Scientia Horticulturae 231 (2018) 151–157

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Determinants of sensory acceptability in grapefruit☆

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ARTICLE INFO

Keywords:
Sensory
Sweetness
Tartness
Bitterness
Soluble solids
Acidity

ABSTRACT

Increasing consumer demands regarding fruit quality coupled with decreasing consumption of grapefruit in the United States prompted a reassessment of the factors that influence consumer acceptability in grapefruit in this study using more thorough methods of sensory evaluation and fruit sampling for analytical characteristics than had been previously employed. Over a 9 month period commercially-packed grapefruit were obtained on seven different harvest dates during the commercial season from either California, Texas, or Florida, sometimes obtaining fruit from multiple states at the same time. The fruit were evaluated by the panelists for overall likeability, grapefruit flavor intensity, juiciness, sweetness, tartness and bitterness. The panelists were also asked questions regarding purchase intent. From the same grapefruit halves that were tasted juice was obtained that was used to assay for soluble solids (SSC) and titratable acidity (TA). It was found that likeability was most strongly linked to sweetness, with bitterness having a lesser role. Accordingly, SSC, an estimate of the sugar concentration within the fruit, was positively related to likeability. It was not possible to determine whether SSC/TA, the traditionally-used measure for harvest maturity, or CAstd, a calculated value that subtracts acidity from SSC rather than dividing, was more effective in predicting good grapefruit flavor. Estimates of SSC/TA that associated with the range of hedonic scores indicated that current levels of SSC/TA used for maturity standards in the United States are likely set too low to consistently satisfy consumers. Purchase intent data gathered during sensory evaluation indicated that grapefruit should have a very high flavor quality (like moderately and above) to make more likely both an immediate and future purchase.

1. Introduction

Research on determining the basis of flavor in grapefruit has a long history in the United States, having been initiated in Florida during the 1912–1913 season (Collison, 1913). In this early study the authors determined sugar and acid content present in a number of different grapefruit varieties throughout the season and classified the resulting juice from very sour to very sweet using informal tasting. Similar work, utilizing numerous locations and multiple seasons, was conducted in Florida, California, Arizona and Texas (Wood and Reed, 1938; Harding and Fischer, 1945; Rygg and Getty, 1955; Deszyck and Ting, 1956). Use of a more refined numerical grading system to rate fresh grapefruit palatability was introduced by Harding and Fisher (1945) and also used by Rygg and Getty (1955) where a final score of 70 was considered to be the lowest acceptable score for consumers. Although the influence of factors such as location, environmental effects, variety, and tree age were found to impact the maturation of the fruit and subsequent flavor, the consensus of these research projects was that the content of soluble solids (SSC), titratable acidity (TA) and juice content were the primary drivers of flavor quality in grapefruit, SSC being the major contributor to sweetness and TA to tartness. Bitterness was recognized as a negative sensory attribute in immature fruit and specifically evaluated for in one of the studies (Wood and Reed, 1938), but the inability to associate bitterness with an easily-quantifiable test led to the reliance on other more easily measured parameters. Also, the inability to relate palatability and the content of naringin, the major bitter component in fresh grapefruit (Kesterson and Hendrickson, 1957), inhibited further efforts to utilize bitterness as another standard of maturity (Rygg and Getty, 1955).

Results from the before-mentioned research associating grapefruit flavor with measured levels of SSC, TA and juice content were used over the years to develop regulations in different regions of the United States to dictate when grapefruit could be legally harvested, with the goal being to keep poor-tasting fruit out of the marketplace. Currently California and Arizona minimum maturity standards are based upon peel color and SSC/TA ratio, while Florida also includes juice content

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https://doi.org/10.1016/j.scienta.2017.12.026
Received 28 September 2017; Received in revised form 8 December 2017; Accepted 12 December 2017
0304-4238/ Published by Elsevier B.V.

and SSC as part of the standard in addition to SSC/TA ratio (Grierson, 2006). Texas relies on juice content, SSC and SSC/TA ratio to define their standard (Grierson, 2006).

While the implementation of maturity standards has been useful in lessening the number of poor quality grapefruit reaching consumers it was recognized very early that SSC/TA ratio was an imperfect predictor of flavor quality (Rygg and Getty, 1955). One response to this issue has been the development of alternative means of expressing the SSC and TA relationship, such the concept of BrimA developed by Jordan et al. (2001). In the BrimA index TA is multiplied by a constant that is dependent on the fruit type and then that product is subtracted from SSC. The authors reanalyzed some of the original grapefruit data of Harding and Fischer (1945) and Rygg and Getty (1955) and found the BrimA value calculated from this data to be more predictive of flavor than was SSC/TA in those datasets. BrimA was also demonstrated to be a more effective predictor in navel oranges (Jordan et al., 2001; Obenland et al., 2009) and is now currently used as a maturity standard in California under the name “California Standard”.

Consumers are becoming increasingly discerning with regard to fruit quality and there are many alternative choices of fruit within the marketplace. While citrus such as mandarins have been increasing in popularity, to a large extent due to the ease of eating, the consumption of fresh grapefruit in the United States has been declining (USDA, 2017). As a result, it is important that the determinants of grapefruit sensory quality be fully understood so that only fruit of superior quality be marketed to consumers. This will act to help to enhance the reputation of grapefruit among consumers and maintain or enhance its profitability for grapefruit growers and packers.

