6.2 Incomplete cultivation regulation technology system

Although cultivation and management technologies for Chinese bayberry have continuously developed, there is still a lack of standardized, systematic, and region-specific regulation systems aimed at fruit quality improvement. Most existing studies focus on individual production stages or single technologies, such as water and fertilizer management, canopy regulation, bagging, insect- and rain-proof nets, LED supplemental lighting, and postharvest preservation, whereas studies on the synergistic effects, application boundaries, and long-term ecological impacts of these measures remain limited. For example, insect- and rain-proof nets can effectively control fruit flies, improve fruit size, edible rate, and sugar-acid ratio, and optimize fruit-surface microbial communities, but related studies are still mainly restricted to single cultivars and regions, and continuous evaluation of their long-term effects on tree vigor, soil microorganisms, and orchard ecosystems is lacking (Yu et al., 2021).

Facility cultivation and precision light environment regulation also exhibit strong cultivar dependence and insufficient standardization. LED supplemental lighting can significantly improve fruit size, soluble solids, and vitamin C content in the cultivar 'Black Charcoal', but its effects are relatively limited in cultivars such as 'Dongkui', indicating that different cultivars respond differently to light intensity, spectral composition, and lighting periods. Therefore, cultivar-, region-, and developmental stage-specific light regulation systems still need to be established (Tang et al., 2025). Similarly, technologies such as water and fertilizer regulation, flower and fruit thinning, canopy pruning, and harvest maturity management may produce different effects under different ecological regions and cultivars, but systematic comparisons and standardized technical protocols are currently lacking.

The postharvest preservation technology system also requires further improvement. Technologies such as ultrasonic treatment combined with slightly acidic electrolyzed water, ozone water treatment, low-temperature storage, and optimized temperature management can reduce microbial populations, delay fruit softening, and maintain sugar-acid balance and phenolic contents. However, most studies are still limited to experimental conditions or small-scale validation and have not yet formed integrated systems linked with harvest maturity, transportation damage control, packaging materials, cold-chain logistics, and market circulation periods (Suo et al., 2023; Gao et al., 2024). Moreover, current research mainly focuses on short-term quality or shelf-life indicators, while comprehensive evaluations regarding economic cost, carbon footprint, low-residue production, farmer operability, and industrial promotion models remain insufficient. Therefore, future cultivation regulation of Chinese bayberry should shift from optimization of individual technologies toward integrated "cultivar-environment-tree-facility-postharvest" management systems.

6.3 Lack of unified quality evaluation standards

At present, Chinese bayberry quality evaluation has not yet formed unified and widely applicable industrial standards, which to some extent restricts the standardization, branding, and commercialization of the industry. Current quality evaluation systems have gradually expanded from traditional sugar-acid indices to multidimensional indicators including external appearance, phenolic compounds, flavonoids, anthocyanins, antioxidant activity, texture, volatile compounds, sensory evaluation, and postharvest storability (Gao et al., 2024; Saeed et al., 2025; Yang et al., 2025). However, different studies, production regions, and enterprises often adopt different detection methods, indicator combinations, and evaluation thresholds, resulting in poor comparability among research results.

For example, studies on Chinese bayberry juice processing indicate that sugar-acid ratio, total sugar, and titratable acidity are key factors influencing sensory preference and can be used to screen suitable processing cultivars. However, these evaluation criteria have not yet been effectively linked with fresh fruit commercial grades, processing grades, or national and industry standards. Flavor studies can classify cultivars according to aroma-active compounds and sensory characteristics, but corresponding grading systems applicable to market circulation, brand construction, and trade evaluation have not yet been established. In postharvest quality research, methods such as electronic nose off-flavor classification, artificial neural network models, volatile markers, and