CHEMICAL AND SENSORY QUALITIES OF FRESH MARKET TOMATOES

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ABSTRACT

Chemical and sensory attributes of table-ripe tomatoes harvested at different stages of maturity were evaluated. Intensities of nine sensory attributes were similar in table-ripe tomatoes harvested at the "mature-green" and "breaker" stages. Intensities of "sweetness," "saltiness" and "fruity-floral" flavor were higher in tomatoes harvested at the "table-ripe" stage than at earlier stages of maturity. Desirability of tomatoes was closely associated with the fruity-floral attribute. Variations of sensory attributes were due to volatile and nonvolatile components. The amount of the variation explained by the components generally increased when the areas of the volatile peaks were converted to logarithms for the stepwise regression analysis.

INTRODUCTION

MANY CONSUMERS comment, especially after eating vine-ripened summer tomatoes, that winter tomatoes lack desirable sensory qualities. Sensory panelists have noted differences in flavor of fruit ripened on and off the plant (Kader et al., 1977) and preferred fruit ripened on the plant (Bisogni et al., 1976). In seeking objective ways to quantify sensory attributes, Kader et al. (1977) and Bisogni et al. (1976) analyzed the composition. Bisogni et al. (1976) found that the titratable acid content correlated with "acidity," and the soluble solids content with sweetness, "overall quality" and "flavor." Kader et al. (1977) found that pH correlated with "sourness," the reducing sugar content with sweetness and the volatiles with "off-flavor." Similar findings were made by Stevens et al. (1977) when analyzing only tomatoes ripened on the plant. Stevens et al. reported that large percentages of the variations of sensory attributes could be accounted for by volatile and nonvolatile components. These studies indicate that sensory attributes can be quantified by objective measurements.

We studied the sensory attributes of 'Walter' cultivar tomatoes, which are grown extensively in Florida and Mexico during the winter months. The intensities of sensory attributes of ripe tomatoes harvested at different stages of maturity were determined and quantified by objective measurements. Maturity of fruit was determined objectively to minimize the range and deviations that occur in subjective selections.

EXPERIMENTAL

TOMATOES were picked randomly from 'Walter' cv. plants that were grown on trellis and plastic mulch by a commercial grower. Harvest dates of mature-green, breaker (incipient-ripening) and table-ripe fruit were scheduled so that fruit of all maturities would be table ripe on the same day.

Fruit selection of desired maturity was made with a light transmittance instrument (Worthington et al., 1976). Fruit having a ΔOD (510–600 nm) of 0.100–0.300 were used as mature-green, those with a reading of 1.100–1.500 were used as breaker and those with a ΔOD (600–690 nm) of 2.000–2.400 were used as table-ripe. Maturity selection by this method avoided the use of extremely young (immature) fruit as mature-green and minimized the variation in the ripeness of table-ripe fruit among and within samples. Mature-green and breaker fruit were ripened at 20°C in a sealed drum which had humidified air passed through it at a rate of 9 L/kg-hr. Table ripe fruit harvested as mature-green, breaker and table-ripe are designated MG, B and TR, respectively, in this paper.

Tomatoes, ten per sample, were sliced to 6 mm thickness, and slices were selected randomly for analyses of sensory attributes, composition and volatiles. This study was repeated with samples from each of six harvests during July and August.

Sensory analysis

Five to seven semi-trained panelists evaluated the flavor of each sample by rating the intensities of nine flavor components: sweetness, acidity, saltiness, grassiness, stemminess, fruity-floral flavor, mustiness, bitterness and astringency. The ballot was a series of vertical seven-point scales (0 = none, 7 = very intense) which the panelists marked with horizontal lines to indicate intensities. Each sample was also rated on a seven-point scale for "flavor desirability." Water solutions of sucrose, citric acid, sodium chloride and caffeine were used as guides in rating sweetness, acidity, saltiness and bitterness, respectively. During preliminary sessions, the panelists agreed upon the flavor components to be evaluated and the order in which they would appear on the ballot.

