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Organic Acids in Grapefruit Fruit Tissues

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Abstract. **Organic acid components of tissues of grapefruit (*Citrus paradisi* Macf.) were analyzed by gas-liquid chromatography. At harvest, in autumn, malic acid was the main component of the flavedo (78% of total acid content), with malonic, adipic, citric, succinic and oxalic, ranging in order from 11% to 2%. In the albedo, malic was again the prevalent acid (67%), with malonic, adipic, oxalic and succinic acids ranging in order from 19% to 2%; citric acid was present in traces only. In the juice, citric was the prevalent acid (87%), malic attained 12% while other acids were present only in minute amounts. Malic, malonic, adipic and succinic acids in the flavedo declined when the fruit was left on the tree but increased during off-tree storage. Oxalic acid disappeared from the flavedo during storage. Orange and grapefruit acids are compared.**

During investigations on the quality and storage capacity of grapefruit from various locations in Israel, the organic acid composition of several fruit tissues was determined, in order to test whether patterns of organic acid metabolism are useful for better defining fruit characteristics (5). Determination of the organic acid composition of grapefruit by gas liquid chromatography has not been previously reported; such results should be more reliable than those obtained with other procedures.

Materials and Methods

'Marsh' seedless grapefruits from several different locations in Israel were used. For flavedo, albedo and juice tests, fruits from Bashit (B) in the central coast area and from Tel Joseph (T-J) in the Guilboa, interior region were tested on 3 occasions between early September and early December. At B fruit matures about 3 weeks later (by November) than at T-J. For additional flavedo determinations, wire-bound boxes of fruit were collected at the beginning of March, from 10 locations including B and T-J, from Hulata in Upper Galilee south to Maguen in the Northern Negev. Fruit was stored at 17°C and samples were analyzed 7 and 54 days after harvest.

Organic acids were analyzed by a modified GLC method (2, 4, 6) allowing detection and quantitation in juice and in ethanolic extracts of peel. Data presented are means of 3 or 4 samples of 6 fruits each, for each tissue, location and harvest. Data are presented on fresh weight basis. The suitability of this basis of calculation has been discussed in our previous paper (6).

Results

Fig. 1 shows concentrations of the main acids in flavedo, albedo and juice. Data presented are means of analyses done in September, October, and December on fruit from B and T-J. Fig. 2 shows seasonal trends of 4 main acids in the flavedo at the 2 locations. The data obtained immediately after harvest in September, October, and December are shown with data from fruit harvested at the same locations in March and stored for 47 days. A decrease in concentration from November to March is evident in most cases. During storage, however, most acids increased in fruit from both locations. The increase in storage is somewhat larger if data are calculated on dry weight basis.

The average content of the acids in the flavedo from the 10 different locations also increased during storage. The increase is significant at the 5% level for all acids, although the variability between locations is rather high (Table 1).

Malonic acid showed the largest increase in absolute units, followed by malic acid. The increase of other acids in absolute units is much smaller. The increase relative to values at the

