

consumption, with consumers paying greater attention to low-sugar formulations, natural ingredients, functionality, and cultural expression (Liu et al., 2024; Qin and Zhou, 2024; Huang, 2025; Yang, 2025). The high-value utilization of Hangbaiju flavonoids has enabled its application not only in traditional RTD teas but also in functional beverages, nutritional drinks, and cross-category beverage products (Lu and Liu, 2025). For example, cold-brew Hangbaiju tea can better preserve its fresh floral aroma and align with the trend of light wellness consumption; low-sugar or sugar-free RTD Hangbaiju beverages can meet consumer demands for sugar control; and sparkling Hangbaiju beverages can enhance drinking experiences through flavor innovation and appeal to younger consumers.

In terms of processing and product innovation, Hangbaiju beverages can draw inspiration from products such as matcha, kombucha, and fermented teas to create a more diversified product portfolio. Studies have shown that matcha can be combined with proteins, inulin, and other functional ingredients to develop convenient nutritional beverages, while kombucha and novel fermented teas can generate distinctive flavors and potentially increase levels of organic acids and γ -aminobutyric acid (GABA) through fermentation (Tong et al., 2019; Najman et al., 2023; Onsun et al., 2025). Therefore, Hangbaiju can be explored for use in instant powders, plant-based mixed beverages, chrysanthemum-fermented drinks, and low-sugar functional beverages. Moreover, technologies such as ultra-high-temperature sterilization, aseptic filling, microencapsulation, and nanoencapsulation can improve the stability and bioavailability of active compounds in RTD products, ensuring flavor quality and functional properties during storage and transportation (A'yuni et al., 2022; Gupta et al., 2023; Munarso et al., 2026).

In the future, innovation in Hangbaiju tea beverages should also be closely integrated with digital consumption models and cultural storytelling. Through co-branded product development, customized packaging design, online interactive marketing, and regional cultural IP creation, brand communication can be strengthened, transforming Hangbaiju beverages from traditional herbal infusions into scenario-based functional drinks with modern consumer appeal and international market potential (Qin and Zhou, 2024; Huang, 2025; Yang, 2025). At the same time, continuous development of new products featuring antioxidant, soothing, anti-fatigue, and light wellness functions should be pursued based on advances in functional ingredient research and evolving consumer demands, thereby enhancing technological content and market value while providing new growth drivers for the transformation and upgrading of the Hangbaiju industry.

3 Key Processing Technologies for Hangbaiju Tea Beverages

3.1 Raw material quality control technologies

The quality of Hangbaiju tea beverage products first depends on the quality of raw materials. Therefore, establishing a scientific, stable, and standardized raw material quality control system is the foundation for ensuring product quality and industrialized production. The contents of flavonoids, polyphenols, amino acids, pigments, and volatile aromatic compounds in Hangbaiju flowers are greatly affected by variety, cultivation environment, harvest period, and primary processing methods (Aaqil et al., 2023; Tang et al., 2025). In production, high-quality local varieties should be prioritized, standardized cultivation techniques should be adopted, and water-fertilizer management, pest and disease control, and harvesting standards should be unified to improve raw material quality stability. At the same time, standardized cultivation bases should be established to control the use of pesticides and chemical fertilizers at the source, reduce exogenous contamination risks, and ensure that raw materials meet the requirements for green food, functional beverages, and deep-processed product development.

With the development of quality control technologies for tea and floral raw materials, rapid and non-destructive detection methods such as spectroscopy, computer vision, chromatographic analysis, and electrochemical detection are increasingly being used for real-time evaluation of raw material appearance, chemical composition, and contaminant levels (Bhargava et al., 2022; Moreira et al., 2024). Among them, spectroscopy and improved chromatographic techniques can rapidly determine polyphenols, amino acids, pigments, and inorganic/organic contaminants, improving detection sensitivity and accuracy. Computer vision combined with deep learning can classify chrysanthemum tea according to type and flowering stage, providing technical support for appearance grading, authenticity identification, and pre-processing screening of Hangbaiju flower buds (Figure 1) (Liu et al.,