We used a balanced incomplete block design of two units per block to evaluate the three maturities of each harvest. A separate session was scheduled for each of the three incomplete blocks per harvest during a 2-day period. The sequence of serving samples within blocks and blocks within harvests was balanced over the six harvests. The incomplete block design was preferred because of the complexity of tomato flavor and the carryover from sample to sample.

Compositional analysis

Soluble solids content was determined with a bench-top model Bausch and Lomb Abbe-56 refractometer. The pH was determined with a Beckman pHasar-1 digital pH meter and the titratable acid was determined by titrating the tomato juice to pH 8.1 within 0.1N NaOH.

Volatiles

A 125 ml-aliquot of macerated tomato slices was transferred to a 250-ml Erlenmeyer flask containing 29g NaCl and a 3.8-cm magnetic stirring bar. The flask was closed with a rubber stopper containing a 11.4-cm-long 17-gauge hypodermic needle and a stainless steel tubing with 3.2 mm outer diameter. The needle was immersed in the macerate for pressure equilibrium, and the stainless steel tubing, which was connected to the sample loop, was exposed to the headspace. The flask was immersed to a constant depth in a 40°C water bath and the macerate stirred at a low speed. After 10 min of incubation, an aliquot was drawn into the 5-ml sample loop.

The volatile components were analyzed with a Hewlett-Packard Model 7624A gas chromatograph fitted with dual 3.65M by 3.18 mm stainless steel columns, containing 15% Carbowax 20M on 80/100 acid-washed Chromosorb W, and flame ionization detectors. Nitrogen was metered through the columns, and the oven temperature was programmed to 8 min at 60°C, followed by 4°/min increase to 110° and hold at 110°. Retention times and peak areas were measured with a Hewlett-Packard model 3370A electronic digital integrator.

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RESULTS

INTENSITIES of some of the attributes differed with harvest date, but no trend occurred with time. Sweetness scores increased up to the fourth harvest and the scores of

Table 1—Average sensory scores and compositional values[a] of table-ripe 'Walter' tomatoes harvested as mature-green, breaker, and table-ripe

Attribute	Harvest period 1	2	3	4	5	6
Sensory						
Sweetness	2.7 b	2.8 ab	3.0 ab	3.3 a	3.1 ab	3.2 a
Acidity	3.4 ab	3.4 ab	2.9 b	2.9 b	3.7 a	3.4 ab
Saltiness	2.3	2.3	2.2	2.3	2.3	2.6
Grassiness	2.3 a	1.8 ab	1.4 b	1.4 b	2.0 a	1.8 ab
Stemminess	1.2 a	0.7 b	0.7 b	0.7 b	0.5 b	0.8 b
Fruity-floral flavor	3.5 a	3.2 b	3.3 b	3.3 b	3.1 b	3.1 b
Mustiness	0.3	0.5	0.5	0.5	0.2	0.5
Bitterness	0.8	0.7	1.0	1.1	0.9	1.3
Astringency	1.4 a	0.9 b	1.3 ab	1.5 a	1.3 ab	1.2 ab
Desirability	4.0 a	3.4 b	3.5 ab	3.7 ab	3.2 b	3.4 b
Composition						
Soluble solids (%)	4.33 bc	4.20 c	4.30 bc	4.47 bc	4.93 a	4.57 b
Citric acid (%)	0.52 a	0.44 b	0.44 b	0.45 b	0.49 a	0.49 a
Soluble solids/acid ratio	8.3 c	9.5 ab	9.8 ab	10.0 ab	10.0 ab	9.3 b
pH	3.90 c	3.90 c	3.93 bc	3.91 c	3.97 b	4.03 a

[a] Scores or values in the same line not followed by a common letter are significantly different at the 5% level (Duncan, 1955). Sensory scores based on a seven-point scale (0 = none, 7 = very intense).

the fourth and sixth harvests were significantly higher than the score of the first harvest (Table 1). Acidity, grassiness and the citric acid content were lower in tomatoes from the middle harvest than in those from the beginning or end harvest; only some of the differences were significant. The soluble solids content and pH increased slightly with later harvests. Interaction of harvest and maturity was not significant (data not presented).

