Existing studies have shown that multi-index comprehensive evaluation is applicable not only to fresh peaches but also to processed products. For example, in fresh peach studies, an evaluation system based on 11 indicators—including shape index, volume, weight, density, firmness, color, impedance, phase angle, SSC, TA, and sugar-acid ratio—was able to classify fruits into different quality grades and revealed the important fact that the proportion of red peel color is only weakly correlated with internal eating quality (Zhang et al., 2020). This indicates that external traits intuitively preferred by consumers do not necessarily represent the true comprehensive quality of the fruit. Similarly, in freeze-dried peach powder studies, researchers integrated 14 indicators related to physicochemical properties, nutrition, and processing performance to evaluate samples of different cultivars and ripening stages, and found that a smaller number of core indicators could be selected without losing discriminatory power, suggesting that comprehensive evaluation systems also have potential for indicator compression and optimization (Liu et al., 2017).

From the perspective of evaluation logic, the advantages of a multi-index system are mainly reflected in three aspects. First, it can simultaneously take into account appearance, flavor, and nutritional value, thereby better meeting the actual needs of consumers and industry. Second, it helps compare materials for different purposes, such as distinguishing “high-quality fruit for fresh consumption” from “raw materials suitable for processing.” Third, it provides quantitative support for cultivar selection and optimization of cultivation practices, rather than relying solely on empirical judgment. In practice, multi-index comprehensive evaluation usually requires standardization of different indicators first to eliminate the influence of dimensional differences. Common methods include range standardization and Z-score normalization, which place all indicators on a comparable scale. Subsequently, weighted summation, comprehensive scoring functions, or multivariate models can be used to integrate multiple indicators into a single comprehensive quality score, enabling comparison among different treatments, cultivars, or regional materials (Zhang et al., 2020). At the same time, these methods are often combined with correlation and regression analyses to reveal internal relationships among different quality traits, such as sugar-acid ratio versus sensory sweetness, firmness versus maturity, and overall color parameters versus consumer preference, thereby providing a basis for selecting key indicators and improving evaluation efficiency.

6.2 Weight determination and model construction

After establishing a multi-index evaluation system, how to scientifically determine the weight of each indicator and construct a comprehensive evaluation model becomes the key step in achieving quantitative peach quality assessment. Because different quality indicators contribute unequally to overall quality, it is necessary to adopt reasonable weighting methods and model-construction strategies to transform raw data into interpretable comprehensive scores. Principal component analysis (PCA) is one of the most commonly used objective weighting and dimensionality-reduction methods in fruit quality evaluation studies (Farina et al., 2019; Zhang et al., 2020). Its core function is to deal with multicollinearity among multiple indicators, extract information components that explain the main variation from the original variables, and thus reduce redundancy while improving model simplicity. For example, in fresh peach studies, PCA based on 11 indicators extracted five principal components explaining about 85% of the total variation, and further combined with K-means clustering to classify fruits into five quality grades (Zhang et al., 2020). Similarly, in freeze-dried peach powder evaluation, PCA extracted five principal components from 14 variables, with a cumulative contribution rate of 84.46%, effectively distinguishing among cultivars and ripening stages. Thus, PCA not only increases the information density of evaluation models but also helps identify the dominant factors underlying comprehensive quality.

The analytic hierarchy process (AHP), by contrast, is a subjective weighting method that places greater emphasis on consumer preference or expert experience in evaluation systems. Its basic principle is to construct a judgment matrix and compare indicators pairwise to determine their relative importance. The advantage of AHP lies in its ability to reflect production goals and market demand. For example, in the evaluation of fresh peaches, consumers are often more concerned with sweetness, juiciness, and aroma than with firmness or external appearance alone. Studies have shown that, when AHP is combined with sensory analysis in peach and nectarine quality evaluation, the gustatory phase emerges as the most critical in overall quality judgment, with sweetness and juiciness usually