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EFFECT OF SUGAR TYPE AND CONCENTRATION ON PERCEPTION OF TOMATO SWEETNESS

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Abstract. **Coarse chop tomato puree was spiked with two levels of glucose, fructose, glucose/fructose, or sucrose and presented to a trained descriptive panel for flavor analysis. The resulting sugar levels of the tomato puree were increased 0, 2 or 3 percent, respectively. Six to eight panelists rated 5 aroma, 6 taste, and 3 aftertaste descriptors on a 15 cm unstructured line scale. Panelists detected significant differences ($P < 0.15$) for overall aroma, sweetness and sourness intensities. Overall aroma intensity was higher and overall taste generally lower in unspiked controls and samples with elevated glucose. Sweetness intensity in samples with elevated sucrose or fructose was rated higher, and sourness rated lower, than controls or samples with added glucose. Tomato samples spiked with fructose or sucrose were perceived by the panelists to be similar in sweetness and both were rated sweeter than controls or samples with added glucose. Samples with the higher concentrations of sugars were generally perceived to be sweeter and less sour than those with less sugar. In view of these results, breeding or engineering tomatoes to have higher levels of sucrose at the expense of fructose and glucose would not seem to improve flavor quality.**

Flavor of fruits and vegetables is generally attributed to aroma factors, detected by the nose, and taste factors detected by the tongue (DeRovira, 1996). Taste factors include sweetness, attributed to sugars, and sourness, attributed to acids. There are other taste factors including astringency and bitterness that are also detected by sensors in the tongue. Presence of aroma compounds can influence perception of sweetness and sourness (Baldwin et al., 1998), while presence of sugar and acids can potentiate perception of aromatics (Malundo et al., 2000). This type of interaction is little understood and complicates sensory studies.

The major sugars in tomato are glucose and fructose in almost equal amounts, with little or no sucrose in ripe fruit (Baldwin et al., 1991). Breeders and molecular biologists are interested in increasing the levels of sucrose in order to make a sweeter tomato. However, it has been established that fructose is sweeter than sucrose, and both sugars are sweeter than glucose. Sucrose equivalents were used to show the relative sweetness of these sugars, with coefficients of sucrose, glucose and fructose as 1, 0.74, and 1.73, respectively (Koehler and Kays 1991). The question is, then, would a tomato with high levels of sucrose, at the expense of fructose and glucose, taste sweeter than one with comparable levels of fructose and glucose in combination, or fructose alone. In this study we explore this question by doing sensory analysis of tomato homogenate to which we added various levels of these three sugars.

Materials and Methods

Tomatoes were purchased from a local grocery store. A homogeneous tomato mixture was made from 10 fruit by slicing the tomatoes into 0.25 inch wedges and then cutting into halves. These pieces were coarsely chopped in a Cusinart (East Windsor, NJ) with 10 pulses. The tomato puree was weighed out into 200g portions, to which various sugar solutions were added. The base solutions were 16% sucrose, glucose, fructose, or a glucose/fructose mixture (equal levels of both sugars) in water. The same volume of water/sugar solutions were added to all samples. The levels that were added to tomato puree resulted in 0, 2 and 3% added sucrose, glucose, fructose, or glucose/fructose (0, 1, and 1.5% of each of glucose and fructose for a total of 0, 2, and 3% added sugar, v/w) to the base sugar levels in the tomato puree (2-3% total sugar). Once the solutions were added, the tomato was pulsed in the Cusinart an additional 5 times and immediately served to the panel.

The samples (approximately 30 ml) were presented to a descriptive analysis panel in 113 ml cups with lids. A 150 mm unstructured line scale was used to evaluate the following descriptors: overall aroma intensity, tomato green aroma, tomato ripening aroma, earthy aroma, tomato sweet aroma, overall taste intensity, sweet taste, sour taste, tomato ripening taste, bitter taste, astringent taste, overall aftertaste, bitter aftertaste, and sour aftertaste. The experiment was repeated three times.