Sensory attributes of ripe tomatoes changed with harvest maturity. Intensities of sweetness and fruity-floral flavor increased with maturity on plant and the scores for these attributes of TR tomatoes were significantly higher than those of MG and B tomatoes (Table 2). Saltiness of tomatoes also increased with maturity and the scores of TR were significantly greater than those of MG. The acidity increased slightly but not significantly, with maturity. The remaining attributes (grassiness, stemminess, bitterness, and mustiness) did not change with maturity, and the scores for mustiness were very low. Scores for flavor-desirability increased with maturity, and the scores of TR differed significantly from those of MG and B fruit. The desirability scores need to be considered lightly, however, for the test was not designed as a preference evaluation.

Compositions of table-ripe tomatoes were affected by the stage of maturity at harvest (Table 2). The citric acid contents of B and TR fruit were significantly greater than those of MG fruit. The soluble solids content also was greater with later maturity, but the differences were not significant. The sugar-acid ratio decreased significantly with maturity, which indicates that the increase in acid content with maturity was greater than that of soluble solids content. The pH of fruit differed with maturity, but no trend occurred.

Several gas chromatogram peaks changed quantitatively with maturity (Table 3). In general, the peak areas de-

Table 2—Average sensory scores and composition values[a] of table-ripe 'Walter' tomatoes when harvested as mature-green, breaker or table-ripe

Attribute	Maturity: Mature-green	Breaker	Table-ripe
Sensory			
Sweetness	2.7 b	3.0 b	3.4 a
Acidity	3.2	3.2	3.5
Saltiness	2.2 b	2.3 ab	2.6 a
Grassiness	1.9	1.7	1.6
Stemminess	0.8	0.7	0.8
Fruity-floral flavor	2.9 b	3.1 b	3.7 a
Mustiness	0.4	0.5	0.3
Bitterness	1.1	0.9	0.9
Astringency	1.3	1.3	1.2
Desirability	3.2 b	3.5 b	4.0 a
Composition			
Soluble solids (%)	4.4	4.5	4.5
Citric acid (%)	0.45 b	0.49 a	0.48 a
Soluble solid/acid ratio	9.9 a	9.2 b	9.4 b
pH	3.94 ab	3.92 b	3.96 a

[a] Scores or values in the same line not followed by a common letter are significantly different at the 5% level (Duncan, 1955).

Table 3—Average areas of selected gas chromatogram peaks of volatile components of table-ripe 'Walter' tomatoes harvested as mature-green, breaker or table-ripe fruit[a]

Peak no.	Peak area ($\times 10^{-3}$): Mature-green	Breaker	Table-ripe
2	109	94	70
3	6.8	5.6	4.3
4	1.3	0.7	0.5
5	11.8	14.6	20.9
6	10	9.2	6.2
7	14	14	10
8	4.7 ab	8.4 a	0.4 b
11	98 a	63 ab	21 b
12	89 b	86 b	159 a
13	10	11	12
15	1240 a	1195 a	865 b
16	21 a	18 a	4 b
18	196 a	164 b	56 c

[a] Values in the same line not followed by a common letter are significantly different at the 5% level (Duncan, 1955).

Table 4—Simple correlation matrix for selected flavor characteristics, desirability and compositional components

	Soluble solids (%)	Titratable acid (%)	pH	Stemminess	Fruity-floral flavor	Desirability
Sweetness	0.20	–0.02	0.30	–0.08	0.47**	0.23
Acidity	0.21	0.44**	0.03	–0.05	0.05	–0.14
Fruity-floral flavor	0.11	0.33	–0.15	0.06		0.83**
Grassiness	0.12	0.39*	–0.10	0.66**	–0.28	–0.34*
Desirability	–0.05	0.27	–0.22	–0.05	0.83**	

* ** Significant at the 5% and 1% level, respectively

creased with maturity, in contrast with the findings of Dalal et al. (1967). Only peak 18 decreased significantly with each stage of maturity. Peaks 6, 11, 15 and 16 decreased with maturity, and the decreases of 11, 15 and 16 were significant. Peaks 2, 3, 4 and 7 decreased with maturity, but the changes were not significant. Peaks 5, 12 and 13 increased with maturity, but only the change of peak 12 from B to TR was significant.

