Food Chemistry 126 (2011) 411–416

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Vitamin C and carotenoids in organic and conventional fruits grown in Brazil

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ARTICLE INFO

Article history:
Received 29 January 2010
Received in revised form 21 October 2010
Accepted 31 October 2010

Keywords:
Organic farming
Conventional farming
Fruit culture
Ascorbic acid
Dehydroascorbic acid
Provitamin A

ABSTRACT

This study compared the concentration of vitamin C (ascorbic acid, AA, and dehydroascorbic acid, DHA) and carotenoids (lycopene and β-carotene) between three fruits produced by organic and conventional farming. Vitamin C and carotenoids were analysed by high-performance liquid chromatography. The Student *t*-test ($\alpha = 5\%$) was applied to determine differences between the organic and conventional production systems. AA content was significantly higher in organic acerola (4023.39 mg/100 g) compared to its conventional production (2294.53 mg/100 g). Conversely, AA content was significantly higher in conventional strawberries (42.45 mg/100 g) than the organic ones (30.74 mg/100 g). The conventional production also showed significantly higher contents of DHA (persimmon: 7.50 mg/100 g vs. 0.96 mg/100 g) and β-carotene (acerola: 6130.24 μg/100 g vs. 2486.38 μg/100 g) than the organic fruits. Lycopene was only detected in persimmons, but no significant difference was observed between farming systems. There was no evidence of the nutritional superiority of the organically grown fruits.

1. Introduction

Organic agriculture is a holistic production system that promotes health and the sustainable development of agroecosystems by obeying biodiversity, biological cycles and soil biological activity using fertilizers of organic origin and renewable energy sources (FAO/OMS, 1999; Guzmán Casado & González de Molina, 2009). Increasing knowledge and the concern of consumers regarding food quality, food safety and environmental protection have led to an increase in the demand for organic foods over the past few years (Magkos, Arvaniti, & Zampelas, 2006; Saba & Messina, 2003).

Apparently, there is a general perception in the population that organic foods are healthier, tastier and more nutritive than conventionally produced foods (Araújo, Santos, & Monteiro, 2008; Ismail & Fun, 2003; Saba & Messina, 2003). However, scientific evidence is insufficient to confirm or reject this assumption (Magkos et al., 2006), since comparative data of the two production systems are inadequate or inconsistent due to the heterogeneity of the material and research methodology used (Hoefkens et al., 2009; Kumpulainen, 2001).

Different foods are currently produced by organic farming. Although still not completely established, the segment of organic fruit production has grown significantly over the past few years (Borges & Souza, 2005).

Fruits are excellent sources of antioxidant vitamins, as well as of other vitamins, minerals, flavonoids, and phytochemicals (Ismail & Fun, 2003). Vitamin C is one of the most important antioxidants found in fruits and vegetables (Odriozola-Serrano, Hernández-Jover, & Martín-Belloso, 2007). This vitamin is important for human nutrition (Hernández, Lobo, & González, 2006) and for the food industry as an additive of processed foods (Rios & Penteado, 2003). The main biologically active form of vitamin C is L-ascorbic acid (AA), but its reversibly oxidised form, dehydroascorbic acid (DHA), also presents vitamin activity (Deutsch, 2000; Lee & Kader, 2000), a fact demonstrating the need for the determination of these compounds in foods to estimate total vitamin C value.

Carotenoids have an important antioxidant potential (Stahl & Sies, 2005), with the main carotenoids being lycopene (Shami & Moreira, 2004) and β-carotene (Miller, Sampson, Candeias, Bramley, & Rice-Evans, 1996). One of the most important roles of carotenes, especially β-carotene, is its provitamin A activity, considering that vitamin A deficiency is one of the main nutritional problems of populations in developing countries (Rodriguez-Amaya, 1989).

Data from epidemiological studies have shown an inverse association between the consumption of fruits and vegetables and the incidence of different diseases such as cardiovascular, ophthalmological and gastrointestinal diseases, neurodegenerative

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0308-8146
doi:10.1016/j.foodchem.2010.10.109

disorders, and some types of cancer (Van Duyn & Pivonka, 2000). Furthermore, it has been suggested that the interaction between different dietary antioxidant compounds such as vitamins C and E and carotenoids, especially lycopene and β-carotene, exerts a synergistic effect on free radicals and, consequently, a health protective effect (Stahl & Sies, 2005).

