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Farmer's Markets Versus Retail Grocery Stores: How the Market Source Contributes to Differences in Bioactive Content of Selected Citrus Grown in California

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Abstract

While commercial retailers are increasing the amount of organic produce they sell, farm stands and farmers' markets continue to be the primary source for consumers accessing organically grown produce in the U.S. Consumer willingness to pay higher prices for organic produce is partially fueled by the perception that organic production methods yield foods with higher nutritional value. Results from studies comparing the nutritional value of organically and conventionally grown crops are mixed and suggest that nutritional value may be equally influenced by the type of crop, cultivar and environmental factors.

Conventionally and organically grown citrus fruits were sourced from retail grocery and farmers' markets, respectively, and the bioactive content, antioxidant activity, and organoleptic properties of the fruits compared. Titrable acidity was higher in all cultivars purchased in the organic farmer markets and also color analysis showed significant differences. Total flavanone concentrations were 30% to 120% higher for the fruits from farmers' market than that of fruit obtained from grocery stores and antioxidant capacities of fruits from farmers' market were also significantly higher. The cultivation method (organic versus conventional) was not an influencing factor for limonin and ascorbic acid contents.

The physiochemical, nutritional and bioactive contents of citrus fruits may be more dependent on species, cultivar, and environmental conditions (e.g., soil, climate) than production method. The willingness for consumers to pay more for organic citrus fruits may have more to do with perception than actual nutritional content.

Keywords: Antioxidant; Ascorbic Acid; Grapefruit (*Citrus paradisi*); HPLC; Naringin; Valencia orange

Introduction

During last century, trends in food production changed from local farms to large enterprises. The large production system, favored by technological advances, turned to chemical solution to control pests and diseases and optimize soil productivity, obtaining at the same time an enhancement of yield and the external quality of fruit and vegetables products. Although unintended, pollution problems and food contamination by chemicals became more frequent as a consequence. Organic farming practices offer an alternative to industrial practices. The word "Organic" refers to the way farmers grow and process agricultural products, such as fruits, vegetables, grains, dairy products and meat. Organic farming practices are designed to encourage soil and water conservation and reduce pollution using natural fertilizers and crop rotation or mulch to manage weeds. Much of the U.S. organic farm sector expansion occurred since the U.S. Department of Agriculture's establishment of uniform organic standards in 2000.

Consumption of foods grown organically is often perceived to reduce risk by reducing exposure to pesticide residues [1]. Consumers, driven by environmental and health concerns are increasing their demand for organically produced food [2]. Surveys indicate

that consumers consider foods produced organically to be more environmentally friendly, to have a greater nutritional quality, better for human health, and just as flavorful as conventionally-grown crops [3]. The scientific evidence to support consumer perception, that organic produced foods possess greater nutritional quality, is mixed. There are studies reporting organic production methods yielding higher levels of nutritionally desirable compounds [4] and others reporting no differences [5]. Thus, the nutritional quality of food grown by organic and conventional methods is still subject of much controversy [3,6-9].

Objective of the present work was to compare the organoleptic properties, bioactive content and antioxidant activity of Navel and Valencia orange fruits and Pink Star Ruby grapefruit obtained from organic farmers' market to conventionally grown fruits purchased in retail grocery stores in order to examine if cultivation method contributes to differences in fruit attributes.

Materials and Methods

Plant Material

The study was performed in March 2015 on citrus fruits, i.e., Navel and Valencia oranges (*Citrus sinensis Osbeck*) and Pink Star Ruby grapefruits (*Citrus paradisi Macfadyen*) with fresh appearance, free of rotting and bruising or any other signs of deterioration. The citrus fruits were purchased from 4 sources (2 farmers' markets and 2 retail grocery stores) located in the San Francisco Bay area (Table1). Both sources were chosen to obtain the same environment conditions. After purchasing the samples were kept at 4 °C until the time of preparation, which was within 24 hours of the purchase.