A correlation matrix (Table 4) indicated that sweetness correlated significantly with fruity-floral flavor (r = 0.47) but not with the soluble solids content. Acidity correlated significantly with the citric acid content (r = 0.44), which agrees with findings of Bisogni et al. (1976). Grassiness correlated significantly with stemminess (r = 0.66), not unexpectedly, for both are associated with freshly cut plant tissue. Fruity-floral flavor correlated more highly with desirability (r = 0.83) than with sweetness (r = 0.47).

The variation in some of the sensory attributes can be accounted for by volatile and nonvolatile components in combination (Table 5). Volatile peaks 1, 6 and (11 + 12) accounted for 48% of the sweetness variation. Volatile peaks 11 and 18 and the citric acid content accounted for 45% of the variation in grassiness. Variations of some of the other sensory attributes could also be accounted for by volatile and nonvolatile components, but the R^2 values were very low.

The R^2 of some of the regressions changed when the gas chromatogram peak areas were converted to $\log_e$ (ln) for the stepwise regression analyses (Table 6). Analysis showed that ln of peaks 6, 18 and (10 + 11 + 12) accounted for 45% of the variation of saltiness. The ln of peaks 7, 9, 18 and (11 + 12) and pH accounted for 61% of the variation of fruity-floral flavor. The ln of peaks 4, 5, 11 and (10 + 11) and pH accounted for 59% of the variation of "desirability."

DISCUSSION

INTENSITIES of flavor attributes such as sweetness, acidity and fruity-floral flavor increased with maturity of fruit on plant. The increase of acidity was not significant, but the pattern of change was similar to that of citric acid content. Kader et al. (1977) found that "sourness" changed with maturation, but the pattern of change differed with cultivar and with year. Sourness probably is comparable to our acidity. Intensities of less favorable attributes such as grassiness, astringency, and bitterness did not decrease with maturity. Levels of factors such as phenols and pigments that affect these attributes decrease with ripening and probably were at minimum levels by the time the fruit were analyzed.

Sweetness did not correlate with the soluble solids content, in contrast to findings of Bisogni et al. (1976) and Kader et al. (1977). However, both groups of investigators analyzed several cultivars that gave a wider range of values, for both subjective and objective measurements than did ours. In their studies, as well as ours, the reducing sugar content or the soluble solids content did not differ with maturity, but sweetness was greater in fruit harvested at a later stage of maturity. Acidity correlated significantly with citric acid content, as noted by Bisogni et al. (1976) and Kader et al. (1977). Desirability correlated highly with fruity-floral flavor, and poorly with sweetness and acidity. In contrast, Bisogni et al. found that the "overall quality" correlated with the soluble solids content, a factor which did not change significantly with maturity.

The R^2 of two attributes increased when volatile peak areas were converted to ln for the stepwise regression analyses. The R^2 for the fruity-floral flavor component increased from 0.20 to 0.61 and the R^2 for desirability increased from 0.15 to 0.59 with the conversion of peak areas to ln. Apparently, sensory response of these attributes was related logarithmically to concentration of the associated substances.

Our results indicate that the fruity-floral attribute

Table 5—Stepwise regression analyses of sensory characteristics of 'Walter' tomatoes and percent soluble solids, percent citric acid, pH and volatile components

Sensory characteristics	Variables	R^2
Sweetness	peaks 1, 6, (11 + 12)	0.48*
Grassiness	peaks 11, 12% citric acid	0.45*
Fruity-floral flavor	peak 16	0.20
Desirability	peak 16	0.15

*Significant at the 1% level

Table 6—Stepwise regression analyses of sensory characteristics of 'Walter' tomatoes and percent soluble solids, percent citric acid, pH and $\log_e$ (ln) area of volatile components

Sensory characteristics	Variables	R^2
Sweetness	ln peaks 1, 6, (11 + 12)	0.47*
Saltiness	ln peaks 6, 18, (10 + 11 + 12)	0.45*
Fruity-floral flavor	ln peaks 7, 9, 18, (11 + 12), pH	0.61*
Desirability	ln peaks 4, 5, 11, (10 + 11), pH	0.59*