Therefore, the precise and specific determination of the content of these nutrients in fruits is extremely important, especially in view of the fact that farming practices may affect their concentration in fruits (Lee & Kader, 2000). Despite the need for data regarding the possible harm and/or health benefits promoted by the consumption of conventionally and organically grown foods, few studies have investigated the nutritional composition of organic and conventional fruits (Magkos et al., 2006).

Official methods for the analysis of vitamins and carotenoids in foods, such as spectrophotometry, colorimetric methods and titration procedures (AOAC), have been reported in the literature. However, high-performance liquid chromatography (HPCL) has emerged over the last years as a high-resolution, precise, reliable and sensitive method for the analysis of carotenoids and vitamin C in foods (Barba, Hurtado, Mata, Ruiz, & Tejada, 2006; Campos, Ribeiro, Della Lucia, Pinheiro-Sant'Ana, & Stringheta, 2009; Ismail & Fun, 2003; Odriozola-Serrano et al., 2007; Pinheiro-Sant'Ana, Stringheta, Brandão, & Azeredo, 1998).

The objective of the present study was to compare the concentration of vitamin C (AA and DHA) and carotenoids (lycopene and β-carotene) between three organically and conventionally grown fruits commonly consumed by the Brazilian population. In this study, lycopene and β-carotene were analysed because they are the most frequent carotenoids in the fruits studied and because of their important role as antioxidants and in the protection of human health. In addition, β-carotene plays an essential role as a provitamin A carotenoid, considering the fact that hypovitaminosis A is one of the main public health problems in developing countries such as Brazil.

2. Material and methods

2.1. Reagents and other materials

The following HPLC-grade reagents were used [the purity grade of the reagents is reported as percentage]: methanol (Tedia, USA) [99.9], acetonitrile (Vetec, Brazil) [99.8], ethyl acetate (Mallinckrodt, USA) [99.9], and acetic acid (Vetec, Brazil) [99.7]. Ultrapure water was produced with the Milli-Q® system (Millipore, USA). The following reagents of analytical grade were used: dithiothreitol (DTT) (Sigma Aldrich, Germany) [99.0], metaphosphoric acid (Merck, Germany) [90.5–99.5], sulfuric acid (Mallinckrodt, USA) [97], Trizma buffer (Nuclear, Brazil) [99.8], ethylenediaminetetraacetic acid (EDTA), phosphoric acid (Proquímios, Brazil) [85.0], monobasic sodium phosphate (Synth, Brazil) [98–102], acetone (Vetec, Brazil) [99.5], petroleum ether (Impex, Brazil) [99.9], ethyl ether (Impex, Brazil) [99.9], anhydrous sodium sulfate (Impex, Brazil) [99], Celite (Synth, Brazil), and magnesium oxide (Vetec, Brazil) [95]. The L-AA standard was acquired from Vetec (Brazil) [99.0]. The lycopene and β-carotene standards were separated by open-column chromatography. The samples were filtered through filter paper. Before injection, the samples and standard solutions were filtered through Millex HV filter units (polyethylene housing, 0.45-μm pore size; Millipore, Brazil).

2.2. Fruits

Persimmon (*Diospyros kaki* L., var. Rama Forte), acerola (*Malpighia punicifolia* L., var. Olivier) and strawberry (*Fragaria vesca* L., var. Oso Grande) fruits were obtained from the São Paulo Company Kórin Agricultura Natural Ltda., located in Atibaia, São Paulo, Brazil. The fruits were grown by organic and conventional farming in the same geographic region (Atibaia, São Paulo, Brazil) under the same climatic conditions and were collected randomly during the harvest season of each fruit throughout 2007. The organic fruits had a certificate issued by the Motika Okada Certification (CMO) service. The fruits were harvested in the partially ripe stage (stage of commercialisation) and properly stored in cardboard boxes protected against shock. The fruits were transported overland and arrived at the Laboratory of Vitamin Analysis, Department of Nutrition, Federal University of Viçosa, Minas Gerais, Brazil, within 48 h post-harvest.

2.3. Experimental design

A completely randomised design consisting of two treatments (organic and conventional production system) and six repetitions per treatment was used. The samples were collected randomly during the harvest season of each fruit.

2.4. Collection, sampling and sample preparation

The organic and conventional fruits were collected in such a way to obtain six different repetitions. The production area was divided into six small plots. In each plot, 2 kg of persimmons and 1 kg of acerola and strawberries produced by organic and conventional farming were collected. The six repetitions were sent to the laboratory in a single step, corresponding to 12 kg of persimmons and 6 kg of acerola and strawberries per treatment.

