Relationship between sugar content and Brix degrees in strawberry.

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Abstract

We have evaluated eight varieties of strawberry, seven short-day and one day-neutral, for two years with two sampling dates and two repetitions by date. The fruits were collected and evaluated at the ripe stage. Contents of sucrose, glucose, fructose, °Brix, citric acid, ascorbic acid and malic acid in the fruit were measured. The data were analyzed using principal component analysis (PCA) and Pearson correlations. The PCA groups most of the variability in the first component (62.2%). This component shows a positive relationship between the Brix degrees, sugars and acids (higher values of this component indicate increased Brix degrees, and the contents of sugars and acids). The second component collects 20.74% of the variability, which is mainly related to differences in the sugars/acids ratio. The plotting of the factor barycenter over the two principal components of PCA analysis shows that second harvest date has a higher content of sugars, organic acids and °Brix. With regard to varieties representation over PCA, the good quality variety "Primoris" is characterized by a high sugar content and a balanced total sugars/acids ratio. Moreover, the variety of day-neutral "Nieva" shows the lowest values of sugars, acids, °Brix and total sugars/acids ratio. Featured correlations exist between ascorbic acid content and glucose and fructose content (R² = 0.82 and 0.81, respectively). The °Brix shows a relative correlation with the total sugars content (R² = 0.74). In conclusion, the genotype has large effect in the content of sugars and organic acids. Therefore, the high content of sugars and acids and a balanced relationship between them could be used as a quality trait for the selection of strawberry varieties. On the other hand, °Brix is relative good measure of the total sugar content.

Keywords: fruit quality, organic acid, vitamin C, fructose, glucose, titratable acidity, Total soluble solids.

INTRODUCTION

The changes in composition of sugars and organic acids and volatile compounds during ripening process play a key role in the development of the taste of a fruit. Sweetness is one of the desirable characteristics in commercially grown strawberry.
Fragaria ×ananassa Duch.), and lack of it has been associated with low soluble solids content (SSC) and/or high titratable acidity (TA) (Jouquand and Chandler, 2008). Organic acids are involved in the sourness, but an adequate content of them contributes to the stabilization of strawberry color (Sistrunk and Cash, 1973). In consequence, a balanced sugar/acid ratio is desirable.

Therefore, sugars and acids of strawberries are regarded as significant quality factors. Nevertheless, fruit ripening is a complex process influenced by several factors, and variations in the composition of individual sugars and acids related to cultivar and maturity stage have been reported (reviewed in Mahmood et al 2012), being the cultivar a major determinant of quality (Pelayo-Zaldívar et al., 2005).

Spain is the second largest source of fresh strawberry in the world and the world’s largest exporter of this berry, annually shipping approximately 285 thousand tons in 2015 (FEPEX, 2016) to international destinations, mainly in Europe. Strawberry is highly perishable fruit and for that reason, longer preservation of color and other attributes is together with flavor an important issue for producers of southern Spain.

Minimum and preferred Brix indices (°Brix) are generally used by food dealers to evaluate ripeness and quality, as °Brix values are relatively straightforward to measure and give an indication of total soluble solids. Although there are discrepancies, some authors have reported that °Brix can be considered a good indicator for the evaluation of sugar content of some cultivars (Kallio et al., 2000). The aim of this study is to determine the influence of genotype and harvest time on fresh strawberry composition, as well as to analyze the correlation between the different parameters and °Brix in order to establish the suitability of this value for assessing quality in the context of a strawberry genetic breeding program in South Spain.

MATERIAL AND METHODS

Experimental data
Six strawberry cultivars (“Antilla”, “Niebla”, “Nieva”, “Primoris”, “Rábida”, “Sabrina”) and two breeding lines (A8-30-2 and A10-48-3) were tested for two years, with two repetitions each year and two harvest dates. The trial was conducted in Gibraleón, Huelva, Spain. The contents of sucrose, glucose, fructose, citric acid, vitamin C, malic acid and degree Brix (°Brix) of the fruits were measured. Variables total sugar content (glucose + fructose + sucrose), total acid content (citric acid + malic acid), total sugar plus total acids and the ratio of total sugar and total acids were calculated from the above data.

