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Evaluation on processing suitability of 17 juice orange varieties planted in three gorges reservoir area of China

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Abstract

From 2014 to 2021, 17 sweet orange varieties and strains were continuously tested for their suitability for orange juice processing, focusing on the physical and chemical indicators of the fruit, namely juice yield, soluble solids, titratable acid, vitamin C, and sensory indicators including color value, defects, and flavor. We developed a numerical (percentage) method to evaluate the processing suitability for the juicing varieties, and all the tested data were processed using this method. A total of 12 sweet orange varieties with early, middle, and late maturity suitable for juicing were screened out, including six early matured varieties: Early Longleaf, Yuzaocheng, Westin, Early Gold, Yunguicheng, and Hamlin; two middle matured varieties: Middle Longleaf and Edangan (Jincheng); and four late matured varieties: Spring orange, Late Longleaf, Algerian Valencia, and Olinda Valencia. At the same time, five varieties, including the Early-maturings: Itaborai and Early Marrs; and the Middle-maturings: Tongshui 72-1, Trovita, and Midsweet, which can be juiced were also screened out. Among the 17 recommended varieties, the Early, Middle, and Late Longleaf are the most prominent.

Keywords: juicing oranges; processing suitability; quantitative evaluation; percentage method; early, middle, and late maturing varieties.

1 INTRODUCTION

NFC (not from concentrate) orange juice is also called non-concentrated restitute juice and original single-strength juice. The worldwide market for commercial orange juice gradually shifts from the dominant Frozen Concentrated Orange Juice to NFC orange juice (Brown *et al*., 1999). NFC juices were squeezed directly by mechanical methods, which could be fermented but not fermented and concentrated. The China Beverage Industry Association promulgated the group standard of Not from Concentrated Orange Juice in 2019, which was officially announced as the industry standard (QB/T 5627-2021) by the Ministry of Industry and Information Technology in 2021 and was officially implemented on April 1, 2022 (China, 2021). NFC juice is different from most of the juice sold in the market, for it is made from high-quality fruits with advanced processing technologies that can maximize and retain the inherent fresh flavor, color, and nutrition. Many studies have evaluated the sensory characteristics of fresh orange, NFC, and concentrated restitute orange juice, involving the appearance, color, flavor, texture, sweetness, acidity, and pulp, and found that the internal properties such as sweetness, acidity, and the texture of pulp can largely affect the preferences of consumers (Han *et al*., 2007; Hyeyoung *et al*., 2015; Ryo *et al*., 2015; Bai *et al*., 2016; Cai *et al*., 2019). Based on a long-term study on the processing suitability of sweet orange (*Citrus sinensis*) for juice, a simple, accurate, and scientific "percentage method" was put forward for the quantitative evaluation of the processing suitability of juice orange according to consumers' preferences and the inherent characteristics and economic characteristics of orange juice, which will be minimized by personal preferences and detailed in this assay. At present, the raw materials used in Brazil and the USA, the two major orange juice producers in the world, are planted at early, middle, and late maturity and can be processed for more than 8 months a year (FAO, 2023). Pera, Natal, and Valencia are the main varieties used in Brazil, and Valencia, Hamlin, Early Gold, Parsons Brown, and Pineapple oranges are the main varieties in the USA. In recent years, the processing volume of NFC orange juice has exceeded that of concentrated orange juice, indicating that the orange juice market is shifting to high-quality orange juice. According to relevant reports, the global consumption of fruit drinks in 2018 was about 95.6 billion liters, of which orange juice ranked first with a 26.2% market share, and the output and use of orange juice still showed a steady growth trend (Allegra *et al*., 2019; Neves *et al*., 2020). NFC orange juice accounts for over 50% of the market in the USA, Japan, and Europe, and the percentage in the UK is up to 70% (Industrial Information Network, 2020). At the same time, the sweet oranges mainly

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used for processing in China are Jincheng, Xianfeng Orange (Jincheng selection), Early Gold, Valencia, Hamlin, and Navel orange. However, except for Jincheng, these varieties have not yet established large-scale planting bases and cannot provide a stable supply of raw materials to processing enterprises. In the absence of special raw materials, some companies have to use other fruits that are not suitable for fresh grade, and it is basically impossible to select juice orange varieties.

