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Potential for Increasing Tomato Flavor via Increased Sugar and Acid Content[1]

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Abstract. **High sugar and acid F_1 hybrids of tomatoes (*Lycopersicon esculentum* Mill.) were rated higher in sweetness, sourness, and overall flavor intensity than the standard cultivar 'Cal Ace'. Titratable acidity and soluble solids content were responsible for most of the differences in overall flavor intensity among these hybrids, their parents, and 'Cal Ace'. The results support the idea that improved tomato flavor can be achieved via increased sugar and acid content.**

There seems to be little doubt that sugars and acids not only contribute to the sweetness and sourness of tomatoes, but are also major factors in overall flavor intensity (1,4). Since lack of flavor is a common complaint about fresh market tomatoes, increases in sugar and acid content could make a contribution to improved tomato flavor. This study was designed to evaluate the impact on flavor of high concn of sugars and acids in specially developed F_1 hybrids.

Materials and Methods

A high sugar breeding line, 75T81-4-1, which was developed from a high solids line resulting from an interspecific cross (3), was crossed with 3 high acid lines from divergent sources. These were: 1) Accession 76, High Crimson/Warecross from South Carolina; 2) Accession 81, PI 263713, from Puerto Rico; and 3) Accession 250, Hi Acid from New Jersey. The resulting 3 F_1 hybrids, the high sugar parent, one high acid parent (Acc. 81), and 'Cal Ace' were grown in the field at Davis, California using typical cultural practices.

Table-ripe fruits were picked the day before evaluation. Excess fruits were picked and sorted, so only fruits in good condition with uniform color were used. At least 15 fruit per line replication were diced (about 1 cm^3) and thoroughly mixed for sensory and compositional analyses.

Sensory evaluation. Panelists were initially screened for taste acuity and trained to use the scoresheet. Scoring was done as in previous work (4) for the flavor characteristics of sweetness, sourness, "tomato-like," and overall flavor intensity. Each line was evaluated 6 times, presented as 3 samples per day over 12 days (August 8 to 23) in a random design. For each characteristic, between-judge correlations were calculated for the 15 judges with complete data and 7 were selected for their better between-judge correlations. The sensory data was normalized (2) and used for analyses of variance and regression analysis with the compositional data.

Compositional analyses. Soluble solids content (SSC) was determined with a bench top model ABBE-3L Bausch & Lomb refractometer. Reducing sugars were determined by using Somogyi's (6) method. Titratable acidity was determined by titrating serum to pH 8.1 with 0.1 N NaOH; pH was measured with a Corning digital 109 pH meter.

Results and Discussion

The F_1 hybrids and parental lines had significantly higher levels of soluble solids and titratable acidity than 'Cal Ace' (Fig. 1), which was included as the control cultivar. The reducing sugars content was significantly greater for 2 of the hybrids. The pH for all hybrids and parents was lower than that of 'Cal Ace.'

Generally, the F_1 hybrids had greater sweetness, sourness, tomato-like flavor, and overall flavor intensity than 'Cal Ace' (Fig. 2). Accession 81 was not different for sweetness. Neither of the parent lines nor F_1 (76) were different than 'Cal Ace' for "tomato-like" flavor.

There was a strong correlation between sweetness and soluble solids content and reducing sugars; these 2 components were also highly correlated (Table 1). Stepwise regression showed that soluble solids describe much (65%) of the sweetness variation (Table 2). The hybrids F_1 (76) and F_1 (250) were judged as equally sweet, but their composition was very different. F_1 (76) had higher soluble solids and reducing sugars and much higher acidity and lower pH than F_1 (250). The effect of the higher sugars may have been offset by the higher acidity. F_1