Farmers' Market (Fm)	Date	Location	Price($)/lb
Navel	2/28/2015	DWTN Berkeley	2
Valencia	2/28/2015	DWTN Berkeley	0.9
Star Ruby	2/28/2015	DWTN Berkeley	2
Navel	3/3/2015	South Berkeley	2
Valencia	3/3/2015	South Berkeley	0.9
Star Ruby	3/3/2015	South Berkeley	2
Grocery Store (Gs)	**Date**	**Location**	**Price ($)/lb**
Navel	2/28/2015	DWTN Berkeley	0.59
Valencia	2/28/2015	DWTN Berkeley	0.69
Star Ruby	2/28/2015	DWTN Berkeley	0.8
Navel	3/3/2015	South Berkeley	0.59
Valencia	3/3/2015	South Berkeley	0.69
Star Ruby	3/3/2015	South Berkeley	0.8
Values are expressed as the mean±standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$)			

Table 1: Analyzed Sample.

Sample Preparation

Samples of 30 fruits were purchased from each of the 4 sources at commercial maturity. Each sample was divided into three subsamples and the fruits were washed, dried and squeezed. Juice was prepared by squeezing the fruits with a hand juicer. A portion of the juice was placed in 50 ml centrifuge tubes and flashes frozen by immersing the tubes in ground dry ice. The remaining juice was immediately used for Total Acidity (TA), Total Soluble Solids (TSS) and color measurements [10]. Frozen samples were kept at -20˚C until time of analysis. Vitamin C, flavanones, limonin and the antioxidant activities by ABTS, TSP and DPPH assays were determined from frozen juice samples.

Chemicals, Materials and Equipment

Analytical grade standards, ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), DL-dithiothreitol, and Trolox (S)-(-)-6-hydroxy-2,5,7,8 tetra-methyl-chroman-2-carboxylicacid) were purchased from Sigma-Aldrich (St. Louis, MO). Acetonitrile HPLC grade) and methanol, formic acid, o-phosphoric acid, m-phosphoric acid and acetic acid (analytical grade) were purchased from Fisher Scientific (Pittsburgh, PA). Folin-Ciocalteu's phenol reagent was sourced from M.P. Biomedical, Inc. (Santa Ana, CA). Water (HPLC Grade) was prepared in-house using in a Millipore Milli-Q System (Bedford, MA, USA).

Experimental

Determination of pH, Total Soluble Solids (TSS) and Titratable Acidity (TA)

A portion of fresh citrus juice was centrifuged at 27,000 x g for 15 min and the supernatant was analyzed for pH, TSS and TA. pH was analyzed using a Beckman 720 pH-meter in combination with a glass-body pH electrode. The percentage of Total Soluble Solids (TSS) was measured using a Rudolph J257 automatic bench Refractometer (Hacketts Town, NJ). Acidity as citric acid (TA) was determined by titration of the juice samples to a target pH of 8.10±0.1 following the AOAC method [10]. The titrant was a 0.1 N sodium hydroxide solution (Fisher Chemical). A Metrohm 730 Sample Changer in conjunction with the 751GPD Titrino automatic titrator (Methrom AG, Switzerland) was used. All measurements were carried out in triplicate.

Color Measurement

The color of citrus juice was analyzed using a Konica Minolta CM700d colorimeter (Konica Minolta Inc., Japan). The instrument (45˚/0˚ geometry, Illuminant D65, 10˚ observer) was calibrated with a black and white ceramic tile (X = 78.66, Y = 83.31, Z = 88.40) before the measurement. Juice samples were placed in a glass cell and their color measured. Color measurements were carried out in triplicate with five readings for each sample. The

recorded XYZ tristimulus values were then converted to CIE L^*, a^* and b^*color values.

