations.

Declarations

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All data generated or analysed during the study are included in the manuscript.
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Approved by the department concerned
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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

All authors contributed equally

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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