The panel consisted of 6 to 8 members who were trained using sucrose, citric acid, sodium chloride, and caffeine solutions to rate sweetness, sourness, saltiness, and bitterness intensity (Table 1). Other samples were brought in, such as grape juice, for other basic taste attributes like bitterness, for example. The panel also developed aroma descriptors for tomato. Individual sample attributes were measured on an unstructured 15 cm line scale.

Sample ratings were analyzed using PROC ANOVA and Least Significant Difference (LSD) of the SAS (Statistical Analysis System, Cary, NC) at $P < 0.15$ unless otherwise specified.

Results

The three experiments yielded similar results and were averaged together for presentation in this paper. Addition of sugars for an additional 2% sugar level influenced several taste and aroma descriptors (Fig. 1). For taste descriptors, overall taste showed differences ($P = 0.05$) with samples

Table 1. Basic tastes training method.

Scale value	Sweetness % sucrose	Sourness % citric acid	Saltiness % sodium chloride	Bitterness % caffeine
2	2	0.05	0.20	0.05
5	5	0.07	0.75	0.07
10	10	0.15	1.00	0.15
15	16	0.20	1.50	0.20

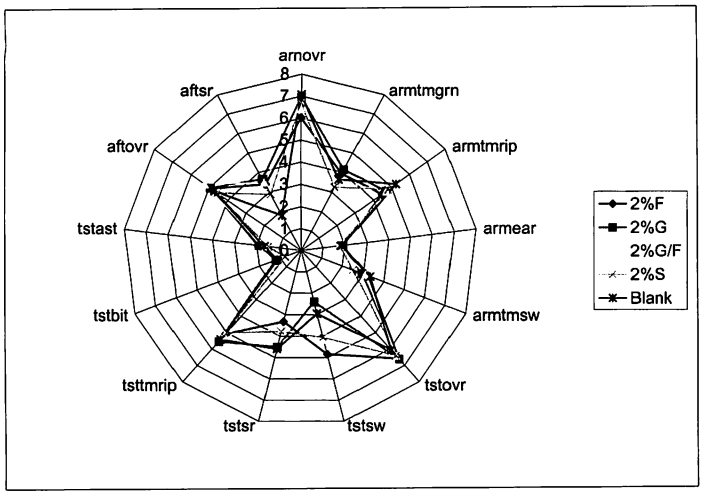

Figure 1. Intensity ratings for overall aroma (arnovr), tomato green aroma (armtmgrn), tomato ripe aroma (armtmrip), earthy aroma (armear), tomato sweet aroma (armtmsw), overall taste (tstovr), sweet taste (tstsw), sour taste (tstsr), tomato ripe taste (tsttmrip), bitter taste (tstbit), astringent taste (tstast), overall aftertaste (aftovr), and sour aftertaste (aftsr) of tomato puree samples spiked with added 0% (control or Blank) or 2% levels of fructose (F), glucose (G), glucose + fructose (G/F), or sucrose (S).

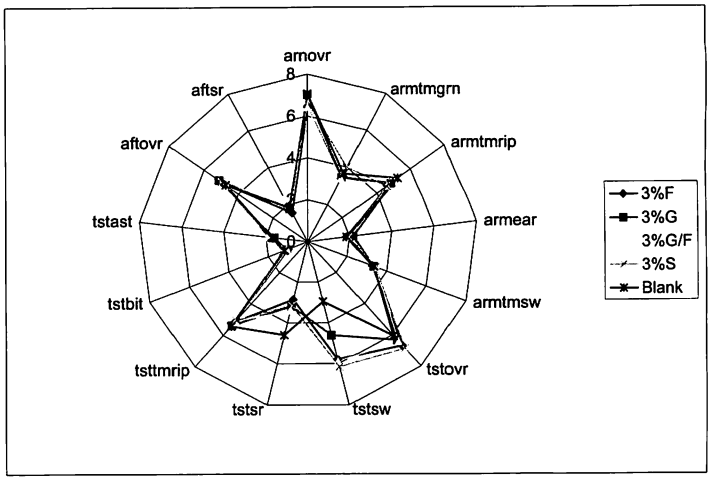

Figure 2. Intensity ratings for overall aroma (arnovr), tomato green aroma (armtmgrn), tomato ripe aroma (armtmrip), earthy aroma (armear), tomato sweet aroma (armtmsw), overall taste (tstovr), sweet taste (tstsw), sour taste (tstsr), tomato ripe taste (tsttmrip), bitter taste (tstbit), astringent taste (tstast), overall aftertaste (aftovr), and sour aftertaste (aftsr) of tomato puree samples spiked with added 0% (control or Blank), or 3% levels of fructose (F), glucose (G), glucose + fructose (G/F), or sucrose (S).

