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Food Science and Technology International 2011 17: 241 originally published online 7 June 2011
DOI: 10.1177/1082013210382334

The online version of this article can be found at:
http://fst.sagepub.com/content/17/3/241

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Consejo Superior de Investigaciones Científicas (Spanish Council for Scientific Research)

Antioxidant Activity, Color, Carotenoids Composition, Minerals, Vitamin C and Sensory Quality of Organic and Conventional Mandarin Juice, cv. Orogrande

P. Navarro,[1] A.J. Pérez-López,[1,*] M.T. Mercader,[1] Á.A. Carbonell-Barrachina[2] and J.A. Gabaldon[1]

[1]*Department of Food Science and Nutrition, Catholic University of San Antonio. Campus de los Jerónimos s/n, 30107 Guadalupe, Murcia (Spain)*

[2]*Department of AgroFood Technology, Miguel Hernández University. Carretera de Beniel, km 3,2. 03312 Orihuela, Alicante (Spain)*

The effects of organic farming on antioxidant activity, CIE $L^*a^*b^*$ color, carotenoids composition, minerals contents, vitamin C and sensory quality of Orogrande mandarin juices were studied. Independent of the farming type, mandarin juices can be considered as good source of some important nutrients, such as potassium and antioxidant chemicals, for example, β-cryptoxanthin. Organic farming of mandarins resulted in juices with higher antioxidant activity, total carotenoids concentrations, minerals (Ca, K and Fe) contents, vitamin C content, more appealing and intense orange color and better sensory quality. For instance, organic Orogrande juice contained significantly ($p < 0.001$) higher total carotenoids content (22.7 ± 0.3 mg/L) than conventional juice (15.7 ± 0.4 mg/L); a similar pattern was observed for the antioxidant activity, with values being 0.076 ± 0.004 and 0.053 ± 0.003 mM Trolox m/L in organic and convectional juices, respectively. A trained panel stated that organic Orogrande juices had higher intensities of orange color, fresh mandarin and floral aromas than conventional juices.

Key Words: β-cryptoxanthin, mandarins, organic farming, Orogrande, juices, sensory evaluation

INTRODUCTION

During the last years, organic farming has experienced a strong growth due to several factors, including growing consumers' interest on: (i) food safety, (ii) healthy diets and (iii) respect for the environment (Burch et al., 2001).

Organic farming could be defined as the agricultural techniques, which exclude the use of synthetic chemicals, such as fertilizers, pesticides, antibiotics, etc., with the objective of preserving the environment, keeping or improving the fertility of soils and providing foods with all their natural properties (Canavari et al., 2002).

In the European Union (EU), the land area dedicated to organic foods is 3.5 million ha, which represents only 3% of the total EU useful agricultural area. Italy is the country within the EU with more land dedicated to organic farming, followed by Germany, UK, Spain and France. Organic farming has become one of the most dynamic agricultural sectors, with organic agricultural products yielding an income of approximately 13–14 billion euros in 2005. In Spain, organic farming started about 25 years ago and nowadays is a quite promising sector, with about 350 000 ha being cultivated in 1999 (Foster and Lampkin, 2005).

Oranges and mandarin oranges are two of the agricultural products with the highest demand among fruits consumers. Spain is the second world producer of mandarin oranges and the main supplier to the international market (MAPA, 2005).

Because prevention of chronic illnesses is always a better strategy than their treatment, reducing the risk of heart diseases and cancer, through a healthier diet, has become a topic of the greatest interest for the health professionals, researchers, food technologists, food chemists and nutritionists. For this reason nowadays, the production of organic fruits and vegetables is being supported by most of the European governments and official institutions and organisms (Liu, 2003).

In general, citric products have high contents of natural antioxidant compounds, which are often related to reduction of neurodegenerative illness, certain types of cancer, heart diseases, etc. Therefore, consumption of

*To whom correspondence should be sent (e-mail: ajperez@pdi.ucam.edu).
Received 17 February 2009; revised: 25 May 2010.

Food Sci Tech Int 2011;17(3):0241–8

Los Angeles, London, New Delhi and Singapore
ISSN: 1082-0132
DOI: 10.1177/1082013210382334

citric products seems to help in maintaining and reinforcing the health of consumers (Thomasset et al., 2007) because of their high antioxidant activity (Vinson et al., 2001; Meléndez-Martínez et al., 2007a, c).

