that honey bees use only a fraction of available flowering plants and display marked selectivity for both nectar and pollen, with plant choices shifting strongly over time and among colonies in the same landscape (Zaldívar-Ortega et al., 2024). Colonies typically exploit a high number of potential floral resources, yet at any moment most of the collected nectar or pollen is dominated by a few taxa, indicating dynamic but non-random preferences that structure honey's botanical fingerprint and metabolite composition (Zaldívar-Ortega et al., 2024).

At the colony level, resource allocation between nectar and pollen foraging is plastic and responds to internal nutritional status and external resource profitability. Experimental manipulations demonstrate that the profitability of nectar sources (sugar concentration or flow rate) alters the probability that bees switch between nectar and pollen collection and changes the colony-level ratio of pollen to non-pollen foragers. Other behavioral studies reveal that only a minority of highly active foragers perform a disproportionate share of trips, and that foraging performance improves with experience, indicating that colony nectar intake and honey yield are strongly dependent on the activity and learning of this subset of workers (McMinn-Sauder et al., 2022). These behavioral mechanisms link environmental floral heterogeneity and colony state to the efficiency and selectivity of nectar collection, shaping both honey quantity and quality.

5.3 Hive health status and microbial influences

Hive health status influences honey quality through both nutritional dynamics and microbiological processes within the colony. Comparative analysis of healthy and stressed hives shows that honey from healthy colonies has significantly higher phenolic content, antioxidant capacity, and antimicrobial activity than honey from stressed hives, despite similar floral resources. Stressed colonies, characterized by poor brood patterns, low bee populations, or disease signs, produce honey with reduced "activity," suggesting that suboptimal colony condition can depress the enrichment of phenolics and other bioactive constituents during nectar processing and storage (Layek et al., 2020).

Microbial communities in and around the hive also modulate nectar transformation and honey properties. Work on nectar-associated yeasts demonstrates that colonization by Metschnikowia reukaufii alters nectar amino acid levels, sugar composition, and volatile emissions, but honey bees avoid yeast-inoculated nectar even when pollen is present, indicating that microbial metabolites can deter foraging and thereby indirectly influence which nectars enter the hive (Yokota et al., 2024). Parallel profiling of gut, hive, and honey microbiomes in healthy versus stressed colonies reveals significant differences in core and opportunistic taxa, with stressed hives showing higher microbial diversity that may reduce the capacity to exclude pathogens and potentially affect honey stability and antimicrobial characteristics (Layek et al., 2020). Together, these results highlight that hive health and associated microbial communities constitute an important internal environmental layer governing honey quality in addition to external floral and climatic factors.

6 Impact of Processing and Storage Conditions

6.1 Honey harvesting and initial processing methods

Harvesting and early handling steps such as extraction, filtration, and moisture reduction shape the initial "starting point" for subsequent quality evolution. Studies on acacia and rape honeys show that centrifugation and filtration generally reduce concentrations of enzymes, phenolics, minerals, and other constituents (due to removal or dilution of pollen and suspended solids), while moisture reduction at elevated temperatures increases HMF and can lower diastase activity (Mohammad et al., 2023; Gruznov et al., 2024). Even relatively mild preheating (45 °C-55 °C) and vacuum drying steps significantly decreased diastase and phenolic contents in rape honey, indicating that functional components are sensitive to routine industrial treatments (Scepankova et al., 2024).

At the same time, some processing innovations seek to minimize quality loss compared with conventional pasteurization. High-pressure processing (HPP) has been evaluated as an alternative that improves microbial safety with less impact on HMF, diastase, and antioxidant activity during storage than standard heat pasteurization (Kamboj et al., 2024). In a comparative study, pasteurization at 78 °C/6 min immediately eliminated microorganisms but led to HMF and diastase values outside legal limits after 12-24 months, whereas HPP-treated and raw honeys stored for 24 months remained within standards and retained higher antioxidant capacity. These