determined by the balance among amino acids, catechins, caffeine, and other compounds, where amino acids contribute to freshness, while polyphenols and caffeine form the structural basis of taste. Bitterness and astringency are mainly associated with catechins (e.g., EGCG) and related flavonoids and are strongly influenced by processing conditions (Shan et al., 2023a; Shan et al., 2025). Therefore, the taste of Longjing tea is essentially the result of the synergistic interaction of multiple compounds.

2.2 Main factors affecting quality formation

2.2.1 Cultivar factors

Tea plant cultivars determine the genetic background and metabolic characteristics of fresh leaves and are the fundamental source of quality differences in Longjing tea. Significant variations exist among cultivars in the composition of amino acids, catechins, flavonoids, alkaloids, and aroma precursors, leading to distinct sensory profiles even under identical cultivation and processing conditions (Shan et al., 2023; Zeng et al., 2024; Ao et al., 2025). For example, commonly used materials such as “Longjing 43,” “Baie No.1,” and local population varieties differ markedly in metabolic profiles and quality expression. Longjing 43 generally contains higher levels of flavonoids and chlorophyll b, contributing to its typical color and style, whereas Baie No.1 often exhibits higher glutamic acid and glutamine levels along with different caffeine/theobromine ratios, influencing freshness enhancement and bitterness expression (Teng et al., 2024; Zhang et al., 2024). Thus, differences in freshness, chestnut-like aroma intensity, body, and briskness among cultivars fundamentally reflect variations in metabolic composition and processing responses.

2.2.2 Environmental factors

Environmental conditions constitute an important external basis for Longjing tea quality formation. Suitable temperature, light, precipitation, soil properties, and ecological conditions promote tea plant growth and metabolite accumulation, thereby improving raw material quality. Recent studies have shown that altitude, habitat, and cultivation environment can significantly regulate key metabolites such as amino acids, flavonoids, sugars, and aroma precursors (Bassiony et al., 2024). For instance, higher altitudes generally favor the accumulation of flavonoids, amino acids, and soluble sugars, enhancing sweetness and freshness, while regional climatic conditions further shape the characteristic flavor profiles of Longjing tea. Therefore, the quality potential of Longjing tea is not determined solely by cultivar but arises from genotype × environment interactions, which establish the metabolic basis later expressed through processing (Ao et al., 2025).

2.2.3 Processing factors

Processing is the key external factor determining Longjing tea quality and the core step in transforming raw material potential into final product quality. The typical process includes withering, fixation (kill-green), shaping/pan-firing, further frying, and drying or aroma enhancement, each contributing differently to the formation of appearance, aroma, and taste (Zeng et al., 2024; Zhang et al., 2024). Withering significantly influences non-volatile compounds such as amino acids, catechin dimers, organic acids, and phenolic acids, thereby affecting taste and liquor color. Studies indicate that optimal sensory quality is achieved when leaf moisture content is about 70% at the end of withering (Shan et al., 2023). Fixation temperature affects enzyme inactivation and thermal reactions; for example, around 215 °C can reduce bitterness while preserving beneficial amino acids and phenolic acids, leading to improved taste balance (Figure 1) (Shan et al., 2025).

Processing is also crucial for aroma development. Metabolomic studies show that flavonoids, amino acids, alkaloids, lipids, and carbohydrates undergo significant changes during processing. While different cultivars exhibit similar trends, the magnitude of change varies. The initial frying stage is critical for the rapid formation of volatile compounds, whereas subsequent steps adjust the balance among fresh, chestnut-like, sweet, and floral aromas (Zeng et al., 2024; Zhang et al., 2024). Brewing conditions also affect quality expression; for instance, lower temperatures (70°C - 80°C) favor amino acid extraction while slowing the release of bitter compounds, enhancing freshness and reducing astringency (Teng et al., 2024; Deng et al., 2025).