6.2 Molecular-assisted breeding and genomic selection

Molecular tools now complement traditional selection by enabling more precise manipulation of sweetness and acidity traits. High-density SNP arrays and pedigree-based QTL analyses have identified loci for SSC on linkage groups/chromosomes 3B and 6A and for TA and pH on 2A, 5B, and 4C, providing markers that can be implemented in marker-assisted selection to shift sugar-acid balance (Porter et al., 2023). Genome-wide association and expression-QTL integration have further pinpointed candidate genes such as starch synthase 4 and sugar transporter 2-like underlying major SSC QTL, facilitating haplotype-based selection for enhanced sugar accumulation (Fan et al., 2021b).

Genomic selection (GS) is emerging as a powerful strategy where sweetness, acidity, and yield are controlled by many loci of small effect. Large multi-parental populations genotyped with SNP arrays and phenotyped for fruit quality and yield show that genomic prediction is effective for complex traits, although a negative correlation between total soluble sugars and marketable yield highlights a key trade-off that GS must manage. Recent reviews emphasize that declining genotyping costs and availability of phased octoploid genomes will make GS for SSC/yield balance feasible in seedling populations, allowing breeders to enrich for sweeter, well-balanced genotypes early in the breeding pipeline.

6.3 Synergistic improvement of multiple traits and comprehensive evaluation of flavor quality

Improving sweetness and acidity cannot be separated from broader flavor and agronomic performance. Large sensory-chemical studies reveal that overall liking is driven primarily by sweetness intensity and strawberry flavor, with sourness playing a lesser direct role, and that specific volatiles can enhance perceived sweetness independently of sugar content (Barth et al., 2020). Descriptive analysis and consumer work consistently show that cultivars combining adequate SSC, moderate TA, and rich ester- and terpene-dominated volatile profiles achieve superior flavor ratings, whereas imbalanced acids or atypical volatile patterns can undermine acceptability even in high-sugar fruit (Liu et al., 2023).

Modern flavor-oriented breeding strategies advocate a multi-trait, consumer-driven framework in which sensory data guide the prioritization of chemical targets—sugars, organic acids, and key volatiles—and these, in turn, drive genetic target discovery and marker development (Jouquand et al., 2008). Multi-year, multi-environment evaluations using integrated sensory, metabolite, and genomic data allow breeders to select genotypes with stable sweetness, balanced acidity, desirable aroma, and acceptable yield across harvest dates and production systems (Patel et al., 2023). Such comprehensive evaluation supports the release of cultivars that deliver consistently high flavor quality while meeting grower requirements for productivity and shelf life.

7 Case Study: Selection and Evaluation of High-Quality, High-Sweetness, Low-Acidity Strawberry Varieties

7.1 Analysis of quality characteristics in typical varieties

High-sweetness, low-acidity cultivars are favored where consumers prefer mild, dessert-type strawberries with intense sweetness and relatively soft sourness. Comparative work across 25 cultivars shows wide inter-cultivar variation in soluble sugars and organic acids, with some genotypes achieving both high sugar content and favorable sugar/acid ratios, reflected in superior total quality index (TQI) scores (Milosavljević et al., 2023). Such cultivars are prime candidates as “high-sweetness” types, because they combine elevated sugars with moderate acidity and beneficial bioactive compounds, aligning with increasing demand for fruits that are both palatable and nutritionally valuable (Ikegaya et al., 2021).

Cultivar-specific evaluations under greenhouse or soilless systems further highlight materials with desirable sensory profiles. In a soilless comparison of four Japanese cultivars, ‘Guimeiren’ exhibited the highest sweetness index, while ‘Tochiotome’ combined relatively high soluble solids and sugar/acid ratios with comparatively low organic acid levels, producing a sweet yet not overly tart taste. Similarly, studies in Greece reported that ‘Sabrina’ had the highest pH and SSC/TA index and was perceived as the sweetest among three commercial cultivars, illustrating how individual varieties can naturally express a high-sweetness, lower-acidity profile under suitable conditions (Ikegaya et al., 2021).