The purpose of this research was to refine in greater detail the understanding of the characteristics that define a good-tasting grapefruit. This was done by performing a more thorough evaluation of the sensory parameters that compose grapefruit flavor than had been performed in previous research. The work also sought to improve on what had been done previously by assaying for potential drivers of grapefruit sensory quality in the same fruit that were being tasted and linking the data back to the tasted fruit. In this way the precision of the associations between flavor and instrumentally-determined characteristics was enhanced. Fruit from California, Florida and Texas were harvested throughout the season and evaluated, providing an overview of determinants of sensory quality from each of the three important grapefruit growing regions in the United States.

2. Materials and methods

2.1. Fruit sampling

During a nine-month period grapefruit were obtained on seven separate dates from commercial packinghouses located in either California, Texas or Florida to span nearly a year of grapefruit production for these three states (Table 1). The origin of the fruit on a specific date depended on whether the fruit were in season for that state. Only on the final harvest were fruit available from all three states at the same time. The varieties used were either Marsh Ruby (California), Super Red (California), Rio Red (Texas), or Marsh Ruby (Florida), the goal being to provide a diverse sampling of fruit from three locations throughout the season rather than attempting to restrict the entire test to a single variety. Fruit were harvested at commercial maturity with the size ranging from 26 to 40 (fruit per 28.1 L box, individual fruit weights approximately 340 g). The date of packing was within one week of the pick date in all but harvest 2 where there was a 22 d differential. Standard commercial degreening protocols were used prior to packing (if needed) that ranged in duration from 1 d to 12 d. At final packing the fruit were treated with postharvest fungicides and coated with a carnauba-based wax as per standard commercial protocols and placed into cold storage. The time spent in cold storage prior to and after shipment to the Kearney Agricultural Research and Extension Center (KARE) in Parlier, CA ranged from 0 to 17 d, with the average being 5 d. Fruit were shipped in standard citrus cartons by two-day air freight and stored at 12 °C until the day of evaluation.

2.2. Sensory evaluation

Grapefruit were removed from cold storage and allowed to warm to 20 °C on the day of evaluation. The top and bottom of each fruit was numbered, the fruit sliced in half equatorially and each section placed into a small cup with the cut end facing up. Four sections were then cut and prepared for easy removal at 90° angles from each other. Toothpicks of two different colors were inserted into each cut segment with the opposing segments being the same color. Six grapefruit halves were presented to each panelist per day of evaluation. Cups containing the grapefruit halves were labeled with random three-digit numbers and the cups presented in random order. Sensory evaluation was conducted at KARE in a dedicated building equipped with sensory booths to help isolate the panelists from outside interruptions and with red lighting in the booths to lessen the potential impact of differing peel color on the results. Sensory panelists were employees of either KARE or the nearby USDA San Joaquin Valley Agricultural Sciences Center (USDA-SJVASC) and most had prior experience in the sensory evaluation of other horticultural commodities. There were 20 panelists per each day of testing with the number of evaluation days per harvest depending on the number of fruit sources (states) being evaluated. For instance, if three states were evaluated the states would be equally represented in each of three days. Panelists were asked to sample at least two opposing segments per fruit and to taste the other two prepared segments if needed. Instructions were given to rinse the mouth with water between samples. For each grapefruit sample ratings were given on overall likeability using a 9-point hedonic scale. In addition, intensity of grapefruit flavor, tartness, sweetness, bitterness and juiciness were evaluated by placing a mark on a 150 mm line scale. Panelists were then asked to evaluate whether they would purchase the grapefruit if it were available at a reasonable price where they normally shop by marking one of five choices ranging from “definitely would not purchase” to “definitely would purchase.” In addition, panelists were asked how the particular sample would influence how they purchase grapefruit in the future by marking one of three choices ranging from “I would purchase less often” to “I would purchase more often.” As a part of the profile for each panelist the degree that they liked grapefruit and preferences for tartness and bitterness in grapefruit were also recorded.

2.3. Determination of fruit analytical parameters

Grapefruit halves (minus two to four segments) remaining from the sensory testing were squeezed by hand to acquire juice, filtered through a screen and the juice frozen at −20 °C in numbered tubes for later analysis. This enabled analytical fruit quality parameters to be acquired for every tasted sample. After thawing, soluble solids was determined using an electronic refractometer (Atago PAL-1, Tokyo, Japan) and titratable acidity by titration with 0.1 mol L^{-1} sodium hydroxide to an endpoint of 8.2 using an automatic titration system (Mettler T50A, Columbus, Ohio, USA). Values of SSC/TA ratio were then determined as well as the California Standard (CAstd) which is calculated as: (SSC-(4*TA))*16.5. The CAstd is a recently-developed maturity standard for navel oranges that arose from the concept known as BrimA, shorthand for brix minus acid (Jordan et al., 2001; Obenland et al., 2009).

2.4. Statistics

The data for the statistical analysis consisted of 1320 observations of 29 variables measuring different aspects of grapefruit chemical composition, sensory characteristics, and panelist purchase intent. The statistical analysis consisted of a step-by-step implementation of different methods also referred to as Knowledge Discovery in Databases