Additionally, leaf mechanical properties vary with moisture content, with the 30%-50% range being optimal for stable shaping, indicating that quality consistency results from the combined effects of cultivar, environment, and process control.

### 6.3 Evaluation indicators and methods for processing suitability

The evaluation of processing suitability of tea cultivars requires a comprehensive approach integrating sensory, physicochemical, and physical performance indicators. Traditional sensory evaluation, based on scoring appearance, aroma, and taste, provides a direct reflection of cultivar performance under different processing conditions. For example, in studies on Baie No.1, subdividing aroma and taste attributes has been effective in identifying optimal processing schemes (Teng et al., 2024). When combined with electronic tongue analysis, sensory results can be linked to changes in chemical composition (Shan et al., 2023).

Physicochemical indicators provide an objective basis for evaluating suitability, including amino acids, tea polyphenols, caffeine, and volatile compounds (Chen et al., 2024; Zeng et al., 2024). At the same time, physical parameters such as leaf thickness, moisture content, and mechanical properties reflect shaping ability and resistance to damage during processing (Li et al., 2023b). Together, these indicators form the foundation of suitability evaluation.

In recent years, multidimensional evaluation methods have been increasingly developed. Near-infrared spectroscopy combined with models such as PLSR and SVR enables rapid prediction of quality indicators (Chen et al., 2024), while technologies such as electronic noses and machine vision provide objective assessments of aroma and appearance. In addition, texture analysis and mechanical modeling can quantify leaf processing behavior and provide parameter support for process optimization (Li et al., 2023b). These approaches are promoting a shift in suitability evaluation from experience-based judgment to data-driven analysis.

## 7 Molecular Mechanisms and Advances in Breeding Research

### 7.1 Genes and regulatory mechanisms related to quality traits

The formation of quality traits in Longjing tea—such as freshness, bitterness–astringency, aroma type, and leaf color—is essentially driven by complex genetic regulatory networks involving the coordinated regulation of multiple metabolic pathways, including those of amino acids, tea polyphenols, alkaloids, and volatile compounds. In recent years, studies based on the reference genome of Longjing 43 (LJ43) and population resequencing have shown that, during the domestication of Camellia sinensis var. sinensis, genes related to flavor formation and stress resistance have undergone strong selection pressure, indicating that quality-related metabolic pathways have long been key targets of artificial selection (Gao et al., 2023b). For non-volatile components, amino acid and polyphenol metabolic pathways are central to taste formation. Genes involved in theanine biosynthesis (e.g., CsTS, CsGS) regulate amino acid accumulation and directly affect freshness, while key structural genes in flavonoid/catechin biosynthesis (e.g., CHS, F3H, DFR) control polyphenol production, thereby influencing bitterness and aftertaste. In addition, caffeine biosynthesis is regulated by N-methyltransferase genes, and differences in their expression among cultivars form an important molecular basis for taste variation.

In terms of pigment formation and bitterness regulation, multi-omics studies have revealed that chlorophyll and carotenoid biosynthesis/degradation pathways, anthocyanin biosynthesis, and transport systems jointly determine leaf color and associated quality traits. For example, in albino materials, chlorophyll synthesis is inhibited while degradation is enhanced, whereas in purple-leaf materials, anthocyanin biosynthesis and transport genes are upregulated. These changes not only affect appearance but also influence amino acid and polyphenol accumulation through altered carbon allocation (Li et al., 2023b). Under environmental regulation, key genes such as CsANS and CsANR respond to changes in light and temperature, modulating catechin and flavonoid levels and leading to differences in quality stability among cultivars under shading or elevated temperature conditions (Wu et al., 2025).

Regarding aroma formation, lipid oxidation (LOX pathway), amino acid degradation, and terpenoid biosynthesis pathways jointly contribute to the production of volatile compounds. LOX and downstream enzymes are involved