In 2020, the planting area of Citrus in China has reached 2.7 million hectares, and the output reached 52.19 million tons, of which more than 95% went to the fresh market by which the market becoming saturated (FAO). For lack of suitable juice orange varieties as raw materials, the amount of orange used for juicing is around 0.6 million tons. At the same time, the domestic market demand for orange juice increases year by year, creating a wild gap between needs and supply that can only be made up by importing. In 2021, the import of orange juice of China reached 500,000 tons (in terms of single-strength juice), which is over 60% of the domestic consumption (Insight And Info, 2021; Santos *et al*., 2013). Therefore, it is urgent to develop the orange juice processing industry in China. First, high-quality raw materials are the critical control point in the processing of orange juice, so excellent special varieties are required. Thus, our study evaluated 17 sweet orange varieties during 8 years to screen excellent early, middle, and late ripening sweet orange varieties for orange juice processing industry.

2 MATERIALS AND METHODS

2.1 Sweet orange varieties

All the sweet oranges tested were obtained from 14 orchards from Zhongxian, Beibei, Jiangjin, and Kaixian in Chongqing, China, including early maturings: Early Longleaf orange, Hamlin, Early Gold, Westin, Itaborai, Early Marrs, Yuzao orange, and Yungui orange; middle maturings: Middle Longleaf orange, Edangan (Jincheng) orange, Tongshui 72-1 (Jincheng Selection), Midsweet, and Trovita; and late maturings: Late Longleaf orange, Spring orange (Kaichen 72-1 for late-picking, one of Jincheng Selection also), Algeria Valencia, and Olinda Valencia. All the trees range from 7 to 12 years old, except Edangan orange, which was 30 years old when we began to sample. The rootstocks of these trees are trifoliate orange and citrange. Early-maturing varieties are sampled from November to mid-December each year; mid-maturing varieties are sampled from mid-December to January each year; and late-maturing varieties are sampled from February to June each year. The sampling time is from 2014 to 2021, 7 varieties have been continuously sampled for 8 years, 8 varieties have been continuously sampled for 7 years, and 2 varieties have been sampled for 5 years. The specific sampling time details are shown in Supplementary Table 1.

2.2 Sample preparation

All the samples were detected within 3 days after sampling. The fruits were randomly selected and squeezed. The juices were filtered with a 40-mesh gauze filter, the weights of pulp were calculated in the edible rate, and the filtered juices were immediately used in the following determinations.

2.3 Determination of physical and chemical properties

The physical and chemical properties were measured according to the Chinese national standard "Method of Inspection for Fresh Citrus Fruit" (General Administration of Quality Supervision, 2011). The juice yield, titratable acid, color value, soluble solid content (SSC), and content of vitamin C were scored, while the number of seeds, average weight of fruit, and edible rate were not scored.

2.4 Determination of sensory properties

The color value was determined by spectrophotometer (Colori5, Gretag Macbeth), according to the method for orange juice of the USDA (Redd *et al*., 1986). The scores of appearance, defect, and flavor were evaluated in the professional sensory evaluation laboratory in an independent and anonymous way by a group of trained and practiced experts and scholars. The evaluation criteria of the percentage method for processing suitability of sweet orange varieties for juice are shown in Supplementary Table 2. The scores and quantitative evaluation were calculated with the Equation 1:

$$\text{Score} = (\text{Juice Yield} \times \text{SSC} / 0.1298 \times 100) + \text{Brix/acid Ratio} + \text{Vc} + \text{Color} + \text{Defects} + \text{Flavor} \quad (1)$$

3 RESULTS

3.1 Physical-chemical properties of variety

Results of the physical-chemical properties of varieties are shown in Supplementary Table 3. It should be noted that the detection results of the characteristic parameters of the same variety are derived from the comprehensive average of different orchards across the years, so they are more representative.

3.2 Scores of processing suitability

The scores for the juicing suitability of oranges are shown in Supplementary Table 4. There was only one variety, namely, medium-ripe Longleaf orange, that scored over 85 points (85.59). Among the early maturing varieties, Early Longleaf orange (84.55 points), Yuzao orange (82.44 points), Westin (81.38 points), and Yungui orange (80.14 points) scored over 80 points. There were two middle ripening varieties, namely, Early Longleaf orange (84.55 points) and Edangan (80.87 points), suitable for juicing along with three late-maturing varieties, namely, Spring orange (84.48 points), Late Longleaf orange (82.72 points), and Algeria orange (84.48 points). There were seven varieties with 70–80 points, including four early-maturing varieties, namely, Early Gold (79.51 points), Itabori (79.31 points), Hamlin (77.61 points), and Early Marsh (77.44 points); two middle-maturing varieties, namely, Trovita (75.44 points) and Tongshui 72-1 (74.41 points); and one late-maturing variety, namely, Olinda orange (79.09 points). There was only one variety, i.e., Midsweet below 70 points (68.47 points).

4 DISCUSSION

According to the evaluation scores in Supplementary Table 4, 12 sweet orange varieties, covering early, middle, and late ripening, are suitable for juicing, and 5 varieties could be used in juicing. Among the 17 evaluated varieties, Longleaf oranges performed particularly well, and its early, middle, and late ripening lines were top-ranked.

