composition (Xue et al., 2024). Dark-colored fruits usually contain higher anthocyanin concentrations and exhibit stronger antioxidant capacity, whereas white or yellow types contain low or undetectable levels of cyanidin-3-O-glucoside, resulting in lighter coloration. At the molecular level, MYB transcription factors and their gene clusters are considered important genetic regulators of fruit color variation in Chinese bayberry. MrMYB1 and related MYB/QTL regions are significantly associated with anthocyanin biosynthesis and fruit pigmentation (Cao et al., 2021; Zhang et al., 2024).

In addition to genetic factors, light, temperature, and water-fertilizer management also affect fruit coloration. Appropriate light conditions promote anthocyanin biosynthesis and deepen peel color, whereas prolonged rainy weather, dense canopies, or insufficient ventilation and light penetration may result in uneven coloration, dull appearance, and reduced commercial quality. Fruit surface integrity is also an important component of appearance evaluation. Fruit cracking, mechanical injury, and pest or disease damage not only reduce commercial value but also accelerate postharvest decay and impair storage and transportation performance. Therefore, research on Chinese bayberry external quality is gradually shifting from simple trait description to comprehensive quantitative evaluation systems based on color parameters, image recognition, fruit shape indices, and fruit uniformity (Zhang et al., 2024).

2.2 Internal quality traits

The internal quality of Chinese bayberry fruit mainly includes sugars, organic acids, vitamin C, phenolic compounds, flavonoids, anthocyanins, volatile aroma compounds, flesh texture, and antioxidant capacity, which are the core factors determining fruit flavor, nutritional value, and functional properties (Zhang et al., 2022). Among these, soluble solids content, titratable acidity, and sugar-acid ratio are important indicators for evaluating fresh-eating quality. Most studies have shown that sucrose is the predominant soluble sugar in ripe Chinese bayberry fruits, followed by fructose and glucose, while citric acid is the major organic acid. During fruit development and ripening, total soluble solids, sugars, and anthocyanin contents generally increase gradually, whereas titratable acidity decreases or stabilizes, resulting in the characteristic sweet-sour flavor balance of mature Chinese bayberry fruits.

Chinese bayberry is rich in various functional bioactive compounds, particularly anthocyanins, polyphenols, and flavonoids. Cyanidin-3-O-glucoside is the major anthocyanin component in Chinese bayberry and usually accounts for a high proportion of total anthocyanins, serving as an important material basis for the dark coloration and antioxidant capacity of the fruit. Significant differences in total phenolics, total flavonoids, total anthocyanins, and antioxidant capacity have been observed among cultivars, with black or dark-red fruits generally showing higher levels than pink or white types. Antioxidant evaluation methods such as DPPH, FRAP, ABTS, PSC, and CAA have demonstrated that the antioxidant capacity of Chinese bayberry is usually significantly positively correlated with total phenolic and flavonoid contents (Xia et al., 2021).

Flesh texture and aroma composition are also important aspects of internal quality evaluation. High-quality Chinese bayberry fruits are typically characterized by tender and juicy flesh, low fiber content, balanced sweetness and acidity, and rich aroma. The volatile aroma compounds of Chinese bayberry mainly include terpenoids such as α-pinene, β-caryophyllene, and D-limonene, as well as aldehydes and esters. Significant differences in volatile composition exist among cultivars and ripening stages, resulting in sensory characteristics such as pine-like, woody, grassy, and overripe aromas. During postharvest storage, temperature and ethylene treatments significantly affect sugar-acid balance, volatile release, firmness retention, and off-flavor formation. Moderate low-temperature storage helps delay quality deterioration, whereas higher temperatures may accelerate flavor degradation and fruit decay (Gao et al., 2024; Saeed et al., 2024).

2.3 Quality evaluation index system

With the continuous development of the Chinese bayberry industry, establishing a scientific, systematic, and quantifiable quality evaluation system has become increasingly important for improving fruit standardization, commercialization, and industrial competitiveness. At present, Chinese bayberry quality evaluation mainly includes sensory evaluation, physicochemical measurements, functional quality analysis, postharvest stability