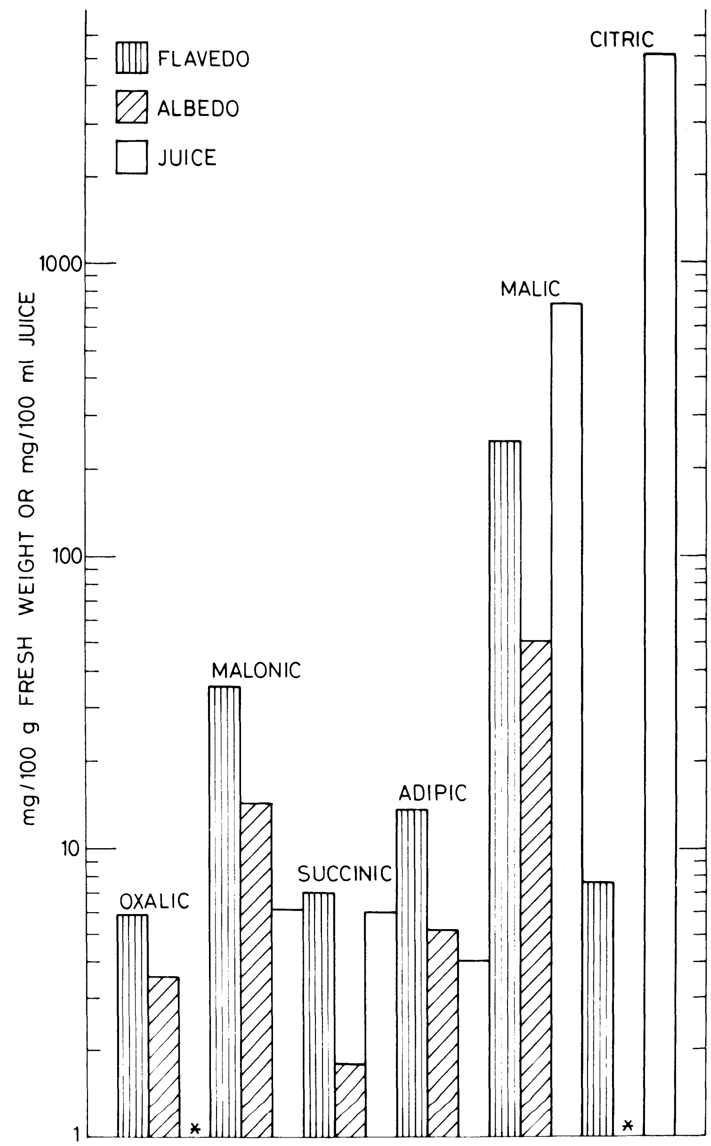

Fig. 1. Organic acid composition of different portions of 'Marsh' seedless grapefruit at harvest, plotted on logarithmic scale. Means of 2 locations (B and T-J) and 3 harvest dates (September, October, December). * = traces.

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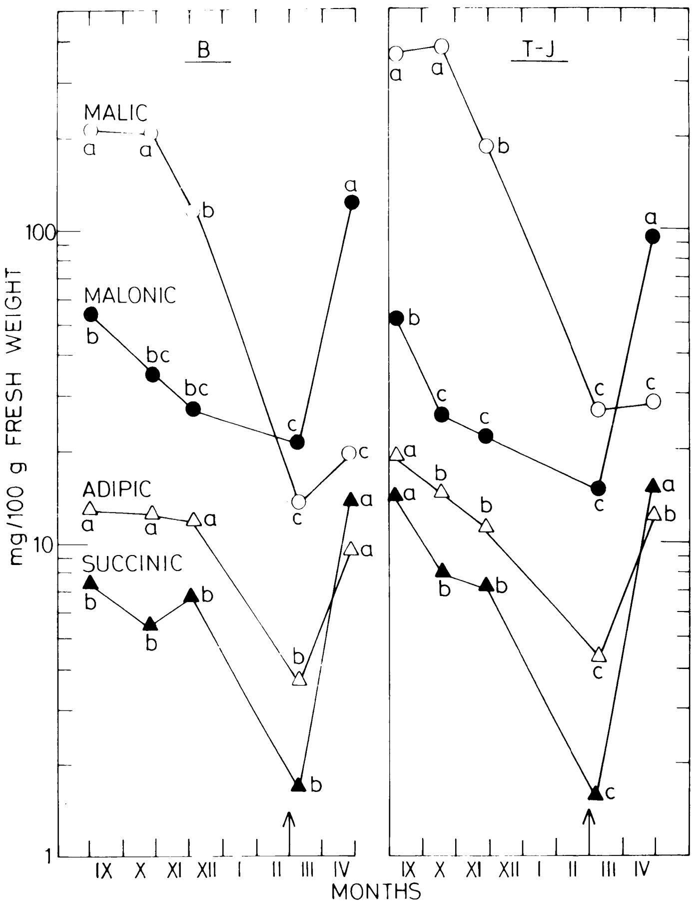

Fig. 2. Organic acid composition of flavedo of grapefruits stored on tree (first 3 sampling dates) and off-tree (in storage 7 and 54 days from harvest) at B and T-J, plotted on logarithmic scale. The arrow indicates harvest time. Letters differentiate means along the time axis within each acid and location.