spiked with fructose and sucrose being perceived as having more intense overall taste compared to controls. For sweetness intensity, samples spiked with fructose, glucose + fructose, or sucrose were rated higher than those with added glucose or controls ($P = 0.0002$). For sourness, controls were found to be more sour than any of the spiked samples ($P = 0.002$). Ripe tomato taste was found to be higher for controls than for samples spiked with sucrose, and sour aftertaste was found to be higher for glucose-spiked samples than controls. For aroma descriptors, overall aroma was found to be highest in controls, which was different than all the spiked samples except for those spiked with glucose. Glucose-spiked samples were found to be higher in overall aroma than samples spiked with fructose or glucose + fructose. Tomato ripe aroma was found to be higher for controls compared to all the spiked samples. It seems that making the tomatoes sweeter with added sugar, especially the sweeter sugars (fructose and sucrose) detracted from the panelists' perception of aroma.

Addition of sugars for an additional 3% sugar level (Fig. 2) did not influence any aroma descriptors. Overall taste, however, was significant ($P = 0.02$), with sucrose- spiked samples having more intense overall taste than those spiked with glucose/fructose, glucose, or the control; and fructose spiked samples were rated higher in this descriptor than those spiked with glucose, or controls. Sweetness was rated higher in fructose-, glucose + fructose-, and sucrose-spiked samples compared to those spiked with glucose or controls, while samples spiked with glucose were also rated higher than controls ($P = 0.0001$). Sourness, conversely, was rated highest in the control compared to all spiked samples, and those spiked with glucose + fructose were rated more sour than fructose-spiked samples.

When the 2 and 3% treatments are compared for effect on taste descriptors, overall taste was more intense in samples with 3% sucrose than those with 2% sucrose and glucose, 3% glucose and glucose + fructose, or controls (Fig. 3). Samples with 2% fructose were rated higher in overall taste than those with 2 and 3% glucose or controls. Sweetness was more intense in samples with 3% sucrose than those with 2% fructose, glucose, glucose + fructose mix, and sucrose; 3% glucose; or controls. Sweetness was also rated higher in samples with 3% fructose and glucose + fructose mix than for 3% glucose; 2% glucose, glucose + fructose mix, and sucrose; or controls. Finally, sweetness was higher in 3% glucose, and 2% fructose, glucose + fructose mix, and sucrose compared to controls. Sourness intensity was higher in controls compared to all spiked samples. Sourness was also higher in samples with added 2% glucose than 3% fructose, sucrose, and glucose; or 2% sucrose. Furthermore, added 2% glucose + fructose was rated higher in sourness than 3% fructose. Overall aftertaste was higher in 3% glucose and 2% glucose + fructose-spiked sam-