Statistical analysis
Principal component analysis with FactoMineR package (http://factominer.free.fr) was carried out to reduce the dimensionality and to group variables that show a high correlation. Correlations of the variables with the first two components were plotted. The different levels factors (variety, year and date of collection) were represented on the two dimensions generated by the first two components. Bivariate Pearson correlations were calculated to estimate the specific relationships between pairs of variables.

RESULTS AND DISCUSSION

PCA analysis
The variability explained by the first two components was above 80% (82.94%) and therefore only the results of these two dimensions are described. The correlation between the variables and the first two components are shown in Figure 1. Component
1 (x axis) contains much of the variability of $^\circ$Brix and sugars and acids in general. A greater value in that axis corresponds to a higher content of $^\circ$Brix, sugars and acids. The $^\circ$Brix are more closely correlated with sugars in general. Contents of each of the monosaccharides are more correlated with the disaccharide sucrose. In a similar way, the content of the different acids is highly correlated with each other and, to a lesser extent, with $^\circ$Brix and sugars in general.

Component 2 (y axis), mainly explains the sugars to acids ratio, which is related to the degree of ripeness. This dimension increases with decreasing acid content, and increasing sugar content and sugar to acids ratio.
The levels of the factors "cultivar", "year" and harvest date were plotted into the PCA components 1 and 2 (Figure 2). In relation with the x axis, cultivar "Primoris" has high values of °Brix, sugar content and acid content independently of the degree of maturity. Berries picked at the second date each year had higher scores on PCA component 1 than berries picked at the first date, indicating higher °Brix. However, the scores on component 2, mainly related to the sugars to acids ratio is different for both dates depending on the year. In year 1 fruit picked on the first date had a higher score (indicating a greater degree of maturity) than the harvested in the second one. By the contrary, berries picked at the second date in the second year were more physiologically mature that those picked at the first date. The scores of cultivars "Antilla" and "Nieva" on component 2 indicate that both have the most extreme degrees of ripening when picked (high and low, respectively) as that dimension explains the sugars to acids ratio, which is related to the physiological maturity.

Table 1 shows the bivariate Pearson’s correlations between pairs of variables studied in this work. Fructose and glucose contents show an outstanding correlation (r² = 0.98), while °Brix best correlates with total sugar content in accordance to that described previously by Kallio et al. (2000), but there are other variables which also correlate though in a lesser extent.

CONCLUSION

The genotype has large effect in the content of sugars and organic acids. Therefore, the high content of sugars and acids and a balanced relationship between them could be used as a quality trait for the selection of strawberry varieties. On the other hand, °Brix is relative good measure of the total sugar content.

ACKNOWLEDGEMENTS

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**Literature cited**

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Figure 1: PCA score plot of TSC, total sugar content to total acid content ratio; Suc, sucrose content; TAC, total sugar content; TSAC, total sugar and acid content; Glu, glucose content; Fru, fructose content; VitC, vitamin C content; CAC, citric acid content; TAC, total acid content; MAC, malic acid content and °Brix. Dimensions (dim) 1 and 2 explain 82.94% of variation.
Figure 2: PCA score plot of the levels of factors “cultivar”, “year” and “harvest date”. The labels “⬆️ sugar, ⬇️ acid, ⬆️ºBrix” below x axis indicate increasing values of the variables for increasing scores on this dimension. The labels “⬆️ sugar/acid ~ ⬆️ maturity index, ⬆️ sugar, ⬇️ acid” on the right side of y axis indicate increasing values of the variables for increasing scores on this dimension.
Table 1: Bivariate Pearson's correlation coefficients. Variables: sucrose content (SC); glucose (GC); fructose content (FC); total sugar content (TSC); citric acid content (CAC); malic acid content (MAC); vitamin C content (vitC); total acid content (TAC); total sugar plus total acids (TSAC); ⁰Brix; and ratio of total sugar and total acids (SA ratio).

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