4 Mechanisms of Variation in Quality Traits

4.1 Physiological and biochemical mechanisms

The formation of peach fruit quality traits depends on a series of complex and coordinated physiological and biochemical processes. As a typical climacteric fruit, peach undergoes increased respiration and ethylene production during ripening, which further triggers a range of physiological changes, including carbohydrate and organic acid metabolism, cell wall remodeling, pigment reconfiguration, and volatile compound synthesis. These processes drive the transition of the fruit from a “growth stage” to a “ripening stage” quality state. Sugar and acid metabolism is the core basis determining peach flavor quality. During fruit development, photosynthetic products are transported to the fruit through the phloem and gradually converted into and accumulated as soluble sugars such as sucrose, glucose, fructose, and sugar alcohols, while organic acids such as malic acid and citric acid change dynamically at different developmental stages. In general, soluble sugars continue to accumulate and organic acids gradually decline during ripening, leading to an increase in the sugar-acid ratio and resulting in enhanced sweetness and reduced sourness. Metabolomic studies have shown that, in cultivars such as ‘Huangjin’, the color-change stage is a critical period characterized by significant accumulation of sugars and sugar alcohols and a marked decline in organic and phenolic acids, indicating that this stage is an important physiological turning point in peach flavor formation (Minas et al., 2018). Meanwhile, these primary metabolic changes also interact with cell wall degradation, causing fruit softening and texture changes, which in turn affect eating quality and postharvest storability.

Pigment synthesis and transformation are important physiological bases for external fruit quality. During peach ripening, chlorophyll gradually degrades, while anthocyanins and carotenoids accumulate, jointly driving the peel and flesh color from green to red, yellow, or mixed hues (Figure 5). Anthocyanin accumulation is usually closely related to red peel coloration, whereas carotenoids are more involved in the formation of yellow flesh and peel background color. Studies have shown that, during the color-change stage, key enzyme genes in the flavonoid pathway, such as CHS, F3′H, DFR, and A3GT, are upregulated, thereby promoting anthocyanin biosynthesis and intensifying red or mixed coloration in the fruit (Serrie et al., 2025). In addition to determining yellow coloration, carotenoids can also generate certain norisoprenoid volatiles through the carotenoid cleavage dioxygenase (CCD) pathway, thereby linking pigment metabolism with aroma formation.

Figure 5 Maturation process of peach fruit