Two other parameters were determined by the following equations:

$$C^*_{ab} = \sqrt{a^{*2} + b^{*2}} \quad (1)$$

$$h_{ab} = \arctan b^{*2}/a^{*2} \quad (2)$$

Flavonoids Determination

The content of the flavonoids narirutin, hesperidin, naringin (for grapefruit) and didymin was determined using High-Performance Liquid Chromatography (HPLC). Frozen juice samples were thawed in a 20°C water bath for 20 min and mixed prior to processing. A portion sample was transferred to 15mL conical vial and clarified by centrifugation using the Sorval model RC 5C Plus centrifuge (15 min, 27000 x g, 4°C). Clarified liquid was collected, diluted 10:1 with the mobile phase and filtered through 0.45 µm Phenomenex PTFE membrane filter (Torrance, CA) prior to HPLC analysis.

HPLC analysis was performed with a Waters 2695 LC (Milford, MA) in series with a Waters 996 Photodiode Array (PDA) detector. Instrument control and data acquisition was accomplished using Masslynx (Version 4.0). Separation was performed on a 5 µm Luna C18 column (50 × 2 mm i.d.) (Phenomenex) operating in gradient with a solution 0.01 N of Acetic Acid (solvent A) and Acetonitrile (solvent B) at a flow rate of 0.6 ml/min. Flavonoids were detected at a wavelength of 280 nm. Quantification was performed based on external standard calibration curves covering the linear concentration of 0-10 mg/L for didimin, 0-100 mg/L hesperidin and narirutin and 0-150 mg/L naringin. The values provided are the average of three replicates.

Limonin Content

Determination of limonin content was accomplished by HPLC. A 1.0 mL aliquot of clarified juice sample was extracted twice with 2 mL of chloroform. The chloroform layer was collected and evaporated to dryness with nitrogen gas and reconstitute with 500 uL of 10 mM formic acid in 30% ACN. Quantification was performed based on external standard calibration curve covering the linear concentration range from 0.05-100 ppm. The HPLC system was comprised of a Waters 2695 LC in series with a Waters 996 PDA detector. Instrument control and data acquisition is accomplished using Masslynx (Version 4.0). Standards and samples (20 µL) were injected on to a 50 x 2.0 mm Phenomenex Phenosphere-Next-5µ Phenyl Column equipped with a guard column of the same material and maintained at 30°C. The flow rate was 1.0 mL/min and an isocratic solvent composition of 70% of 10 mM formic acid, 30% acetonitrile was used. Total run time was 5.5 minutes.

Chromatographic Determination of Ascorbic Acid

Vitamin C is the most important water-soluble antioxidant found in citrus. Both, Ascorbic Acid (AA) and its oxidation product, Dehydroascorbic Acid (DHAA), have vitamin C activity. AA, DHAA and Total Ascorbic Acid (TAA) were analyzed using a modification of the subtraction method [11,12]. The frozen juice samples were thawed in a 20 °C water bath and a portion sample was clarified by centrifugation using the Sorvall model RC 5C Plus centrifuge for 15 min at 27,000 x g at 4 °C. To determine the AA, the clarified liquid was diluted 5:1 with a solution of meta-phosphoric acid 10% and then filtered through 0.45 µm Phenomenex PTFE membrane filter prior to HPLC analysis. To determine the TAA, the same clarified juice sample was combined with DL-Dithiothreitol (DTT) solution (10% w/v) up to obtain a 1% final concentration in DTT. The solution was vortexed on a VWR multitube vortexer (West Chester, PA) for 10 seconds at speed #5 and incubated for 15 minutes at room temperature. After this time, the sample was diluted 5:1 with meta-phosphoric acid 10% and then filtered through 0.45 µm Phenomenex PTFE membrane filter prior to HPLC analysis.