The synthesis and composition of these compounds depend on the species type and even on the fruit cultivar or variety. The farming type, the application of chemical products, such as fertilizers, pesticides and the type and abundance of irrigation will also affect both the biochemical composition (both qualitatively and quantitatively) and the activity of fruits (Meléndez-Martínez et al., 2007b, c).

Carotenoids provide fruits with their characteristic colors and have important biological functions. Although approximately more than 600 carotenoids have been reported, only 60 carotenoids have pro-vitamin A activity. Citrus fruits can have more than 115 different carotenoids. The main carotenoids found in mandarin oranges are: β-cryptoxanthin, violaxanthin, neoxanthin, lutein, antheraxanthin, α-carotene and β-carotene. From these compounds, β-carotene, α-carotene and β-cryptoxanthin are the ones with the highest pro-vitamin A activities (Meléndez-Martínez et al., 2007a). Carotenoids (C_{40} tetraterpenoids) are synthesized by plants from eight C_5 isoprenoid units, producing phytoene as the first C_{40} carotenoid (Rodriguez-Amaya, 2001), as a defensive mechanism against external aggressions. This is the main reason why organic oranges and mandarin oranges, which have not been treated with synthetic pesticides and/or chemicals to protect them against illnesses, usually have higher carotenoids contents than conventionally grown fruits (Heaton, 2001).

The main objective of this study was to assess the effect of different agricultural practices on total antioxidant activity, carotenoid composition, vitamin C, minerals and instrumental color of mandarin oranges (cultivar Orogrande).

MATERIALS AND METHODS

Fruit Material

Both conventional and organic mandarin oranges (*Citrus reticulata* L.), var. Orogrande, were grown in the same farm and under identical conditions of soil, irrigation and illumination in eastern Spain (Librilla, Murcia). The citrus rootstock was the same for both mandarin trees, Carrizo citrange (*Citrus sinensis* L.), and all selected trees were about 10-year-old and free of diseases. Fruits were collected in autumn (second week of October, 2007) when proper values of diameter, pH, total soluble solids content (SSC, °Brix) and maturity index (total soluble content/titratable acidity, SSC/TA) were reached (Table 1).

Table 1. Main properties of Orogrande mandarin oranges (at collection time) and fresh juices as affected by agricultural practice (conventional or organic).

	Farming type	
Property	Conventional	Organic
Weight (g)	94.3±6.9 a	88.5±4.7 a
Diameter (mm)	57.6±2.6 a	52.4±4.1 a
Soluble solid content (°Brix)	12.3±0.5 a	12.6±0.4 a
Titratable acidity (% citric acid)	0.97±0.05 a	0.94±0.04 a
Maturity Index (SSC/TA)	12.7±0.4 a	13.4±0.3 a
Vitamin C (mg/L)	366±18 b	419±25 a
Antioxidant Activity (mM Trolox/mL)	0.053±0.003 b	0.076±0.004 a
L^*	59.42±0.96 a	52.83±0.69 b
a^*	19.94±0.51 b	28.03±0.88 a
b^*	51.36±0.39 b	66.51±0.48 a
C_{ab}^*	55.09±0.42 b	72.17±0.71 a
h_{ab}	68.78±0.64 a	67.14±0.92 a

Mandarin orange fruits with the same letter, within the same row, were not significantly different at $p < 0.005$ for the evaluated property (Tukey's multiple range test).
Maturity index is the ratio between the solid soluble content and titratable acidity.

Orogrande Mandarin oranges were studied on conventional and organic farming. Organic production means that no synthetic chemicals were used in the production of these fruit trees and that only natural substances were used to control pest, weeds, etc. Farming of organic mandarin trees followed all rules established by the Board of Organic Agriculture of the Murcia Region (BOAM, 2009). A complete list of the materials used in both conventional and organic farming is included in Table 2.

