In addition, fluorescence spectroscopy, electrical property detection, and electronic nose and tongue technologies have also expanded the methodological toolbox for peach quality detection (Qi et al., 2024). These methods show considerable potential for maturity recognition, internal defect detection, and flavor evaluation, and are especially suitable for breeding and grading scenarios requiring rapid, large-scale assessment. The introduction of modern analytical techniques has gradually shifted peach quality evaluation from traditional single-indicator measurement toward multidimensional, molecular-level, and high-throughput analysis.

### 5.3 Non-destructive detection and comprehensive evaluation models

Non-destructive detection technology has become an important direction in peach quality evaluation in recent years. Its core objective is to achieve rapid, objective, and highly repeatable detection of internal quality without damaging fruit structure, thereby compensating for the limitations of destructive analysis and subjective sensory evaluation (Qi et al., 2024). Such technologies are particularly suitable for large-scale phenotyping, online grading of commercial fruit, and precision harvest decisions. At present, Vis/NIR and hyperspectral systems are the most widely used. With a single scan, they can rapidly predict SSC, DMC, firmness, and maturity indices (such as IAD), while maintaining high accuracy across different developmental stages, crop loads, and cultivars (Anthony et al., 2023). Studies have shown that by fully accounting for sources of variation such as genotype, canopy position, and management practices during model construction, the stability and generalization ability of predictive models can be significantly improved. This also helps reveal the influence of preharvest factors on fruit quality formation (Minas et al., 2023).

In addition to spectroscopic methods, a range of intelligent detection techniques has gradually been incorporated into non-destructive peach quality evaluation systems (Qi et al., 2024). Machine vision can be used to identify fruit shape, color distribution, and surface defects; hyperspectral imaging can simultaneously capture both external and internal quality information; acoustic vibration and electrical property detection show potential for firmness and internal defect recognition; and electronic noses and tongues enable rapid characterization of aroma and taste features. The integration of these technologies has promoted a shift in peach quality evaluation from traditional "static, destructive measurement" toward "dynamic, online, and intelligent monitoring."

On this basis, the construction of comprehensive evaluation models has become increasingly important for transforming multi-source data into practical applications. Through principal component analysis (PCA), cluster analysis, and machine-learning approaches, multiple indicators such as shape, mass, firmness, color, SSC, TA, and electrical parameters can be integrated to achieve quality grading and to demonstrate that single appearance indicators cannot fully reflect overall fruit quality. In addition, the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation methods can combine physicochemical indicators with sensory evaluation, weighting attributes such as sweetness, juiciness, and overall preference (Baviera-Puig et al., 2023; Sun et al., 2023). Overall, modern peach quality evaluation is shifting from reliance on single-indicator detection toward multi-source data integration, gradually establishing more comprehensive evaluation systems that better reflect actual consumer eating experience.

## 6 Construction of Quality Evaluation Systems

### 6.1 Multi-index comprehensive evaluation methods

Peach fruit quality is inherently multidimensional, and a single indicator cannot fully reflect its overall quality level. Therefore, multi-index comprehensive evaluation has become an important direction in current peach quality research and grading applications. Comprehensive evaluation systems usually integrate external quality (such as fruit shape, color, and size), physical quality (such as fruit weight, density, and firmness), internal quality (such as SSC, TA, sugar-acid ratio, texture, and flavor), and, when necessary, nutritional and functional quality (such as polyphenols and antioxidant capacity), as well as even electrical or spectral parameters, into a unified framework to achieve systematic evaluation of fruit quality (Farina et al., 2019). This approach effectively overcomes the limitations of single indicators and more objectively characterizes the comprehensive performance of fruit quality among different cultivars, maturity stages, and cultivation conditions.