No preparation regarding the DHAA content was used; DHAA was obtained by subtraction between TAA and AA content (TAA content is the sum of AA and Dehydroascorbic Acid (DHAA) after its reduction to AA). HPLC determination of the ascorbic acid was achieved using a Thermo Fisher Hypersil-Keystone BDS C18 (250 x 4.6 mm id, 5 µm) (Pittsburgh, PA) and a guard column of the same material maintained at 35 ˚C. A gradient of mobile phase composed of 0.02 M o-phosphoric acid (solvent A) and acetonitrile (solvent B) was used according to the following program: 0-4 min 0% B (isocratic); 4-6.5 min a linear increment up to 7%B; 6.5-8, 7%B (isocratic) and 8-9.5 return to the initial conditions 0% B and then isocratic until 15 min. The eluate was detected using a Waters 996 PDA detector set at 245 nm. The injection volume was 20 µL. Quantification was performed based on external standard of L-AA purchased from Sigma (St. Louis, MO). Standards used for the calibration curve ranged from 5 to 150 mg/mL. The values provided are the average of three replicates.

Estimating of Antioxidant Activity

DPPH Radical Scavenging Activity Assay

The scavenging effects of the phenolic compounds toward the stable free radical DPPH were measured according to the procedure by Bouaziz, et al. [13], Brand-Williams, et al. [14] and Hamburger, et al. [15] with some modifications. Briefly, samples juices were diluted with methanol to block the action of polyphenol oxidase. Samples, positive (BHT, ascorbic acid) and negative (cinnamic acid) controls (50 µL) and eight Trolox standard samples covering the linear concentration range from 0-0.150 mg/mL, prepared in methanol were combined in triplicate with 155 µM methanolic DPPH (200 µL). Following incubation at room temper-

ature for 30 min, the absorbance at 517 nm was read on a Molecular Devices Spectromax 384-Plus plate reader (Sunnyvale, CA).

ABTS Radical Cation Decolorization Assay (TEAC)

Antioxidant capacity as assessed by the ABTS radical cation (ABTS•+) decolorization assay was accomplished following the methods of Sellappan, et al. [16], and Re, et al. [17], with some modifications. Briefly, ABTS•+ was generated by reacting 7 mM ABTS with 2.45 mM potassium persulfate for 16 h in the dark at room temperature. The ABTS•+ solution was diluted with MeOH to an absorbance of 0.70±0.01 at 734 nm. Citrus juice samples diluted in methanol, positive (BHT, ascorbic acid, Trolox) and negative (cinnamic acid) controls (20 µL, 1 mg/mL, 0.02-1.0 mg/mL for Trolox) prepared in methanol were combined in triplicate with the ABTS•+ solution at a ratio of 20 µL sample or control with 400 µL of ABTS•+ solution. After a brief incubation (6 min, 30 °C), the absorbance at 734 nm was read on a Molecular Devices Spectromax 384-Plus plate reader.

Total Soluble Phenolics Assay (TSP)

This analysis is based on the Folin-Ciocalteu (FC) method [18] with some adjustments made to adapt the procedure to the sample under investigation. The reaction mixture was composed of 0.1 ml of diluted citrus juices, 1.5 ml distilled water, 0.1 ml of Folin-Ciocalteu's reagent, and 0.3 ml of a 7.5% sodium carbonate anhydrous solution (added 5 min after the Folin-Ciocalteu's reagent). After initial mixing the tubes were allowed to stand for 2 h. The absorbance was measured at 765 nm. The total phenolic content was determined as Gallic Acid Equivalents (GAE) and values are expressed as GAE/100 mL juice.

Statistical Analysis

All experiments were performed in triplicate and mean values with standard deviations are reported. Differences between variables were tested for significance by using a one-way analysis of variance procedure, using a level of significance of $p < 0.05$.

Results and Discussion

Physiochemical Differences

Organic plant foods are produced without synthetic pesticides and mineral fertilizers, but with compost, green manure and diversified rotation. Certification in organic farming means that a control unit examines the product according to the accepted rules and production system.