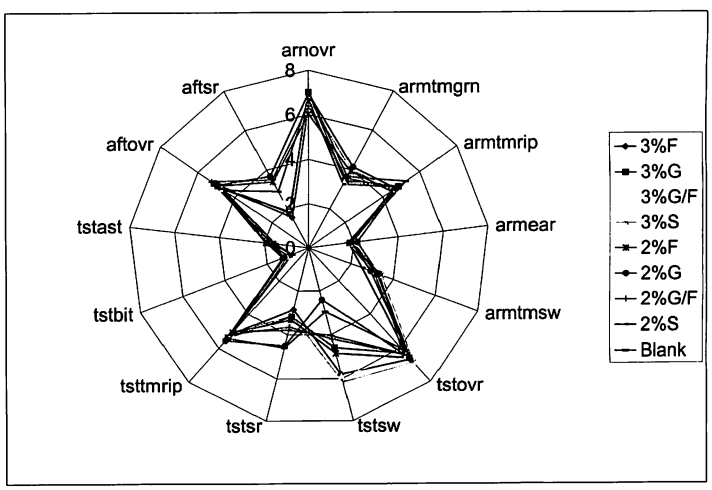

Figure 3. Intensity ratings for overall aroma (arnovr), tomato green aroma (armtmgrn), tomato ripe aroma (armtmrip), earthy aroma (armear), tomato sweet aroma (armtmsw), overall taste (tstovr), sweet taste (tstsw), sour taste (tstsr), tomato ripe taste (tsttmrip), bitter taste (tstbit), astringent taste (tstast), overall aftertaste (aftovr), and sour aftertaste (aftsr) of tomato puree samples spiked with added 0% (control or Blank), 2%, and 3% levels of fructose (F), glucose (G), glucose + fructose (G/F), or sucrose (S).

ples compared to those with added 3% glucose + fructose. In the combined data set, many aroma descriptors showed significant differences. Overall aroma was determined to be more intense in the control and samples with 3% glucose than in samples with added 2 and 3% fructose or 3% glucose/fructose mix. Tomato green aroma was rated highest in samples with added 3% sucrose compared to those with 2% sucrose or 3% glucose/fructose mix. Tomato ripe aroma was perceived to be highest in the control compared to all spiked samples. And finally, tomato sweet aroma was higher in samples with 2% fructose compared to those with 2% sucrose.

When both sugar levels are averaged, overall taste is rated higher in fructose- and sucrose-spiked samples than in glucose-spiked puree or controls ($P = 0.08$). Samples spiked with glucose + fructose were found to have more intense overall taste than controls as well. Sweetness was rated highest in fructose, glucose + fructose and sucrose-spiked samples than for those spiked with glucose, which, in turn, was rated sweeter than controls ($P = 0.001$). Sourness was rated higher in controls than glucose-spiked samples which were rated more sour than those with added fructose. For overall aftertaste, samples with added glucose were rated highest and were different from controls. For aroma, overall aroma was rated most intense in controls which were more intense than those spiked with sucrose, fructose, or the glucose + fructose mix. Tomato ripe aroma was also found to be most intense in controls, which were rated higher than fructose, the glucose + fructose mix, or sucrose.

For sugar levels, samples with added sugars (2 and 3% added sugar to the base level in the tomato puree, v/w) were rated higher in overall taste than controls (0% added sugar). Not surprisingly, sweetness intensity was found to be highest in samples with added sugars at 3%, followed by 2%, followed by controls. Conversely, sourness intensity was perceived to be greater in controls compared to samples with 2 and 3% added sugars. Overall aftertaste was rated higher for samples spiked with 2% sugar levels than for controls.

Generally, addition of sugars raised perception of sweetness and decreased perception of sourness, as expected. However, equal levels of fructose, sucrose, or the glucose + fructose mix were equally effective at both the 2 and 3% levels in this respect. Sucrose-spiked samples were rated higher in overall taste, however, than samples with added glucose + fructose mix at the 3 but not the 2% level. Nevertheless, there does not seem to be much advantage to increasing levels of sucrose in lieu of increasing the normal ratio of fructose and glucose or fructose alone in tomato breeding or genetic engineering programs. Also, addition of extra sugar appeared to result in reduced perception of aromas. This was especially true for the sweeter sugars, fructose and sucrose.

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INTERRELATIONSHIP OF SENSORY DESCRIPTORS AND CHEMICAL COMPOSITION AS AFFECTED BY HARVEST MATURITY AND SEASON ON FRESH TOMATO FLAVOR

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Abstract. **Tomatoes (*Lycopersicon esculentum*), harvested at breaker and red-ripe stages from two different locations and two different seasons, were evaluated for flavor characteristics. Tomato flavor was studied using a trained sensory panel and instrumental and chemical techniques to measure sugars, acids, and aroma volatiles. The tomatoes harvested at the red-ripe stage were rated higher for fruitiness and tomato-like descriptors and lower in pH than those harvested at the breaker stage. The correlations of sensory descriptors with volatile and non-volatile flavor measurements were different for the two crops. The fall crop (Bradenton, FL) had more significant correlations than the spring crop (Homestead, FL). Tomatoes,**

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