Table 1. Organic acid components of grapefruit flavedo 7 and 54 days after harvest (storage at 17°C, averages of 10 locations).

Acids	Mg/100 g fresh wt March 8	Mg/100 g fresh wt April 24	Absolute increase (mg)	Relative increase (% of values on March 8
Malonic	18.2 ± 9.9[z]	68.7 ± 34.0	50.5	277
Malic	20.1 ± 9.3	47.5 ± 28.1	27.4	136
Adipic	4.3 ± 0.6	9.4 ± 1.8	5.1	119
α-ketoglutaric	4.2 ± 1.3	9.3 ± 2.2	5.1	121
Oxalic	4.0 ± 2.2	0.0	–	–
Succinic	1.6 ± 0.9[y]	10.5 ± 3.0	8.9	556
Citric	1.5 ± 0.8	5.8 ± 2.3	4.3	287

[z]± SE.

[y]Average of 8 locations only.

Table 2. Comparison between the relative contents of different organic acids in fruit tissues of 'Shamouti' orange and 'Marsh' seedless grapefruit (source of grapefruit data, see Fig. 1).

Tissue	Species	Oxalic	Malonic	Succinic	Acipic	Malic	Citric
		Acids (%)[z]					
Flavedo	Grapefruit	1.8	11.4	2.3	4.3	77.6	2.5
	Orange	4.7	70.0	2.7	4.5	15.3	2.8
Albedo	Grapefruit	4.7	18.9	2.3	6.7	67.2	0.2
	Orange	10.7	32.0	1.9	1.9	38.5	15.0
Juice	Grapefruit	tr[y]	0.1	0.1	tr	12.4	87.3
	Orange	0.1	0.2	0.8	0.4	6.7	91.8

[z]% of total acid content (mg/100 g fresh wt for flavedo and albedo, mg/100 ml for juice) in each tissue and cultivar.

[y]Traces.

beginning of storage was largest with succinic acid (one of the minor components), followed by citric and malonic acids which had similar increases.

Discussion

In general, absolute amounts of organic acids are much higher in grapefruit than in orange tissues (3, 6), Benzoic acid has not been detected in grapefruit tissues. Lactic and isocitric acids have been found only occasionally so that their detection is not considered reliable and they have been omitted from this report.

The relative amounts of oxalic, malonic, succinic, adipic, malic and citric acids in the 2 species are presented in Table 2, where values of these acids have been calculated in % of total acid concentrations in each tissue and cultivar.

Malic and malonic are the main acids in the flavedo of both species, but their ranks interchange; other acids attain only 2 – 5% of total acid concentration in both species.

Malic is the main acid in the albedo of both species, while malonic acid comes next, but again its relative content is much higher in orange. Considerable amounts of citric and oxalic acids are present in the orange, while adipic and oxalic acids are prevalent amongst the minor components in grapefruit and only traces of citric acid can be detected.

Citric acid predominates in the juice of both species. In addition only malic acid is present in significant amounts, while other acids are present only in very minute amounts.

Few data on organic acids in grapefruit are found in the literature (1, 7); all work has been done before suitable gas-liquid chromatography methods had been developed (2). Malic, oxalic, malonic and citric acids had been reported (1) in grapefruit peel but no discrimination was made between flavedo and albedo. However, relative values do not agree with out data (Table 2) as oxalic acid values are close to those of malic acid and citric acid values only slightly lower than those of malonic acid. Especially the large amounts of oxalic acid (Ca. 82 mg/100 g fresh weight) (1) do not agree with out results of 3.5 – 5.9 (Fig. 1). We could not detect oxalic acid 54 days after harvest (Table 1).

The decrease of all flavedo acids in the fruit while still on the tree (Fig. 2), is parallel to the decrease in titratable acid in juice during maturation.

Malonic, adipic and succinic acids content has been also found to increase in 'Shamouti' peel tissues during storage (3, 6) although there are obviously differences in relative amounts.

