(Bao et al., 2026). These findings support the view that monitoring sugar accumulation, acid decline or redistribution, and their resulting ratio provides a biologically meaningful and commercially useful framework for judging kiwifruit maturity, readiness to eat, and market performance.

The formation of this balance is highly dynamic across fruit development and ripening, reflecting coordinated changes in carbohydrate metabolism. Kiwifruit differs from many fruits because it stores substantial carbohydrate as starch during development and converts that reserve into soluble sugars only after physiological maturity or during ripening (Nardozza et al., 2013). Net starch accumulation begins after cell division, intensifies during the slower fruit growth phase, and is followed near maturity by rising sucrose and hexose pools together with increased activities or transcripts of starch- and sucrose-related enzymes such as AGPase, SPS, AMY, and BAM-associated genes (Tian et al., 2021). During postharvest ripening, glucose, fructose, and sucrose typically increase markedly, although the dominant sugar can vary among genotypes, with sucrose predominating in some cultivars and glucose/fructose in others (Mao et al., 2023). Carbohydrate supply from the vine also alters this trajectory: enhanced supply promotes earlier maturation and higher starch and soluble sugar accumulation, whereas restricted supply delays maturity and weakens flavor development. These results show that sugar formation in kiwifruit depends on developmental stage, sink strength, genotype, and the regulation of starch–sucrose interconversion rather than on simple linear sugar accumulation.

Organic acid metabolism is equally dynamic and is a major counterpart to sugar accumulation in shaping flavor during maturation and ripening. Across kiwifruit species and cultivars, quinic acid, citric acid, and malic acid are the major organic acids, but their relative abundance and developmental trajectories differ substantially by genotype and storage environment (Mao et al., 2023). In several developmental studies, quinic acid is more prominent early, whereas citric acid increases as fruits mature, while malic acid either remains comparatively stable or changes more modestly (Lin et al., 2022; Jia et al., 2023). During postharvest ripening, titratable acidity usually declines, and this decline is often driven mainly by citric acid degradation, although malic acid can remain stable or even increase under some storage temperatures, helping explain differences in acidity perception between ripening conditions (Mao et al., 2023). Mechanistically, citric and malic acid accumulation is linked to the TCA cycle and to the coordinated regulation of synthesis and degradation enzymes, including citrate synthase, aconitase, isocitrate dehydrogenase, malate dehydrogenase, and phosphoenolpyruvate carboxylase. The objective of the present study is to clarify how sugars and organic acids are coordinately regulated during kiwifruit fruit development and ripening, to identify the metabolic and molecular factors that determine sugar–acid balance, and to provide a basis for improving maturity evaluation, flavor quality, and breeding or postharvest management strategies.

2 Dynamic Changes in Sugars and Organic Acids During Kiwifruit Development

2.1 Sugar composition and accumulation patterns

The main soluble sugars in kiwifruit are sucrose, glucose, and fructose, but their relative abundance changes with developmental stage and genotype. During fruit growth, Nardozza et al. (2023) reported that sugar concentrations often decline during early cell division and then rise again during cell expansion and maturation, with glucose sometimes peaking before net starch accumulation begins. In later developmental and ripening stages, sucrose, glucose, and fructose all increase substantially and contribute directly to ripe-fruit sweetness (Mao et al., 2023). However, the dominant soluble sugar is not uniform across kiwifruit types: glucose and fructose predominate in some *A. chinensis* fruit such as ‘Jinyan’, whereas sucrose is more prominent in ‘Hongyang’, ‘Kuilv’, and some hardy kiwifruit backgrounds (Li et al., 2021).

Starch accumulation and conversion are central to sugar formation in kiwifruit because this fruit stores much of its carbon as starch before harvest and converts it to soluble sugars during maturation and postharvest ripening. Net starch accumulation begins after cell division is completed, increases during the slower fruit growth phase, and then declines when maturation starts and soluble sugars rise rapidly. This pattern is consistent across cultivars, although the timing differs: starch peaks earlier in fast-developing ‘Kuilv’ than in ‘Hongyang’ or ‘Hayward’, and