Methods

Sample Preparation

Mandarins were collected and processed the same day. The exact weights of fruits processed were 8550 and 9240 kg of conventional and organic Orogrande mandarin oranges, respectively. Mandarin juices were processed in a commercial plant (Murcia, Spain) and were obtained using a Premium Juice Extractor (FMC Corporation, Florida, USA; FMC, 2009). This machinery leads to a juice with a low content of essential oils (Kimball, 2002) because after a proper calibration of fruits the contact between the juice and the skin of mandarins is minimized.

Freshly squeezed juices were treated in an Alfa Laval plate heat exchanger (Alfa Laval Iberia S.A., Madrid, Spain), for 20 s at a temperature of 98 °C. After this heat treatment, the juice was first transferred to a pre-cooler, which cooled the juice down to 30 °C using forced air and then to a cooler, which finally took the temperature

Table 2. Materials used in both conventional and organic farming (Source: Beltrán et al. 2008b).

Compound	Agricultural practice	
	Conventional	Organic
Soil fertilizers	Ammonium nitrate, calcium nitrate, ammonium sulphate, phosphoric acid, diammonium phosphate, potassium sulphate, potassium nitrate, potassium chloride	Manure, compost, and fulvic and humic acids
Foliar fertilizers	potassium phosphate, magnesium nitrate, urea, mixture of oligoelements	algae extracts, aminoacids
Herbicides	Bromacil, diuron, diquat, fluroxypyr, glyphosate, norflurazon, paraquat, sulfosate, simazine.	None; weeds are removed by mechanical methods
Pesticides	Malathion, dicofol, methidathion, clopidol	Neem oil, pheromone traps

down to 2 °C. Heat-treated juices were stored in aseptic metallic deposits at a temperature of 4 °C.

Physico-Chemical Analyses

The soluble solids content, SSC (°Brix), was determined using a portable refractometre Comecta, S.A., model C3 (Barcelona, Spain). Titratable acidity, TA (% citric acid), was determined in 10 mL of juice by titration to pH 8.2 ± 0.1 with a 0.1 N NaOH solution. The maturity index, MI, was calculated for each mix and expressed as the percentage of the ratio between the SSC and TA.

Vitamin C (reduced ascorbic acid) was measured following the AOAC Official Method 985.33 (Horwitz, 2000). Ascorbic acid was estimated by titration with colored oxidation-reduction indicator, 2,6-dichloroindophenol. EDTA was added as chelating agent to remove Fe and Cu interferences.

All physico-chemical analyses were analyzed in 20 fruits of each agricultural practice.

Instrumental Measurement of Color

Color determinations were made, at 25 ± 1 °C, using a Hunterlab Colorflex® (Hunterlab, Reston, Virginia, U.S.A.). This spectrophotometer uses an illuminant D65 and a 10° observer as references. A sample cup for reflectance measurements was used (5.9 cm internal diameter × 3.8 cm height) with a path length of light of 10 mm. Blank measurements were made with the cup filled with distilled water against a reference white background (Pérez-López et al., 2006).

Color data are provided as CIE $L^*a^*b^*$ coordinates, which define the color in a three-dimensional space (Minolta, 1994). Color analyses were run in 6 replicates.

Antioxidant Activity

The oxygen radical absorbance capacity (ORAC) analyses were conducted using a Synergy HT multidetection microplate reader (Bio-Tek Instruments Inc., Winooski, VT), using 96-well polystyrene microplates with black sides and clear bottom. Fluorescence was read through the clear bottom, with an excitation wavelength of 485/20 nm and an emission filter of 528/20 nm. The ORAC was determined as described by Dávalos (2004) with slight modifications (Lucas-Abellán et al., 2008). All reaction mixtures were prepared in triplicate and at least three independent assays were performed for each sample. To avoid temperature effect, only the inner 60 wells were used for experimental purposes, while the outer wells were filled with 200 μL of distilled water.

The results were expressed as relative fluorescence with respect to the initial reading. The area under the fluorescence decay curve (AUC) was calculated by the equation:

$$AUC = 1 + \sum_{i=1.14}^{i=120} f_i/f_0$$

where f_0 is the initial fluorescence reading at 0 min and f_i is the fluorescence reading at time i. The net AUC corresponding to the sample was calculated by subtracting the AUC corresponding to the blank to the sample AUC. The results of antioxidant capacity were expressed as mM of Trolox C per μL of juice.

