

At the circulation and consumption stages, digital technologies such as QR-code traceability systems, the Internet of Things, big data, blockchain, and online sensors can be used to enable full-process product information inquiry and real-time quality monitoring. Research on intelligent technologies shows that big data, the Internet of Things, and blockchain can support the development of transparent, traceable, and sustainable tea industrial chains, enabling quality information connectivity from plantation to end product. Consumers can use traceability systems to understand the source of Hangbaiju raw materials, cultivation processes, processing techniques, and quality test results, thereby enhancing consumer trust. In the future, with the continuous improvement of intelligent detection technologies and digital management platforms, the Hangbaiju tea beverage industry should gradually establish a quality and safety management system covering cultivation, processing, and sales, providing solid support for high-quality industrial development and brand building.

## **4 Industrial Chain Extension Models for the Hangbaiju Industry**

### **4.1 Construction of standardized upstream cultivation bases**

The foundation of industrial chain extension lies in the stable, high-quality, and sustainable supply of raw materials, while the construction of standardized cultivation bases is an important link in enhancing the competitiveness of the Hangbaiju industry. At present, some Hangbaiju cultivation still relies on fragmented operations, with differences in seedling selection, field management, harvesting standards, and primary processing methods, resulting in insufficient stability of raw material quality. Studies on the tea industry and ecological tea industrial chains indicate that fragmented smallholder production restricts quality control and modern management, whereas integrating scattered plots through land transfer, trusteeship management, or cooperative models helps achieve intensive operation, effective pest and disease control, and efficient resource utilization (Zhang et al., 2024). Therefore, upstream Hangbaiju base construction should promote large-scale production through organizational models such as “enterprise+cooperative+farmers,” establish unified cultivation technical specifications, quality standard systems, and harvesting management systems, and improve the consistency of raw material quality.

In the construction of cultivation bases, efforts should be made to strengthen the breeding of superior varieties and the establishment of seedling propagation systems, so as to improve varietal purity, stress resistance, and the stability of active components in Hangbaiju. Related studies have shown that low-carbon ecological tea production can reduce environmental burdens while enhancing product value and ecological resilience by expanding plantation scale, optimizing planting density, and promoting organic or reduced-input production systems (Zhang et al., 2024). For Hangbaiju, green cultivation technologies should be promoted, the use of chemical pesticides and fertilizers should be reduced, and integrated pest management, water-fertilizer integration, ecological certification, and low-carbon production methods should be adopted to improve raw material safety and market recognition. Meanwhile, the stable supply of functional components such as Hangbaiju flavonoids is an important foundation for subsequent functional tea beverage development; therefore, upstream bases should also establish quality control standards based on raw material specifications for functional beverages (Lu and Liu, 2025).

With the development of digital agriculture, information-based management technologies are increasingly being applied in standardized cultivation bases. Research on whole agricultural industrial chains shows that agricultural production capacity, technology extension, informatization, marketization, and risk protection jointly affect industrial chain performance (Ying et al., 2022). Internet of Things sensors, drone monitoring, big data platforms, and intelligent management systems can be used to monitor soil conditions, meteorological factors, input use, crop growth, and yield levels in real time, thereby realizing precision cultivation management (Zhang et al., 2024). Therefore, the construction of standardized Hangbaiju cultivation bases should integrate agronomic standards, digital traceability, ecological certification, and low-carbon practices, providing a stable, traceable, and high-quality resource foundation for midstream processing and downstream brand building (Lu and Liu, 2025).