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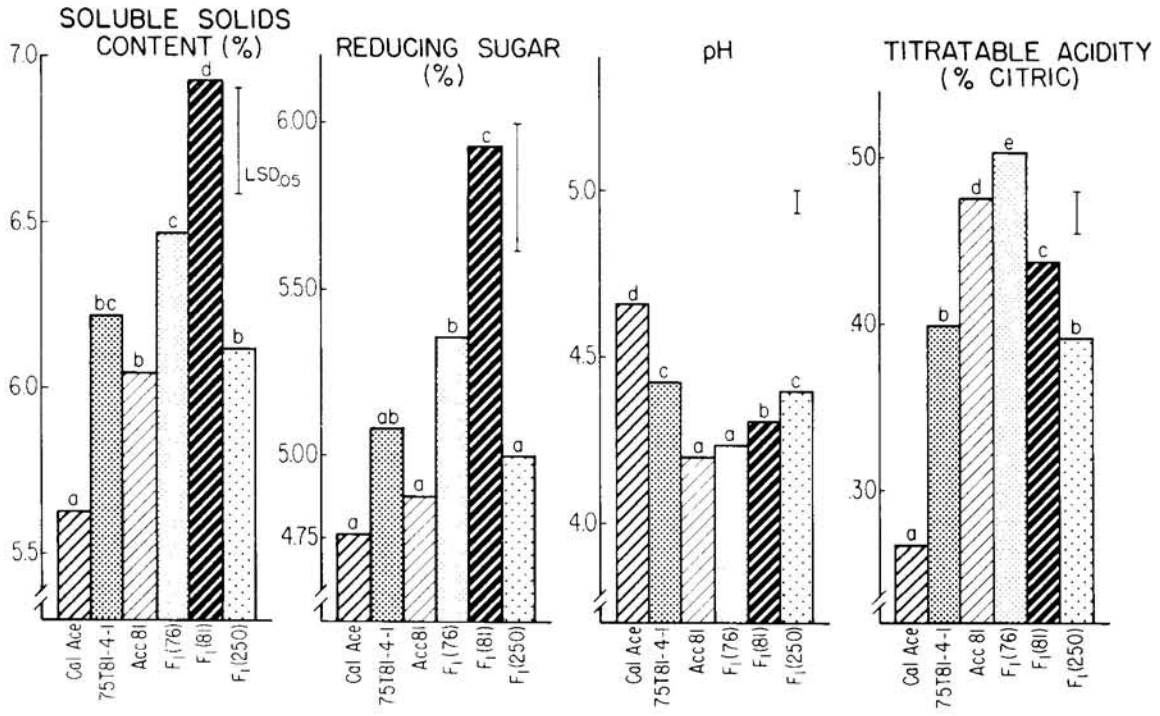

Fig. 1. Mean composition of 'Cal Ace', the high-sugar parent (75T81-4-1), one high-acid parent (Acc. 81), and 3 high-sugar and high-acid hybrids. Means with common letter do not differ significantly at the 5% level.

(76) had significantly greater overall flavor intensity than F_1 (250).

Sourness was highly correlated with titratable acidity and pH, which were highly correlated with each other (Table 1). Stepwise regression analysis indicated that titratable acidity was most important to the differences in sourness.

The components measured accounted for a small portion of the "tomato-like" differences (Table 2). It is assumed that differences in "tomato-like" are related to variation in aroma which is attributable to volatile compounds. Detailed evaluation of the volatile compound composition of the parents and hybrids is under way.

Statistically, there were 3 groups for overall flavor intensity (Fig. 2). 'Cal Ace' was distinctly lowest. The high sugar parent (75T81-4-1) and F_1 (250) were the intermediate group and have similar sweetness and sourness scores and composition (Fig. 1). The other 3 lines formed the high intensity group. Generally, overall flavor had the highest correlation with sourness, titratable acidity, and pH (Table 1). The F_1 (81) hybrid was the exception in that it was in the high overall flavor intensity group, but had only intermediate sourness. In this hybrid higher overall intensity appeared to be a result of much greater sweetness. Titratable acidity and soluble solids content were responsible for most of the differences in overall flavor intensity (Table 2).

This study supports the previous observation that soluble solids and acids are key components in the overall flavor intensity of tomatoes (4). It appears clear that tomato breeders interested in high quality should intensify efforts to breed cultivars with higher levels of soluble solids and acids. An increase in soluble solids will be difficult to achieve because of the negative relationship between solids content and yield (5).