In the present study, the physicochemical characteristics were evaluated and compared for three cultivars. The analyses showed a significantly higher difference in the pH value (except for Navel cultivar) and the titrable acidity of juices of all organic cultivars compared with conventional (Table 2). Total Solid Soluble Content (TSS) showed the same trend for Navel and Pink Star Ruby but organically grown Valencia oranges had lower TSS than conventionally grown even though not statistically significant (Table2).

Cultivars	pH	TA (%ascorbic acid)	TSS (°Brix)	TSS/TA
Navel Fm	3.85±0.19a	2.00±0.44a	13.90±0.59a	7.14±1.10a
Navel Gs	3.92±0.18a	1.76±0.38b	12.15±0.36b	7.21±1.59a
Valencia Fm	3.33±0.05a	4.11±0.41a	10.72±0.49a	2.62±0.15b
Valencia Gs	3.80±0.07b	2.62±0.34b	11.33±0.33a	4.32±0.12a
Star Ruby Fm	3.12±0.04a	4.66±0.25a	11.47±0.39a	2.47±0.14b
Star Ruby Gs	3.30±0.07b	3.93±0.17b	10.24±0.20b	2.61±0.12a
[a]Values are expressed as the mean±standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$).				

Table 2: Physicochemical Characteristics of Different Citrus Cultivars[a].

Candir, et al. [19] compared organically and conventionally grown Washington Navel oranges and found lower TA values for the organic oranges, but no significant differences in TSS content. Similar findings were also reported by others for sweet orange cultivars Valencia Late [20] and Salestiana [21] and for clementines [22]. In contrast to this, Duarte, et al. [23] compared 18 different citrus cultivars, including orange, lemon and mandarin fruits, and found TSS content and organic acid concentrations higher in most of the citrus fruits from organic farming. Based upon our results and those reported by others, gross physiochemical properties of TSS content, pH and TA are not always associated with production system but depend strongly on citrus species, cultivar, and environmental conditions (e.g., soil, climate).

Color Measurements

Color is defined as the impact of the wavelengths of light in the visible spectrum (390-760nm) that can be detected by human eyes [24] and it is one of the main attributes that is strongly associated with the concept of quality [25]. The deliverance of a good impression through color will determine consumers' acceptability and their purchase decision. In this study, at least 3 of 5 measured parameters showed significant differences especially for lightness and yellowness (Table 3). Color difference, chroma (Cab) and hue (hab) were calculated to provide additional information about the color characteristics of the citrus juice samples. Chroma difference was insignificant for the Navel cultivars, but for the other cultivars tested, organically grown samples showed a hue significantly different compared to the conventional grown samples.

Cultivars	L*	a*	b*	C*ab	hab
Navel Fm	20.76±1.78a	2.63±0.43a	19.39±2.22a	19.94±2.49a	1.55±0.00b
Navel Gs	18.85±1.55b	1.26±0.75b	19.45±2.22a	19.23±2.16a	1.57±0.00a
Valencia Fm	21.51±4.89a	2.39±0.39a	18.34±1.56a	18.50±1.54a	1.55±0.01b
Valencia Gs	18.84±1.48b	-0.06±0.87b	16.77±1.04b	16.79±1.05b	1.57±0.00a
Star Ruby Fm	13.31±1.59a	4.48±0.39a	4.54±0.32a	6.38±0.43a	0.80±0.08a
Star Ruby Gs	12.94±1.19a	4.29±0.69a	3.76±0.93b	5.75±0.78b	0.65±0.28b
[a]Values are expressed as the mean±standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$).					

Table 3: Color CIE L*, a*, b* values, Chroma (C*ab) and hue (hab) of Citrus Cultivars[a].

Differences in Bioactive Compounds

Total Ascorbic Acid (TAA) and AA values were determined by reducing any potentially present DHAA with DTT. TAA levels in the sweet oranges ranged from 51.52±3.23 mg/100 mL juice to 58.12±6.89 mg/100 mL juice (Table 4). TAA concentrations in Navel oranges were slightly higher than those in Valencia oranges. Although market source was not significant factor in sweet oranges, TAA concentration in Pink Star Ruby juice was 1.5 times higher in the organic fruits. DHAA concentrations, determined from the differences between DTT treated and non-treated juices, were less than 1 mg/100 mL juice for all the samples.

