potential, although imbalanced proportions may lead to excessive bitterness (Shan et al., 2025). Studies indicate that flavan-3-ols are the most abundant compounds in Longjing tea and constitute the main chemical basis of bitterness and intensity. Differences among cultivars in polyphenols and their derivatives further result in the differentiation of “fresh-type” and “mellow-type” flavor styles (Huang et al., 2024). Caffeine also plays a regulatory role in bitterness perception and taste balance; for example, the lower caffeine content in “Baie No.1” is consistent with its milder bitterness (Shan et al., 2023).

In addition, processing and environmental conditions further regulate the dynamic changes of these components. Studies have shown that with increasing withering degree, amino acids and certain catechin dimers increase, while organic acids and phenolic acids decrease, thereby affecting taste and liquor color (Shan et al., 2025). Multi-cultivar studies also demonstrate that tea polyphenols, catechins, and amino acids exhibit significant cultivar-dependent differences (Zeng et al., 2024). Overall, the proportional relationships among these three major components are more explanatory than individual component levels: a high amino acid/low polyphenol combination favors a fresh style, whereas higher polyphenols enhance body and aftertaste.

5.2 Differences in volatile aroma composition

Volatile aroma compounds are fundamental determinants of the aroma type and complexity of Longjing tea, and their composition varies significantly among cultivars. The aroma of Longjing tea mainly consists of alcohols, aldehydes, esters, ketones, and heterocyclic compounds, which originate from precursor substances in fresh leaves and are gradually formed through enzymatic and thermal reactions during processing (Gao et al., 2023b; Zhang et al., 2024). Therefore, cultivar differences are first reflected in the composition of aroma precursors.

The aroma profiles of different cultivars exhibit clear specificity. Studies have identified 97 key aroma-active compounds across multiple cultivars, among which aldehydes, ketones, and heterocyclic compounds play important roles in aroma formation (Zeng et al., 2024). Core aroma compounds such as linalool, geraniol, hexanal, and β-ionone are commonly present in Longjing tea, but their relative contents differ significantly and are closely related to quality evaluation (Zhang et al., 2024). This indicates that aroma differences are mainly derived from variations in the proportions of multiple compounds rather than the presence or absence of a single compound.

Differences among aroma types further highlight the role of cultivars. For example, in bean-aroma Longjing tea, geraniol and (E,E)-2,4-heptadienal contribute significantly, whereas fresh-aroma types are more associated with hexanal and heptanal (Bassiony et al., 2024). During processing of Baie No.1, volatile compounds change dynamically, with floral and fresh aromas dominating in the early stage and chestnut-like aromas forming in the later stage (Gao et al., 2023b). Thus, cultivars determine aroma style by influencing precursor metabolism and transformation pathways during processing (Li et al., 2024).

5.3 Correlation between chemical components and quality traits

There is a clear correlation between tea chemical composition and sensory quality, which provides an important basis for explaining quality differences among cultivars. In general, amino acids are positively correlated with freshness, tea polyphenols and caffeine with bitterness, astringency, and intensity, while volatile compounds determine aroma types (Huang et al., 2024). Studies on different withering degrees show that compounds such as theaflavins, thearubigins, organic acids, and amino acid derivatives are significantly correlated with taste and liquor color, indicating that quality formation depends on the synergistic effects of multiple components (Shan et al., 2025).

Large-scale sample analyses have identified EGCG, caffeine, theanine, and organic acids as key quality markers, which can be used to achieve high-accuracy predictions through statistical models. For example, specific flavonoid derivatives and amino acids can effectively distinguish different taste types, with model accuracy reaching 97.6%. This demonstrates that quantitative relationships between chemical composition and quality traits can be established.