After receiving the fruits, each repetition was subdivided into two parts for sample preparation. One half was used for analysis of vitamin C on the same day and was therefore stored at room temperature. The other half was stored in a refrigerator at approximately 10 °C for sample preparation and analysis of carotenoids on the next day.

Persimmons, acerola and strawberries were washed under running water and the non-edible parts (acerola seeds and leaves of persimmon and strawberry) were removed. The fruits were then chopped and homogenised in a multi-purpose food processor for 5 min until complete homogenisation of the sample, thus guaranteeing more reliable sampling. This procedure was performed six times for each treatment (organic and conventional farming).

2.5. Extraction of vitamin C and carotenoids

Vitamin C was extracted from the fruits according to the method of Campos et al. (2009). The previously homogenised sample was weighed (about 1 g) and 15 ml extraction solution (3% metaphosphoric acid, 8% acetic acid, 0.3 N sulfuric acid and 1 mM EDTA) was added. Next, the sample was triturated in a micro-homogenizer for 5 min and vacuum filtered through filter paper. The filtrate was diluted in ultrapure water until a volume of 25 ml in a volume balloon and centrifuged at 1789*g* for 15 min. The supernatant was stored in a refrigerator at about 5 °C until the time for chromatographic analysis.

Carotenoids were extracted as described by Rodriguez-Amaya, Raymundo, Lee, Simpson, and Chichester (1976), with some modifications. Approximately 1 g of previously homogenised persimmons and acerola and 5 g of strawberries were triturated with cold acetone (60 ml), vacuum filtered through a Büchner funnel, and transferred to cold petroleum ether (50 ml). The extract was concentrated in a rotary evaporator at a temperature of 35–37 °C. Next, the carotenoids were dissolved in 25 ml petroleum ether and stored frozen (at about −5 °C) in amber glass flasks until the time for chromatographic analysis.

The samples were protected from light throughout the process of chemical analysis using amber glass ware and aluminum wrapping.

2.6. Determination of ascorbic acid and carotenoids

The presence of ascorbic acid and carotenoids in fruits was analysed by HPLC using a Shimadzu liquid chromatography system (model SCL 10AT VP) equipped with a high-pressure pump (model LC-10AT VP), automatic loop injector (50 μl; model SIL-10AF), and UV/visible detector (diode array; model SPD-M10A). The system was controlled with the Multi System software, Class VP 6.12.

AA was analysed using the method optimised by Campos et al. (2009). The mobile phase consisted of 1 mM monobasic sodium phosphate (NaH_2PO_4) and 1 mM EDTA, with the pH adjusted to 3.0 with phosphoric acid (H_3PO_4), and was eluted isocratically on a Lichospher 100 RP18 column (250 × 4 mm, 5 μm; Merck, Germany) at a flow rate of 1 ml/min. AA was detected at 245 nm.

Carotenoids were analysed using the chromatographic conditions described by Pinheiro-Sant'Ana et al. (1998), with some modifications. The mobile phase consisted of methanol:ethyl acetate:acetonitrile (50:40:10) and was eluted isocratically at a flow rate of 2 ml/min on a Phenomenex C18 column (250 × 4.6 mm, 5 μm) coupled to a Phenomenex ODS guard column (C18, 4 × 3 mm). β-Carotene and lycopene were detected at 450 and 469 nm, respectively.

AA, lycopene and β-carotene were identified in the samples by comparison of the retention times obtained with those of the respective standards analysed under the same conditions, and by comparison of the absorption spectra of the standards and peaks of interest in the samples using a diode array detector.

2.7. Validation tests

Recovery of AA, lycopene and β-carotene was analysed, in triplicate, by the addition of the standard to persimmon, acerola and strawberry samples at a proportion of 20–100% of the average original content in the samples.

The linear range was determined by injection, in duplicate, of five increasing concentrations of the standard solutions of AA, lycopene and β-carotene under the same chromatographic conditions as those used for sample analysis.

The limit of detection was calculated as the minimum concentration able to provide a chromatographic signal three times higher than the background noise (Rodriguez-Amaya, 1999). The limit of quantification was calculated as the minimum concentration able to provide a chromatographic signal five times higher than the background noise (Rodriguez-Amaya, 1999).

2.8. Conversion and quantification of dehydroascorbic acid

DHA was quantified in the fruits by determination of the difference between total AA content (after conversion of DHA into AA) and original AA content (before conversion of DHA). DHA was converted into AA according to the method of Campos et al. (2009), adapted for fruits. Trizma buffer (0.5 M) containing 40 mM DTT (2.0 ml for persimmons and acerola and 2.5 ml for strawberries) was added to 1 ml of the sample extract. Addition of the buffer to the extract increased the pH to a value close to neutrality (pH 5.5–6.0). The mixture was left to react for 10 min at room temperature in the dark. After this period, 0.4 M H_2SO_4 was added (1.5 ml for persimmons and acerola and 2.0 ml for strawberries) to again reduce the pH before chromatographic injection.

