From Molecules to Bioactivity: Proteomic and Metabolomic Profiling of Honeybee Products

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Honeybee products, including honey, bee pollen, royal jelly, propolis, venom, and larvae, are complex mixtures essential for bee colony nutrition and defence. Due to their rich composition of pharmacologically active compounds, these products exhibit diverse biological properties, such as immunomodulatory, antimicrobial, and analgesic effects. While their nutritional and medicinal value has been recognised since antiquity, the underlying molecular mechanisms of these bioactivities remain uncharacterised.

Proteomics and metabolomics provide comprehensive insights into the intricate composition of these natural matrices. By enabling the precise identification and quantification of specific constituents, these omics approaches facilitate the elucidation of both the interactions between bee products and human physiological systems and the systemic molecular changes induced within the host.

In this research, a multi-platform analytical approach was employed to map the comprehensive molecular landscape of various honeybee products. Proteomic profiling using mass spectrometry significantly expanded the known proteomes of these matrices, leading to the identification of novel bioactive components. Complementary metabolomic analyses elucidated the characteristic profiles of low-molecular-weight constituents across the different products, providing a holistic view of their chemical diversity. Finally, elemental and pesticide analyses underscored the role of these products as bioindicators of anthropogenic environmental impact.

Furthermore, functional assays demonstrated that while melittin exhibits potent lytic activity on cell membranes, apamin and tertiapin exert potentially protective, stabilizing effects. Using an *in vitro* infection model, both bee venom and its selected components (apamin and tertiapin) were found to suppress SARS-CoV-2 infectivity in hACE2 cells, inducing distinct changes in the host proteomic profile.

This study demonstrates that the diverse molecular composition of honeybee products dictates their broad spectrum of biological activities. By bridging high-resolution omics profiling with functional bioassays, it is possible to provide a holistic framework for understanding how these natural matrices interact with human physiological systems. These findings not only support the traditional medicinal use of bee products but also highlight their potential as sources for novel therapeutic agents.