* Significant at the 1% level

should be considered strongly in assessing quality or desirability of tomatoes. The fruity-floral attribute can be estimated objectively by using the following regression equation:

$$\text{Fruity-floral} = 18.1 + 0.5 \ln \text{peak } 7 + 0.1 \ln \text{peak } 9 - 0.6 \ln \text{peak } 18 + 0.6 \ln \text{peak } (11 + 12) - 5.4 \text{ pH}$$

Since factors other than fruity-floral contributed to the desirable attribute, the desirability can be assessed directly by a different regression equation as follows:

$$\text{Desirability} = 21.4 + 0.1 \ln \text{peak } 4 + 0.7 \ln \text{peak } 5 + 2.4 \ln \text{peak } 11 - 2.6 \ln \text{peak } (10 + 11) - 5.6 \text{ pH}$$

Fresh market tomatoes occasionally have a musty taste, and this was noted occasionally with tomatoes in our previous studies. Kader et al. (1977) noted off-flavor with ripe tomatoes that were harvested as mature-green and suspected that the off-flavor came from the storage atmosphere. In this study the tomatoes were ripened in a sealed container with humidified air metered through it at a rate of 9 L/kg-hr, which apparently circulated and exchanged the air in the chamber sufficiently to minimize accumulations of volatiles or factors that cause musty taste or off-flavor.

In conclusion, sensory attribute intensities of table-ripe tomatoes were greater when fruit was harvested as table-ripe than as mature-green or breaker. However, most tomatoes are harvested as breaker or mature-green because those harvested as table-ripe cannot withstand the current methods of handling and transportation. Sensory intensities of table-ripe fruit were similar when harvested as breaker or mature-green, but results of this study may not be applicalbe to commercially harvested fruit. Commercially harvested mature-greens take 6–21 days at 20°C to ripen, whereas ours took 8 days to ripen at 20°C. Tomatoes that take longer than 15 days to ripen probably do not have the potential to develop satisfactory flavor. Thus, efforts need to be made in selecting mature-green fruit that will ripen in less than 10 days and/or harvest tomatoes as breakers to supply consumers with satisfactory tomatoes.

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Ms received 9/21/78; revised 12/31/78; accepted 1/8/79.

The authors thank Mr. James Koch, Biometrician, USDA, for the statistical analysis.

References to a brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned.

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that with respect to dry beverage formulations, sweetness (as a reciprocal) can be used as a sole predictor for preference since sourness varied very little between samples (the range was 0.6 cm) and appearance was well correlated with sweetness (Table 4). Canned juice preference was more strongly related to sourness (log (sourness) and the (sourness/sweetness) ratio) than the dry beverage formulations because correlations between preference and sourness and its transformations were numerically higher. Appearance was very poorly correlated with preference in this group. For frozen juices the sole criterion required to predict preference was the (sweetness × sourness) variable.

DISCUSSION & CONCLUSIONS

AS OUTLINED EARLIER, the purpose of this work was to determine the extent to which orange beverage groups differed in preference and then to establish the criteria which consumers use to evaluate them. In other words, do consumers use the same sensory properties to assess orange drinks as they do, for example, orange juice?

This study has shown that a range of dry orange flavoured beverage formulations commercially available compared very favourably in preference to frozen, canned, or bottled juices. These synthetic orange drinks were consistently sweeter, less sour and had a more attractive appearance to consumers than many canned or bottled juices readily available.

Interesting differences in the relative importance of perceived sensory properties emerged which showed that dry orange flavoured beverage formulations were judged for preference in relation to the reciprocal of sweetness and that appearance was well correlated with sweetness. However, canned orange juice preference could be predicted from the (sweetness/sourness) ratio and log (sourness), while frozen orange juice preference was related to (sweetness × sourness).

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Ms received 6/26/78; revised 9/29/78; accepted 10/5/78.

This work was supported in part by the Canadian Department of Industry, Trade and Commerce and the Ontario Ministry of Agriculture and Food.