2.9. Calculation of vitamin A value

Vitamin A value is expressed as retinol activity equivalent (RAE) per 100 g sample according to the conversion factors for vitamin A value established by the Institute of Medicine (Institute of Medicine (IOM-US), 2001). According to the IOM definition, 1 RAE corresponds to 1 μg retinol or 12 μg β-carotene.

2.10. Statistical analysis

The results were analysed by the Student *t*-test ($\alpha = 5\%$) using the SAS (Statistical Analysis System) program, version 9.1, licensed to the Federal University of Viçosa, Minas Gerais, Brazil.

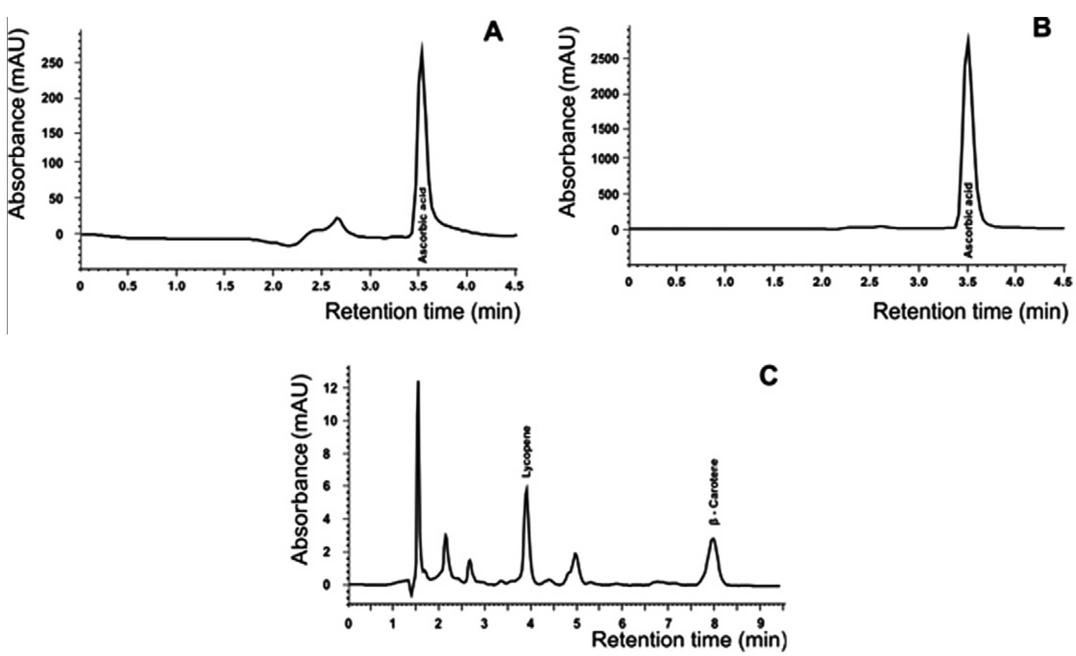

Fig. 1. HPLC analysis of ascorbic acid in conventional strawberry (A) and organic acerola (B), and of lycopene and β-carotene in organic persimmon (C). The chromatographic conditions are described in Section 2.

3. Results and discussion

3.1. Qualitative separation of the compounds

Fig. 1 shows typical chromatograms obtained for the analysis of AA, lycopene and β-carotene in fruits. AA and β-carotene were found in all fruit samples, whereas lycopene was only detected in persimmons. DHA was detected in all fruits analysed, except for conventionally grown acerola.

3.2. Validation tests

All components presented good linearity in the range of concentrations tested (injected weight: AA, 0.204–113.75 μg; lycopene, 0.0012–0.0572 μg; β-carotene, 0.0085–0.4905 μg). The coefficients of determination were 0.9975 for AA, 0.9932 for lycopene, and 0.9985 for β-carotene.

For persimmons, mean recovery of AA, lycopene and β-carotene was 99.5%, 102.8% and 85.2%, respectively. For acerola, mean recovery of AA and β-carotene was 101% and 90.6%, respectively. For strawberries, mean recovery of AA and β-carotene was 95.7% and 97.7%, respectively.