We proposed (5) that the increase in malonic acid could be an indication of progressive senescence in orange fruit tissues. In grapefruits its increase is also the largest in absolute values and, amongst the main components, in relative values (flavedo, see Table 1).

However, no substantial quantitative differences in this or in other organic acids or in the rate of their changes in storage could be detected between fruit from different locations although they differed in degree of maturity and in storage ability.

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Estimating Yield and Fruit Numbers of Apple Trees from Branch Samples[1]

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Abstract. **Yield and fruit numbers data were collected from whole trees and sample branches in 4 orchards of 3 cultivars of apple (*Malus domestica* Borkh.) over a 4-year period. Coefficients of correlation between yield/tree and (crop load x geometric mean of trunk circumference and trunk cross-sectional area), and between number of fruits/tree and (fruit set x geometric mean of trunk circumference and trunk cross-sectional area), were 0.91 and 0.93, respectively. Using regression analyses, the error of estimate for individual trees was ±11.0% for yield/tree and ±10.4% for number of fruits/tree. The corresponding values for treatment means were ±6.4% and ±5.4%, respectively.**

The yield of an apple tree is determined by the density of the crop and the size of the tree. Crop load, as calculated from branch samples (5, 7), is a reflection of crop density and, as such, permits *relative* yield comparisons. However, the estimation of *absolute* yield/tree requires adjustment for tree size.

The total weight of the above-ground portion of an apple tree is closely related to the size of the trunk (2, 10, 14, 20, 25). There is also a close relationship between trunk size and the combined girths of the scaffold branches (12, 15). Yield has been related to various expressions of trunk size such as circumference (13, 21, 24), cross-sectional area (9, 11), circumference squared or cubed (20), and the geometric mean of circumference and cross-sectional area (27). In some studies, efforts have been made to correct for variability in yield due to differences in tree size by expressing yield per unit of trunk cross-sectional area (3, 4, 6, 22). However, in spite of high correlations between trunk size and tree size, the use of trunk size as a measure of bearing surface is not without limitations. The relationship between trunk size and tree size varies with such factors as rootstock (14, 15, 16, 17, 18), pruning (15, 25, 26, 27), soil conditions (23), fertilization (20), biennial bearing (26), tree size (8, 25), and spacing, crowding, and missing trees (26, 27). In addition bearing surface does not increase in direct proportion to tree size (25, 26). Because of these complications, expressing yield/unit of trunk cross-sectional area may provide a better measure of productive efficiency (8, 17, 19, 25) than a means of adjusting yield for differences in tree size. It would appear that precise yield adjustments for tree size may be difficult or impossible, but much of this past work was done in an era of larger trees, lower productivity, and markedly different cultural practices.

There have been recent attempts to use branch samples and trunk measurements to estimate yield/tree of apples (21) and cherries (1). This study was conducted to compare yield/tree with crop load, adjusted for tree size by commonly employed expressions of trunk size, in an effort to develop a simple procedure for estimating yield/tree. An attempt was also made to similarly estimate the number of fruits/tree from fruit set data.

Materials and Methods

The experimental procedure has been described, in part, in previous publications (6, 7). In all cases, treatment units were whole trees and there were 4 or 5 replicates/treatment. The crop was adjusted by thinning treatments in 4 commercial apple orchards over a 4-year period as follows:

'McIntosh', 1975. Three chemical fruit thinning treatments (unthinned, NAA 5 ppm, NAA 10 ppm) were applied to 16-year-old trees on seedling rootstocks.
'McIntosh', 1976-77. Three hand fruit thinning treatments (unthinned, 1 fruit/spur, fruits spaced 10-15 cm) were made to 10-year-old trees on MM 106 rootstocks in 1976. To evaluate carryover effects of differential cropping, the trees were untreated in 1977.
'Empire', 1977-78. The 3 hand fruit thinning treatments described above were made to 7-year-old trees on MM 106 rootstocks. As with the 'McIntosh' above, the trees were untreated in 1978.
'Delicious', 1978. Two chemical fruit thinning treatments (unthinned, Sevin 1 lb/100 gal) were applied to 6-year-old trees on MM 106 rootstocks.

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