

differently to the same treatment. Earlier-harvested Taiju appears to provide the strongest starting point for comprehensive quality, since it balances functional constituents with yield better than Hualei, Youju, or Quanju. It also shows stronger antioxidant activity than later-harvested Duoju and carries a distinctive flavor-related metabolite profile (Gong et al., 2019; Yang et al., 2022). This makes Taiju-stage raw material especially suitable for high-quality processing, provided that the drying method protects both phenolic compounds and volatile aroma substances.

Among processing options, no single method dominates all endpoints, but several combinations stand out. Infrared-assisted hot-air drying increased chlorogenic acid, luteolin, total phenolics, total flavonoids, and volatile concentration, while sequential IR-HAD plus HAD better controlled color deterioration (Xu et al., 2022a). High-humidity air impingement kill-green for 60 s improved PPO and POD inactivation, retained more individual phenolics, sugars, amino acids, and volatiles than steam kill-green, and produced higher sensory acceptance (Xu et al., 2024). Freeze-drying maintained bioactive compounds and strong antioxidant and antibacterial activities in Taihang chrysanthemum, but other work showed that microwave-assisted or moderate-temperature oven drying can provide better efficiency or a more practical quality-cost balance (Shi et al., 2017; Fan et al., 2024). For Hangbaiju, the current evidence therefore supports a strategy in which Taiju or near-Taiju raw material is paired with a moderate, staged, or assisted drying process rather than late-harvest material combined with simple high-temperature drying.

6 Comprehensive Quality Evaluation Methods for Hangbaiju

6.1 Determination and comparison of single quality indicators of Hangbaiju

The determination and comparison of single quality indicators of Hangbaiju should begin with the targeted quantification of representative active constituents. HPLC has been used to simultaneously quantify eight bioactive compounds in chrysanthemum flower heads harvested at different stages and subjected to different drying processes, showing that single-index comparison remains the foundation of process evaluation. Near-infrared hyperspectral imaging has also shown good feasibility for the rapid prediction of luteolin and quercetin in fresh and dry Hangbaiju, indicating that instrumental screening can complement conventional wet chemistry for routine quality control (He et al., 2021). In practice, chlorogenic acid, luteolin-7-O-glucoside, 3,5-O-dicaffeoylquinic acid, flavonoids, phenolics, soluble sugar, amino acids, and vitamin C are the single indicators most often compared across harvest and drying treatments (Shi et al., 2017; Sun et al., 2021).

Single indicators should not be limited to chemical contents alone, because sensory, morphological, and functional traits also discriminate quality. Inflorescence diameter was negatively correlated with chlorogenic acid and 3,5-O-dicaffeoylquinic acid in Fubaiju, and samples with smaller diameters had higher polyphenol contents, supporting the use of appearance traits as measurable grading indexes. Electronic tongue analysis further distinguished high- and low-grade samples by stronger saltiness and astringency, while antibacterial assays confirmed better inhibitory activity in the higher-grade group (Yang et al., 2025). Antioxidant activity can also serve as a single functional endpoint, and antioxidant activity–fingerprints based on HPLC-DPPH-MS and NIR calibration have shown strong predictive ability for chrysanthemum quality assessment (Zhang et al., 2022).

6.2 Construction of a multi-indicator comprehensive evaluation model for Hangbaiju

A multi-indicator comprehensive evaluation model for Hangbaiju should integrate fingerprint similarity, multi-component quantification, biological activity, and multivariate statistics into one framework. In *Chrysanthemum morifolium*, chromatographic fingerprints of 30 flower-head samples were analyzed by similarity analysis, cluster analysis, and principal component analysis, and the common peaks accounted for major differences among samples (Lu et al., 2022). Spectrum–effect analysis further linked chemical peaks to antioxidant activity and identified chlorogenic acid, 3,5-O-dicaffeoylquinic acid, 4,5-O-dicaffeoylquinic acid, and kaempferol-3-O-rutinoside as candidate Q-markers, which provides a model for linking measurable compounds to actual efficacy. A related integrated approach in edible chrysanthemum combined HPLC, chemometrics, chromatogram–effect relationships, and bioinformatics to discover Q-markers and authenticate samples, showing that multi-indicator models can simultaneously serve quality evaluation and authenticity control (Yuan et al., 2022).