identified cultivars like ‘Albion’, ‘Sweet Charlie’, ‘Camarosa’, ‘Camino Real’, and ‘Chandler’ as ideal for local conditions because they combined high °Brix and favorable TSS/TA ratios with desirable flavor volatiles, underscoring the success of breeding programs that explicitly target balanced sweetness and acidity alongside regional adaptation (Scott et al., 2021).

8 Future Directions for Strawberry Sweet-Sour Quality

Multi-omics approaches in cultivated strawberry now combine phased genomes, transcriptomes, metabolomes, and volatile GWAS to dissect flavor genes and regulatory elements. An integrated framework in octoploid strawberry exploited genomic heterozygosity and metabolomic diversity to link allele-specific expression and structural variants with key flavor volatiles, demonstrating how such datasets can systematically uncover flavor genes. Conjoint metabolome-transcriptome analyses across cultivars with contrasting flavor have further highlighted fructose and citric acid as central non-volatile drivers of sweetness and acidity, and revealed that citrate cycle, phenylpropanoid, and flavonoid pathways are major regulatory hubs.

Future research will likely deepen integration of sugar-acid metabolism with broader flavor networks using expanded omics resources. Integrative analyses in contrasting cultivars already identify candidate structural genes and transcription factors associated with soluble sugars, organic acids, and vitamin C, indicating that coordinated regulation of multiple quality components can be mapped at pathway level. At the same time, comparative metabolomics across diverse wild *Fragaria* accessions shows that amino acids, sugars, and anthocyanins co-vary with flavor, suggesting that extending multi-omics to wild relatives will enrich sweet-sour regulatory models and provide novel alleles for breeding.

Precision flavor breeding is moving toward genomics-informed strategies that explicitly target sweetness, acidity, and key volatiles. Large-scale sensory-chemical studies have identified sugars, two main acids, and sets of volatiles that enhance sweetness and liking, while genetic association analyses mapped loci for ester production that can be targeted by marker-assisted selection. A broader review of strawberry flavor breeding emphasizes that phased haplotype genomes, SNP arrays, and extensive fruit transcriptomes now allow localization of genes for volatile synthesis, anthocyanins, and sweetness perception, paving the way for more precise manipulation of flavor traits.

Genomic selection and marker-assisted breeding for quality traits are expected to expand as genotyping costs fall and prediction models mature. Genomic-informed studies in multi-parental populations reveal a negative correlation between total soluble sugars and yield, and identify QTNs for perceived acidity and other traits, supporting combined use. Updates from breeding programs adopting DNA testing show that high-throughput markers for disease resistance and fruit quality are already being used to cull seedlings efficiently, illustrating how precision breeding pipelines can be scaled in practice.

Future progress in sweet-sour improvement will depend on aligning biochemical targets with consumer sensory preferences. Large multi-year consumer and descriptive-panel studies demonstrate that overall liking is driven mainly by sweetness and strawberry flavor intensity, not sourness, and reveal volatile compounds that enhance perceived sweetness independently of sugars, providing concrete chemical targets for breeding and quality control. Bayesian modeling of soluble solids-sweetness relationships further refines selection criteria by quantifying how small SSC changes shift the probability of achieving above-average sweetness in sensory panels.

Industrial application will likely leverage these insights across fresh and processed product chains. Studies relating cultivar traits to consumer preference show that higher sweetness and strawberry flavor predict better acceptance in fresh fruit, while work on strawberry-flavored dairy products indicates that consumers prefer high sweet taste, relatively low acid taste, and strong strawberry aroma, even when delivered by added flavorings.

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