Minerals Contents

A multi-place digestion block, Selecta Block Digest 20 (Barcelona, Spain), was used for sample mineralization. 15 mL of juice were treated with 5 mL of concentrated HNO_3 (65%, w/v) in Pyrex tubes, placed in the digestion block, and heated at 60 °C for 60 min and at 130 °C for 120 min (Carbonell-Barrachina et al., 2002). Solutions were left to cool to room temperature, transferred to a volumetric flask and diluted to a final volume of 25 mL with ultra-high-purity deionized water.

Determination of Ca, Mg, K, Cu, Fe, Mn and Zn in previously- mineralized samples was performed with a Unicam Solaar 969 atomic absorption spectrometer

(Unicam Limited, Cambridge, U.K.). Minerals were analyzed in five replicates.

Instruments were calibrated using certified standards. In each analytical batch, at least one reagents blanks, one international reference material (CRM) and one spike were included to assess precision and accuracy for chemical analysis. The certified material selected for the current experiment was GBW07603 (bush, branches and leaves); this material was provided by LGC Deselaers S.L. (Barcelona, Spain) and produced by the Institute of Geophysical and Geochemical Exploration of China (GBW07603).

Carotenoid Compounds Extraction and Quantification

The quantification of total carotenoid content and carotenoids profiling were carried out following the methods previously described by Darnoko et al. (2000) and Andreu-Sevilla et al. (2008). Mandarin orange juices were extracted with acetone; samples were later saponified with 20% KOH-methanol. Finally, pigments were extracted with diethyl ether, evaporated in a rotary evaporator and taken up in a maximum of 10 mL of acetone.

The high-performance liquid chromatography system consisted of an HP-1100 series unit with a photodiode array detector equipped with HP ChemStation software (Hewlett Packard, Palo Alto, CA). The column used was a 250 mm × 4.6 mm i.d., YMC C30, S-5 μm (YMC, Schermbeck, Germany). The mobile phase for this column was 81:15:4 methanol:methyl tertiary butyl ether (MTBE): H_2O (solvent A) and 91:9 MTBE: methanol (solvent B). The gradient elution was 100% A to 50% A and 50% B in 45 min followed by 100% B in the next 10 min and 100% A in the next 5 min at a flow rate of 0.8 mL/min (Darnoko et al., 2000; Andreu-Sevilla et al., 2008). Carotenoids were monitored at 450 nm and analyses were carried out in triplicate.

Identification was based on the order of elution, retention time and spectra of absorbance maxima of a particular peak. Standards of violaxanthin, antheraxanthin, β-cryptoxanthin and α- and β-carotene for quantification purposes were obtained from CaroteNature (Lupsingen, Switzerland); besides, standards of lutein and zeaxanthin were obtained from Extrasynthase (Genay, France).

The absolute concentrations of the main mandarin juices carotenoids (violaxanthin, antheraxanthin, lutein, zeaxanthin, β-cryptoxanthin, α-carotene and β-carotene) were worked out by external calibration in the range of 0–15 mg/L for β-cryptoxanthin and 0–6 mg/L for the rest of carotenoids. On the other hand, the levels of luteoxanthin-like, 9-*cis*-violaxanthin, luteoxanthin b, mutatoxanthin-like, *cis*-antheraxanthin and zeionoxanthin were calculated out using β-apo-8′-carotenal as internal standard (Hans-Dieter et al., 1999), due to lack of proper commercial standards. Total carotenoid content was assessed as the sum of the content of the 13 individual carotenoids studied in this experiment.

Sensory Evaluation

Sensory analysis was performed by a trained panel to evaluate the quality of mandarin orange juices. A panel of 10 panellists, ages from 20 to 50 years (8 female and 2 male, all members of the Catholic University San Antonio of Murcia), with sensory evaluation experience, was trained in descriptive evaluation of citrus juice (Serrano-Megías et al., 2005).

The panel was selected and trained following the ISO standard 8586-1 (AENOR, 1997; Meilgaard, 1999). Further details on selection, training and validation of the panel can be found in Pérez-López et al. (2006).

