

For Hangbaiju, the construction of such a model should also include weighted evaluation and classification steps. Analytic hierarchy process can be used to assign weights to different indicators, simplify complex evaluation problems, and identify the best scheme when multiple traits must be balanced (Zhao et al., 2022). In garden chrysanthemum, AHP combined with K-means clustering generated comprehensive scores and classified materials into four grades, illustrating a transferable framework for grading Hangbaiju lots or process treatments (Zhao et al., 2022). Spectroscopic chemometric models also support rapid multi-index evaluation: excitation-emission matrix fluorescence with random forest regression predicted 12 functional compounds while simultaneously authenticating geographical origin, and this “two-in-one” strategy is directly relevant to rapid Hangbaiju screening (Guo et al., 2025).

6.3 Screening of the optimal combination of harvest period and drying method for Hangbaiju

The screening of the optimal combination of harvest period and drying method for Hangbaiju should be based on comprehensive quality rather than on yield or one compound alone. Harvest stage significantly affected the functional constituents of Hangbaiju, and the contents of total flavonoids and chlorogenic acid were highest at the Hualei stage, whereas luteolin-7-O-glucoside and 3,5-O-dicaffeoylquinic acid were highest at the Taiju stage (Zhao et al., 2022). Because yield increased as collection time was delayed, the best harvest period could only be selected after balancing constituent retention against output, and that comparison favored the Taiju stage overall (Lu et al., 2020). This conclusion is consistent with metabolomic evidence showing that Taiju and Duoju have distinct volatile and flavonoid profiles, giving Taiju a different flavor and efficacy basis (Yang et al., 2022).

Drying-method screening should then be matched to the selected harvest stage. For flower heads harvested at two developmental stages, the appropriate drying process was suggested to be oven-drying at 60 °C for Xiaobaiju and 70 °C for Taiju, directly showing that maturity stage changes the optimal drying condition. Other studies indicate that microwave drying best preserved flavone, vitamin C, and soluble sugar when efficiency was considered (Shi et al., 2017), while microwave treatment for 30 s combined with 75 °C hot air was most effective at preserving biologically active compounds and antioxidant capacity (Wang et al., 2019). More advanced methods such as tempering-incorporated infrared-assisted hot-air drying and pulsed vacuum drying further improved chlorogenic acid, luteolin, total phenolics, total flavonoids, antioxidant capacity, volatile retention, or color preservation (Xu et al., 2023; Sun et al., 2021). Across specialty crops more broadly, intermediate harvest timing and drying temperatures around 30~60 °C tend to perform best, which supports the principle that Hangbaiju optimization should avoid both overly early harvest and excessive thermal stress (Pedrosa et al., 2024).

7 Existing Problems and Optimization Strategies

7.1 Non-uniform harvest standards for Hangbaiju and optimization strategies

A major problem is that Hangbaiju harvest standards remain insufficiently uniform, even though harvest stage clearly changes composition, antioxidant capacity, and product identity. In Hangbaiju, total flavonoids and chlorogenic acid peaked at the Hualei stage, while luteolin-7-O-glucoside and 3,5-O-dicaffeoylquinic acid peaked at Taiju, and overall evaluation favored Taiju when constituents, yield, and timing were considered together. Taiju and Duoju also separate clearly by phenolic profile, with Taiju showing higher caffeoylquinic acids and stronger antioxidant activities, and PCA distinguished the two groups using phenolic variables (Gong et al., 2019). Metabolomics likewise identified 11 markers that can authenticate Taiju and Duoju, indicating that harvest period creates stable chemical signatures rather than only visual differences (Yang et al., 2022).

Optimization should therefore replace rough visual or customary picking rules with maturity-indexed harvest criteria. A practical framework is to define harvest windows by inflorescence opening stage together with indicator compounds such as chlorogenic acid, luteolin-7-O-glucoside, and 3,5-O-dicaffeoylquinic acid. Diameter-based grading can help operationalize this, because smaller-diameter Fubaiju samples had higher chlorogenic acid and 3,5-O-dicaffeoylquinic acid contents and were validated by sensory and antibacterial differences (Yang et al., 2025). Since Hangbaiju quality also varies with geography, harvest time, and cultivation management, unified standards should combine maturity stage with origin and batch testing rather than rely on calendar date alone (Zhang et al., 2023).