Longleaf orange is a high-quality variety bred from the common sweet orange in Jiangjin County of Chongqing in the 1970s, named for its long and narrow leaves. In 1994, a good strain, i.e., 94-1 (He *et al*., 2013), was selected from the local Longleaf orange, and the early, middle, and late ripening lines were further selected. The late ripening Longleaf orange, however, colors later, while the other characters were not very different from the early and middle ripening lines. It was found that Longleaf orange had better quality, higher sugar, lower acid, and a pleasant flavor. Under the climatic conditions of long winter and low temperature in Chongqing, the sugar content was still higher than 11°Brix, and the brix/acid ratio was more than 15. It has been approved as Longleafxiang orange by the Chongqing Crop Variety Certification Committee in 2014 (Chongqing Crop Variety Examination and Approval Committee, 2014). At present, it is being recommended to plant in sweet orange-producing areas.

The United States Department of Agriculture issued the orange juice grade standard in 1983 (United States Department of Agriculture, 1983), which quantitatively evaluates the sensory indicators of color, defect, and flavor of orange juice with scores of 40, 20, and 40 points, respectively. The color is measured with a colorimeter or a color scale, and the score is 30–40 points. At the same time, the highest and lowest soluble solids and titratable acids, brix/acid ratios, and the highest recoverable essential oils of orange juice are specified. Brazil and other major orange juice-producing countries also adopt the US standards. The author began to study the method of quantitative evaluation of juice using sweet oranges since the last century (Han *et al*., 2010; Momin & Thakre, 2015; Wu et al., 2006), in order to minimize the interference of personal preferences on the evaluation and make the evaluation more scientific, accurate, and simple. The above-mentioned "percentage method" was proposed in this study through the "Eleventh Five-Year" research projects supporting and the evaluation practice and continuous improvement of more than 200 sweet orange varieties in China (W u, 2009). This evaluation method fully studies the characteristic attributes of sweet oranges and orange juice as foods and commodities at three levels. First, consumers' perception of sweet orange and orange juice's color, flavor, and taste, SSC, brix/acid ratio, and other sensory properties and nutrients such as vitamin C. The second is the orange juice standards formulated by China, Europe, the United States, Brazil, and other countries, and the third is the economic attributes of sweet oranges and orange juice, such as high juice yield and high sugar content, and low raw material ton consumption rate, which cause high product yield and good quality, so the raw fruit and juice price are also high. According to the characteristics of these three aspects, a comprehensive comparison was carried out, and the key indicators and their weights for the suitability of sweet orange processing were determined through repeated investigation and verification. The established sensory indicators include the appearance, flavor, and color of the juice; the physical and chemical indicators include the juice yield and the ratio (the ratio of brix to acid), which is also closely impact to the flavor; the nutritional indicator is namely vitamin C; economic indicators are mainly composed of juice yield and soluble solids, which represent the net sugar production of the fruit and are also related to flavor. In developed countries, sweet oranges are priced not by the weight of the fruit but by the amount of sugar produced by the fruit, which is fair and reasonable and encourages fruit farmers to plant superior varieties with high sugar and high juice yield.

To evaluate a superior juicing variety, in addition to good fruit quality, it also needs to have excellent horticultural traits, that is, high yield, stable yield, strong reversibility, and wide adaptability to climate and soil. These would include a comprehensive evaluation with the "percentage method."

Supplementary Figure 1 tells us the year with the highest score in the test period of different varieties: 2015: Early Longleaf (90.35 points), Late Longleaf (86.52 points), Yunguicheng (85.64 points), and Midstreet (77.32 points); 2016: Westin (90.99 points), Mid Longleaf (90.30 points), Hamlin (83.44 points), and Early Gold (82.15 points); 2017: Spring orange (87.99 points) and Olinda Valencia (87.82 points); 2018: Yuzaocheng (90.15 points) and Algerian Valencia (84.10 points); 2019: Early Marrs (83.02 points); 2020: Edangan (Jincheng) (93.78 points) and Tongshui 72-1 (83.55 points); and 2021: Trovita (87.73 points), Itaborai (82.47 points). It can be seen that 2015 and 2016 have the highest frequency of high-quality performance, and 2017, 2018, 2020, and 2021 also have good performance. The overall performance of 2014 and 2019 is not ideal, which may be closely related to the phenology of the year.

In addition, superior varieties need to be cultivated with good methods, especially the cultivation methods of processing raw materials aiming at improving unit yield and quality and reducing costs, which can provide sufficient, high-quality, and reasonably priced raw materials for orange juice processing.

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