Measurements were performed in individual booths with controlled illumination (750–1000 lux) and temperature ($23 \pm 2\,^{\circ}C$) (AENOR, 1997; Meilgaard, 1999). The individual products were scored for the intensities of color, sweetness, acidity, fresh mandarin juice aroma, floral aroma and off-flavor using a scale of 0–10, where: 0 = extremely slight intensity, and 10 = extremely high intensity.

Samples were presented in 50 mL plastic cups with lids. The entire experiment was repeated three times (all judges scored two juice samples on each session for a total of three sessions) and the sensory scores were presented as the overall means.

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) and the Tukey's least significant difference multi-comparison test to determine significant differences among mandarin orange juices. Significance of differences was represented as $p < 0.001$. The statistical analyses were done using SPSS 14.0 (SPSS Science, Chicago, USA).

RESULTS AND DISCUSSION

Mandarins from the cultivar Orogrande were selected for this study because they present adequate technological (quite homogeneous in size and form, making peeling and squeezing easy) and sensory (intense sweetness) properties for juice making (García-Lidón et al., 1996).

No significant differences ($p < 0.05$) in quality parameters of the conventional and organic mandarins were found at picking time (Table 1). The main properties of the Orogrande mandarins selected for this experiment were: 91.4 g, 55.0 mm of diameter and a maturity index of 13.1 (mean values of conventional and organic mandarins). However, organic mandarins contained a significantly ($p < 0.001$) higher content of vitamin C than conventional fruits, 419 ± 25 and 366 ± 18 mg/L, respectively (Table 1).

Antioxidant Activity

Organic farming resulted in significantly higher antioxidant activity compared to conventional farming, with values being 0.076 ± 0.004 mM Trolox/mL of juice and 0.053 ± 0.003 mM Trolox/mL, respectively (Table 1). One possible explanation for this experimental finding is that organic trees are not treated with synthetic pesticides and therefore these trees must induce the synthesis of natural protecting compounds, such as carotenoids, leading to a final increase in their natural antioxidant activity.

These results agreed with those previously reported for other agricultural products such as red grapes (Negro et al., 2003; Rivero-Pérez et al., 2008), tomatoes (Toor and Savage, 2006) and oranges (Arena et al., 2001; Riso et al., 2005).

Instrumental Measurement of Color

Beltran et al. (2008a) studied the effect of the mandarin cultivar on the color coordinates of mandarin juices and concluded that juice from Clemenules mandarins presented the higher values of coordinate a^*, and coordinate b^* and Chroma, C_{ab}^*, of eleven mandarin cultivars under study. In that study, the values of L^*, a^*, b^* and C_{ab}^* for the conventional Orogrande juice and the mean of the 11 mandarin orange cultivars studied were as follows: a) 50.75, 7.79, 28.42 and 29.47; and b) 51.85, 8.21, 28.91 and 29.52, respectively.

Juices from organic Orogrande mandarins presented better color characteristics than juices from conventional fruits (Table 1); juices are better considered by consumers when being less clear but having more intense color coordinates (a^*, b^* and C_{ab}^*). A change from traditional agricultural practices to more environmentally friendly organic farming practices resulted, in this particular study, in a significant ($p < 0.001$) increase in the intensity of the orange color of mandarin juices. This improvement in the color of Orogrande mandarin juices was related to significant ($p < 0.001$) increases in some color coordinates a^* (8.09 units), b^* (15.15 units) and C_{ab}^* (17.08 units) and a decrease in the coordinate L^* (6.59 units).

Similar positive effects of organic farming on the color of Hernandina mandarin juices were reported previously by Beltran et al. (2008b), although the increases in the color coordinates caused by organic farming were around three units. On the other hand, no significant effects were found for Clemenules mandarins (Pérez-López et al., 2007). Considering the color data included in Table 1 and literature information, Orogrande cultivar can be considered as very sensitive cultivar to organic farming.

Mineral Contents

Certified values for Ca (%), Mg (%), K (%), Cu (mg/kg), Fe (mg/kg), Mn (mg/kg) and Zn (mg/kg) were: 1.81 ± 0.07, 0.65 ± 0.03, 1.38 ± 0.04, 274 ± 10, 9.3 ± 0.5, 45 ± 2 and 37 ± 1, respectively, while measured values for the same elements were: 1.79 ± 0.04, 0.65 ± 0.02, 1.42 ± 0.02, 270 ± 12, 9.4 ± 0.3, 48 ± 3 and 35 ± 2, respectively. These results show the goodness of the digestion and spectroscopy analyses of minerals.