Cultivars	L-AA	DHAA	TAA	Limonin
Navel Fm	56.37±7.20a	-0.28±1.80a	56.08±6.89a	3.75±2.08b
Navel Gs	57.21±3.06a	0.91±1.14a	58.12±3.19a	5.27±1.17a
Valencia Fm	52.11±4.34a	0.23±1.19a	52.33±4.54a	5.16±0.54a
Valencia Gs	50.90±3.09a	0.62±0.95a	51.52±3.23a	2.86±1.86b
Star Ruby Fm	51.18±3.01a	0.31±1.79a	51.48±2.56a	9.36±1.45a
Star Ruby Gs	33.25±1.69b	0.22±0.50a	33.47±1.48b	9.21±1.83a
[a]Values are expressed as the mean±standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$).				

Table 4: Vit. C (mg 100mL^{-1} juice) and Limonin (mg L^{-1} juice) of Different Citrus Cultivars[a].

In contrast with our findings, Duarte, et al. [23] and Lester, et al. [26] reported an increase in ascorbic acid content in some sweet orange cultivars from organic orchards. For instance, in Valencia Late and Baía oranges the concentration of ascorbic acid was higher in the juice of the fruits from organic farming, but in other orange cultivars, including Dalmau, Newhall, Lanelate and Rohde, no differences were detected between the fruits from different production systems. These observations lead, Duarte, et al. [23] to conclude that increases in ascorbic acid in response to an organic production system was dependent on species and cultivar.

In this study, we also wanted to evaluate if market source contributed to differences in the limonin content. Limonin is a bitter tasting compound and concentrations of 6 mg L^{-1} or more [27] are known to adversely affect quality and consumer acceptance. The limonin concentrations found in the juices ranged from 2.86±1.86 mg L^{-1} juice to 9.36±1.45 mg L^{-1} juice (Table 4) and are in the expected ranges [28-30]. Limonin content in the sweet oranges were below the bitterness threshold (6 mg L^{-1}), but above the threshold in the Ruby Grapefruits (>9 mg L^{-1}).

To the best of our knowledge, there are no reports within the literature on the influence of cultivation method on limonin content. We found no consistent trend between purchase sources and limonin content. Even though the limonin content in Valencia cultivar organically grown was higher than that conventional, we obtained the opposite trend for the Navel cultivar. The difference in limonin content for the Star Ruby grapefruit was not significant. This suggests that the limonin bitterness of juices depends on citrus species and cultivar rather than production system.

Results indicate that the most abundant flavanone glycoside identified in juice samples was hesperidin for Navel and Valencia cultivars, and naringin for Pink Star Ruby grapefruit, followed by Narirutin for all samples. This is in agreement with other authors [31,32]. Citrus plants contain a wide range of flavonoid constituents, including some that are characteristic to citrus [31] and may be used as markers to differentiate citrus varieties [33]. The content of the flavonoids narirutin, hesperidin, naringin and didymin as determined in the samples is shown in (Table 5).

Cultivars	Narirutin	Hesperidin	Naringin	Didimin	Tot Flavon
Navel Fm	14.87±2.75a	31.59±1.37a	ND	3.70±1.67a	46.87±9.57a
Navel Gs	11.98±1.13b	13.47±1.08b	ND	2.70±0.45b	28.18±1.49b
Valencia Fm	5.29±1.15b	29.52±1.43a	ND	1.76±0.85b	36.57±8.22a
Valencia Gs	9.01±1.64a	16.58±1.74b	ND	2.51±0.42a	28.10±1.37b
Star Ruby Fm	37.95±6.92a	2.72±0.42a	100.10±15.25a	1.57±0.33a	142.34±21.01a
Star Ruby Gs	17.21±6.75b	1.08±0.32b	46.37±13.96b	1.03±0.24b	65.70±21.12b
[a]Values are expressed as the mean±standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$).					

