transporters such as TMT2 and STP7 may participate in regulating sugar accumulation within citrus fruit vacuoles. Related studies in tomato, melon, and magnesium-treated citrus have also demonstrated similar regulatory patterns, showing that potassium or other nutritional treatments can increase the expression of *SUT*, *SWEET*, *VPP*, and vacuolar sugar transporter genes, thereby enhancing sugar import and storage capacity in fruits (Wu et al., 2023; Han et al., 2024; Shah et al., 2025).

Potassium-induced sugar accumulation does not rely solely on sugar transport processes but also involves regulation of carbon metabolism-related gene networks. In Newhall navel orange, potassium increased the activities of key sucrose metabolism enzymes and the expression of related genes in both fruits and leaves, indicating that potassium coordinates carbon metabolism in source tissues with sugar utilization in sink tissues (Wu et al., 2024). Citrus *SPS* genes themselves are regulated by multiple factors, including developmental stage, tissue type, light conditions, hormone levels, and abiotic stresses, suggesting that external nutritional signals, such as potassium, may be integrated into broader sugar signaling regulatory networks (Lu et al., 2024). Further co-expression analysis revealed that WRKY transcription factors, particularly CsWRKY20, may participate in regulating citrus sugar accumulation through the CsSPS-mediated pathway. Studies in grapevine and melon also support this integrated regulatory model, showing that potassium-responsive genes are mainly enriched in pathways related to carbon metabolism, glycolysis/gluconeogenesis, fructose and mannose metabolism, as well as SPS/SUS-mediated regulation (Wang et al., 2024; Shah et al., 2025).

4.3 Relationship between potassium supply and soluble solids content

Adequate potassium supply generally results in a stable increase in total soluble solids (TSS) and soluble sugar content in citrus fruits. In Nanfeng mandarin, six consecutive foliar applications of K_2SO_4 significantly increased fruit TSS and soluble sugar content (Thu et al., 2024). In Cara Cara navel orange, potassium application increased sucrose, fructose, and glucose contents, as well as the ratio of total soluble sugars to citric acid, with the most pronounced improvement observed at an application rate of 0.50 kg potassium per tree (Wu et al., 2021). A meta-analysis conducted by Xu et al. (2024) on Chinese citrus production systems also demonstrated that optimized fertilization management increased TSS by 5.9% and total sugar content by 8.6%. Studies on other fruit crops have shown similar dose–response patterns, indicating that moderate potassium supply generally improves TSS and sugar accumulation more consistently than excessive potassium application (Zhang et al., 2018; Wang et al., 2024).

The effects of potassium on citrus flavor quality are not limited to sugar accumulation but also involve regulation of sugar–acid balance. In Cara Cara navel orange, potassium increased citric acid content by enhancing the activities of citrate synthase and phosphoenolpyruvate carboxylase, while simultaneously increasing the ratio of total soluble sugars to citric acid, thereby improving overall flavor balance (Wu et al., 2021). In contrast, in Nanfeng mandarin, foliar application of K_2SO_4 reduced titratable acidity and increased the TSS:TA ratio, indicating that the effects of potassium on organic acid metabolism are influenced by cultivar characteristics and application strategies (Thu et al., 2024).

Broader integrated studies on citrus have shown that optimized fertilization can reduce titratable acid (TA) and total acid contents while increasing the TSS/TA and TSC/TAC ratios, thereby improving overall fruit quality (Xu et al., 2024). This variation in acidity responses is also consistent with findings from non-citrus crops, where potassium may either promote citric acid synthesis or reduce malic acid and total acid accumulation, depending on plant species, developmental stage, and fertilizer source (Zhang et al., 2018; Wu et al., 2023).

5 Effects of Potassium Fertilization on Citrus Fruit Quality

5.1 Influence on external quality characteristics

Potassium improves the external quality of citrus fruits mainly by promoting fruit enlargement, enhancing peel coloration, and improving market appearance. In Newhall navel orange, combined application of potassium fertilizer and organic fertilizer improved fruit surface color and reduced peel thickness, resulting in a more desirable appearance for consumers (Wen et al., 2021). Shrestha et al. (2025) found that in HLB-tolerant Sugar