Organic farming had a significant effect on the content of some of the analyzed elements, macro-nutrients (Ca and K) and micro-nutrients (Fe). In general, nutrients contents were higher in the juice from the organic mandarins (Table 3); however, differences were not always statistically significant. Mandarin orange juice is a very good source of potassium (mean of 3.2 g/L).

The concentrations of almost all nutrients analyzed in this study fall within the ranges reported in the literature for mandarin juices from different geographical areas, such as Florida, California, México and Brazil, and within the ranges suggested by the guidelines of AIJN (Ting and Rouseff, 1986; AIJN, 2009). Besides and as expected because we worked with natural freshly squeezed juices, the concentrations of Cu, Zn and Fe were below the maximum levels recommended by the Codex Stan 45-1981 of 5, 5 and 15 mg/L.

Table 3. Minerals contents of Orogrande mandarin orange juices as affected by type of farming (conventional or organic).

	Minerals (mg/L)						
Agricultural practice	Ca	Mg	K	Fe	Cu	Mn	Zn
Conventional	74.8 ± 3.8 b	109 ± 16 a	2986 ± 79 b	0.69 ± 0.07 b	0.19 ± 0.06 a	0.18 ± 0.04 a	0.31 ± 0.05 a
Organic	98.7 ± 5.1 a	138 ± 33 a	3325 ± 94 a	0.86 ± 0.09 a	0.17 ± 0.04 a	0.21 ± 0.02 a	0.37 ± 0.02 a

Mandarin orange fruits with the same letter, within the same column, were not significantly different at $p < 0.005$ for the mineral evaluated (Tukey's multiple range test).

Table 4. Carotenoids concentrations of Orogrande mandarin orange juices as affected by type of farming (conventional or organic).

Carotenoid	Farming type	
	Conventional	Organic
Violaxanthin	0.23 ± 0.06 b	0.58 ± 0.13 a
Luteoxanthin-like	0.15 ± 0.03 b	0.41 ± 0.06 a
9-cis-Violaxanthin	0.78 ± 0.15 b	1.59 ± 0.32 a
Antheraxanthin	1.35 ± 0.29 b	2.87 ± 0.24 a
Luteoxanthin b	0.15 ± 0.03 b	0.28 ± 0.05 a
Lutein	0.94 ± 0.20 a	1.21 ± 0.34 a
Mutatoxanthin-like	0.75 ± 0.11 b	1.09 ± 0.18 a
cis-Antheraxanthin	0.88 ± 0.15 b	1.97 ± 0.31 a
Zeaxanthin	0.41 ± 0.11 a	0.62 ± 0.23 a
Zeinoxanthin	2.08 ± 0.14 b	2.92 ± 0.39 a
β-Cryptoxanthin	7.55 ± 0.11 b	8.34 ± 0.09 a
α-Carotene	0.35 ± 0.12 a	0.61 ± 0.20 a
β-Carotene	0.09 ± 0.03 a	0.18 ± 0.06 a
TOTAL	15.7 ± 0.4 b	22.7 ± 03 a

Mandarin orange fruits with the same letter, within the same row, were not significantly different at $p < 0.005$ for the specific carotenoid (Tukey's multiple range test).

Total Carotenoid Content and Carotenoids Composition

Organic farming caused a positive effect on the total content of carotenoids in Orogrande juices, increasing the values of this quality parameter from 15.7 ± 0.4 in conventional juices to 22.7 ± 0.3 mg/L in organic juices (Table 4). A change from traditional agricultural practices to organic farming practices resulted in an increase of about 45% of total carotenoids content, which is a very significant improvement in the nutritional value of this juice. Lee and Castle (2001) concluded that total juice carotenoids increased as the fruit ripening progressed and ranged from about 1 mg/L in unripe oranges up to 9 mg/L in ripe fruits. Values found in the present experiment agreed with ripe mandarins (mean maturity index of 13.1), which have an intense orange color as previously described in the instrumental color section.