Table 5: Flavonoid Content (mg $100mL^{-1}$ juice) of Different Citrus Cultivars[a].

Cultivars	DPPH	ABTS
	(TrEqvmmol $100mL^{-1}$ juice)	(TrEqvmmol $100mL^{-1}$ juice)
Navel Fm	355.09±33.02a	391.28±42.00a
Navel Gs	306.28±21.71b	408.08±13.73a
Valencia Fm	300.83±46.67a	358.27±34.94a
Valencia Gs	303.08±26.17a	374.72±12.56a
Star Ruby Fm	322.04±28.58a	379.47±16.94a
Star Ruby Gs	228.34±12.09b	250.16±26.94b
[a]Values are expressed as the mean ± standard deviation (n=3). Mean values with different letters (a-b) within the same cultivar are statistically different ($p < 0.05$).		

Table 6: Antioxidant Capacity Measured Using DPPH and ABTS Assays[a].

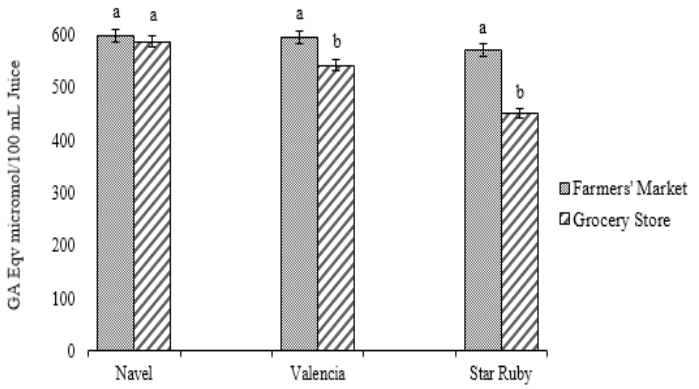

Figure1: Histogram graph of Antioxidant Activity Measured Using TSP Assay for Navel and Valencia oranges and Star Ruby grapefruit. Mean Values with Different Letters Within the Same Cultivar Are Statistically Different.

Results indicate a significantly higher antioxidant activity in the samples from farmers' market except for the Navel cultivar. Since the TSP assay is a measure of the total polyphenols, the results from the assay followed the same trend as found for flavanones glycosides and indeed, like for the flavanones determination, there were differences in the antioxidant activity for the all species under investigation in favor of the farmer source. Tarozzi, et al. [34] compared organically and conventionally grown red Tarocco oranges and, in contrast with our findings, they found a total radical scavenging ability measured with the ABTS assay of the organic oranges significantly higher than the activity of integrated oranges; whereas the phenol concentration was in accordance with our TSP results except for the Navel cultivar.

Conclusion

Farmers' markets are very popular in the United States even though the price of the products purchased is higher (125-170% more) compared to that of retail grocery stores. However, this doesn't keep the consumers away because they seem to perceive that there is a difference in flavor, taste and healthy components. This study showed that the fruits purchased from a farmers' market contained more soluble solids and organic acids, a higher color value and a lower maturation index. Also, the polyphenol content was higher except for the Navel cultivar and the antioxidant activity was significantly higher just for grapefruit fruits. We found no consistent relationship between purchase source and limonin content. Based upon our results and those reported by others, the physiochemical, nutritional and bioactive contents of citrus fruits may be more dependent on species, cultivar, and environmental conditions (e.g., soil, climate) than production method. Although we did not evaluate consumer attitudes as part of this study, we did observe that consumers shopping at farmer's markets were willing to pay a price that was, on a dollar per pound basis, a 125-170%

more expensive. Whether the increased cost over the price of citrus sold at retail grocery stores is justifiable by consumers may have more to do with perception than actual nutritional content.

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