Comprehensive chemical analysis has advanced quality evaluation from simple composition measurement to biomarker identification. By correlating key volatile compounds (e.g., linalool, geraniol, aldehydes, pyrazines) and non-volatile compounds (e.g., theanine, EGCG, flavonol glycosides) with sensory scores, quantitative relationships can be established (Shan et al., 2023; Bassiony et al., 2024; Zhang et al., 2024; Shan et al., 2025).

2.3.3 Chemometrics, intelligent sensing, and rapid detection

In recent years, multivariate analysis, machine learning, and intelligent sensing technologies have been increasingly applied in Longjing tea evaluation. Methods such as PCA, logistic regression, PLS-DA, and neural networks are used to identify key quality markers and predict taste, aroma, and overall quality (Bassiony et al., 2024). Indicators such as total amino acids, theanine, EGCG, and specific flavonol glycosides show strong discriminative ability (Shan et al., 2025).

Meanwhile, technologies such as electronic noses, electronic tongues, and near-infrared spectroscopy enable rapid and non-destructive quality assessment. For example, electronic noses can differentiate tea grades and brands (Moreira et al., 2024), while NIR combined with machine learning can predict sensory scores and chemical composition. Integrated multi-scale analytical frameworks combining metabolomics, colorimetry, intelligent sensing, and sensory evaluation are increasingly used to systematically reveal how processing and brewing influence final tea quality (Shan et al., 2023; Teng et al., 2024; Zhang et al., 2024; Deng et al., 2025).

3 Major Types of Tea Cultivars Used for Processing

3.1 Traditional and main cultivars

Traditional Longjing tea processing has long relied on local population-type tea germplasm, among which the Longjing population variety is the most representative. Population varieties are genetically heterogeneous groups that gradually formed through long-term farmer selection, natural adaptation, and local cultivation practices, and are characterized by broad genetic backgrounds, strong ecological adaptability, and diverse flavor types. These materials show considerable individual variation in bud and leaf size, sprouting time, leaf structure, and metabolite composition. However, it is precisely this within-population variation that provides an important material basis for the formation of the classic Longjing tea style in the core West Lake production area (Yu et al., 2023). From a quality perspective, fresh leaves of population varieties are generally rich in internal compounds, especially with advantages in aroma performance. The teas produced from them often exhibit more complex volatile profiles and stronger aroma layering, forming typical bean-like and chestnut-like notes, and sometimes even certain floral and fruity characteristics (Figure 2) (Ao et al., 2025; Yan et al., 2025). Therefore, population varieties have long been regarded as important raw materials for producing high-quality Longjing tea with a traditional style.

However, the advantages of population varieties coexist with limitations. Due to their large genetic variation within the population, different individual plants vary significantly in sprouting uniformity, bud plumpness, yield potential, and metabolite accumulation. As a result, under modern standardized and large-scale production systems, they often face problems such as uneven sprouting, inconsistent harvesting periods, and large batch-to-batch quality fluctuations (Figure 3) (Ao et al., 2025). Comparative metabolomic studies under uniform cultivation and processing conditions have shown that, between Longjing population varieties and Longjing 43, flavonoid metabolites often contribute the most to quality differences, and this cultivar effect may even exceed some effects of production area and storage time (Yu et al., 2023). This indicates that although population varieties possess advantages in traditional flavor, their insufficient stability in quality expression limits their application in large-scale mechanized production systems.

Compared with population varieties, Longjing 43 (LJ43) is currently one of the most widely used elite clonal cultivars in Longjing tea production and is also the dominant cultivar in the modern standardized production system. Longjing 43 was selected from superior local germplasm and has advantages such as early sprouting, uniform bud emergence, relatively strong cold resistance, wide adaptability, and stable yield, making it suitable for premium green tea processing as well as mechanized harvesting and standardized processing (Gao et al., 2023a). In terms of quality, Longjing 43 generally has relatively high amino acid levels, a well-balanced taste