Organic farming significantly increased concentrations of 9 out of 13 identified carotenoids in Orogrande juice (Table 4); however, no specific effects of organic farming on the different carotenoid biosynthesis pathways can be proposed from results obtained in this experiment and more research is needed to reach such conclusions. The predominant carotenoids found in Orogrande juices were β-cryptoxanthin, zeinoxanthin, antheraxanthin, and *cis*-antheraxanthin with mean concentrations of 7.95, 2.50, 2.11 and 1.43 mg/L, respectively (Table 4). Meléndez-Martínez et al. (2007a) stated that the carotenoid profile of most foods depends on the fruit variety, climatic factors, industrial processing and storage conditions, among others. Even so, β-cryptoxanthin has always been reported as the major carotenoid found in mandarin juices.

Although approximately 700 carotenoids have been reported only those with an unsubstituted β-ring with an 11-carbon polyene chain, have pro-vitamin A activity (Meléndez-Martínez et al., 2007a, c). This structural requirement is satisfied by around 60 carotenoids (Rodríguez-Amaya, 2001). Vitamin A (retinol) can also be provided in the diet as other preformed forms as pro-vitamin A carotenoids, which are subsequently transformed into vitamin A (Meléndez-Martínez et al., 2007a).

The retinol activity equivalents (RAE) of the samples analyzed and discussed here referred to 1 L of mandarin orange juice. The bioavailability of carotenoids is influenced by many factors, such as amount, food matrix, age, existence of certain diseases or parasite infestation, intake of fat, vitamin E and fiber, protein and zinc status (Thomasset et al., 2007). According to this, it is difficult to accurately determine the RAE of any food. In this study, calculations were performed, considering new guidelines according to the following formula (FNBIM, 2002):

$$RAE = \left(\frac{\mu g\,\beta - carotene}{12}\right) + \left(\frac{\mu g\,\alpha - carotene + \mu g\,\beta - cryptoxanthin}{24}\right)$$

The RAE values found in this study for Orogrande traditional and organic mandarin orange juices were 337 and 388 RAE/L, respectively; these high values of RAE/L support the general fact that mandarin products are a very good source of vitamin A and this statement is especially true for organic mandarin juices. These experimental values fit perfectly within the range previously described by Meléndez-Martínez et al. (2007a) for the RAE/L contents of different types of orange and mandarin juices marketed in Spain ranging from 9.7 to 359. This RAE/L range was significantly reduced when only orange juices were considered, 9.7 to 94.8. Without any doubt the high levels of RAE in mandarin juices compared to other citrus juices are related to their higher concentrations of β-cryptoxanthin.

Sensory Quality

The trained panel established that the quality of both juices was high but that organic juice had slightly higher intensities of color, fresh mandarin juice aroma and floral aroma than conventional juice. In fact, the exact values for color, sweetness, acidity, fresh mandarin aroma and floral aroma for the organic and conventional juices were as follows: 8.2 ± 0.1, 6.5 ± 0.1, 5.7 ± 0.1, 8.4 ± 0.1, 5.4 ± 0.1 and 7.7 ± 0.1, 6.4 ± 0.1, 5.7 ± 0.1, 7.4 ± 0.1, 5.0 ± 0.1, respectively. No off-flavors were detected for any of the two juices under study.

CONCLUSIONS

If the most popular mandarin orange cultivar, Clemenules, is not available for juice making, Orogrande is a good option and it has been demonstrated that this cultivar is very sensitive to organic farming (high increases in values of color coordinates, total carotenoids content, etc.). In general, mandarin juices are very good sources of potassium and β-cryptoxanthin. Organic Orogrande mandarin juices were characterized by high antioxidant activity (0.076 mM Trolox m/L), intense orange color (C_{ab}*72.2), high content of total carotenoids (22.7 mg/L), high contents of nutrients such as calcium, potassium, iron and vitamin C content (419 mg/L). Besides, the sensory quality of the organic juice was better than that of the conventional juice based on intensities of color, fresh mandarin and floral aromas. Therefore, organic farming had positive effects on the quality of mandarin juices, cultivar Orogrande.

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