There appeared to be a large heterotic effect for soluble solids content in the F_1 hybrids. However, most of this increased soluble solids in the F_1s is attributable to lower yield. It is possible that because the F_1s did not have as good a fruit load as the parental lines, more photosynthate was available for storage in the fruits.

The hybrids used in this study were developed without regard to yield potential or horticultural characteristics. Although

Table 1. Correlation matrix for flavor characteristics and components.

	Sourness	Tomato-like	Overall	pH	Titratable acidity	Soluble solids content	Reducing sugars
Sweetness	.10	.68**	.43**	-.24	.27	.76**	.64**
Sourness		-.03	.87**	-.88**	.89**	.30	.10
Tomato-like			.25	.04	.01	.52**	.42*
Overall				-.85**	.88**	.60**	.38*
pH					-.95**	-.42*	-.29
Titratable acidity						.51**	.30
Soluble solids content							.78**

*,**Correlations significant at the 5% (*) and 1% (**) level.

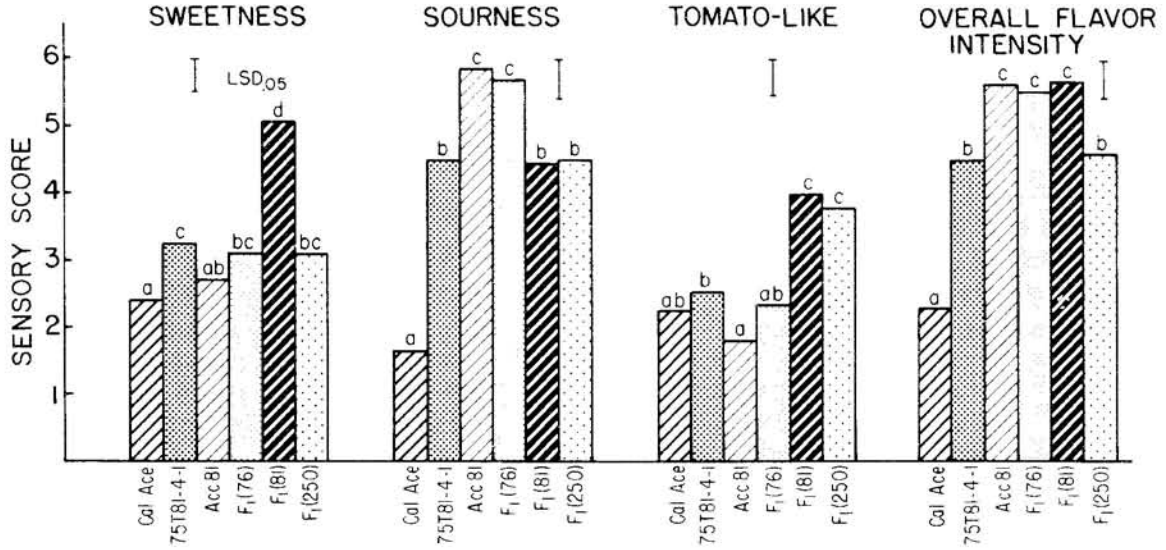

Fig. 2. Mean normalized sensory scores of 'Cal Ace', the high-sugar parent (75T81-4-1), one high-acid parent (Acc. 81), and 3 high-sugar, high-acid hybrids. Means with common letter do not differ significantly at the 5% level.

Table 2. Abbreviated stepwise regression analysis of fruit components and flavor characteristics.

Flavor characteristic	Variable[z]	R^2
Sweetness	SSC^2	.59
	SSC	.65
Sourness	TA	.79
	TA × SSC	.83
	TA^2	.85
Tomato-like	pH × SSC	.35
Overall	TA × SSC	.78
	pH	.80

[z]SSC = soluble solids content, TA = titratable acidity.

their flavor quality was excellent, many of their other characteristics were unacceptable for a cultivar. The characteristics of the high soluble solids parent indicate that potential does exist to develop a cultivar with superior flavor quality and acceptable horticultural and yield characteristics.

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