The limit of detection was 50 μg/L for AA, 60 μg/L for lycopene, and 50 μg/L for β-carotene. The limit of quantification was 75 μg/L for AA, 85 μg/L for lycopene, and 70 μg/L for β-carotene.

3.3. Ascorbic and dehydroascorbic acid content

The mean concentrations of AA and DHA found in the samples of organically and conventionally grown fruits are shown in Table 1.

For persimmons, AA content was similar for the two production systems, whereas DHA content was significantly higher in conventionally grown fruits ($p < 0.05$), accounting for 38.5% of total vitamin C. According to Lee and Kader (2000), DHA may account for up to 47.6% of total vitamin C in persimmons, depending on the variety.

Acerola was the fruit presenting the highest AA concentration. AA content was significantly higher (practically the double) in organically grown acerola compared to conventionally grown fruits ($p < 0.05$). Cultivation factors such as soil preparation, use of agricultural defensives and the type and frequency of irrigation may explain the difference between the two production systems. Vitamin C content has been shown to vary according to soil fertility and nutrient availability (Matsuura et al., 2001). Studies have shown that application of lower nitrogen doses and a lower frequency of irrigation may increase vitamin C concentrations in vegetables and fruits. Another important factor is the use of agricultural defensives such as pesticides and agrochemicals that can indirectly affect the nutritional quality of fruits and vegetables (Lee & Kader, 2000). DHA was only detected in organically grown acerola fruits, further increasing the concentration of total vitamin C, corresponding to 15.5% of total vitamin C content. However, Aldrigue (1998) detected DHA in conventionally grown acerola fruits, with its concentration accounting for 2–20% of total vitamin C.

Mean AA content was significantly higher in conventionally grown strawberries compared to organic fruits ($p < 0.05$). One possible explanation for this finding is the type of fertilisation adopted for conventional farming, which consisted of 40 kg/ha nitrogen, 600 kg/ha phosphorus and 240 kg/ha potassium. In the review of Lee and Kader (2000), the application of lower levels of nitrogenated fertilizers (45 kg/ha) and higher levels of potassium-containing fertilizers has been associated with a higher AA content in fruits and vegetables. The concentration of DHA was similar for the two production systems, with DHA accounting for 34% of total vitamin C value in conventionally grown strawberries and for 44% in organic fruits.

3.4. Lycopene and β-carotene content

The mean concentration of lycopene and β-carotene in organically and conventionally grown fruits is shown in Table 2.

Lycopene was only detected in persimmons, but there was no significant difference between the two production systems. There was also no difference in β-carotene content between organic and conventional persimmons.

β-Carotene was the only carotenoid detected in acerola fruits, with conventionally grown fruits presenting a significantly higher β-carotene content than organic fruits ($p < 0.05$). Lima et al. (2005)

Table 1
Mean concentration of ascorbic acid and dehydroascorbic acid in the edible portion of fruits produced by organic (O) and conventional (C) farming.[A]

Vitamin content (mg/100 g)	Persimmon		Acerola		Strawberry	
	O	C	O	C	O	C
AA	11.85 ± 0.48[a]	11.99 ± 0.33[a]	4023.39 ± 198.62[d]	2294.53 ± 125.62[e]	30.74 ± 3.68[g]	42.45 ± 4.78[f]
DHA	0.96 ± 1.30[c]	7.50 ± 2.67[b]	739.45 ± 455.64[B]	nd	24.33 ± 3.34[h]	22.20 ± 3.42[h]

Results are expressed on a wet weight basis.
nd, not detected.
For each fruit, means in the same line followed by the same letter did not differ significantly by the Student *t*-test ($p \geqslant 0.05$).
[A] Mean of six repetitions ± standard deviation.
[B] Mean of four repetitions ± standard deviation.

Table 2
Mean concentration of lycopene and β-carotene in the edible portion of fruits produced by organic (O) and conventional (C) farming.[A]

Carotenoid content (μg/100 g)	Persimmon		Acerola		Strawberry	
	O	C	O	C	O	C
Lycopene	567.87 ± 269.59[a]	453.27 ± 63.32[a]	nd	nd	nd	nd
β-Carotene	703.24 ± 86.64[b]	645.60 ± 42.58[b]	2486.38 ± 272.48[d]	6130.24 ± 559.17[c]	54.08 ± 7.71[e]	53.02 ± 2.15[e]

Results are expressed on a wet weight basis.
nd, not detected.
For each fruit, means in the same line followed by the same letter did not differ significantly by the Student *t*-test ($p \geqslant 0.05$).
[A] Mean of six repetitions ± standard deviation.

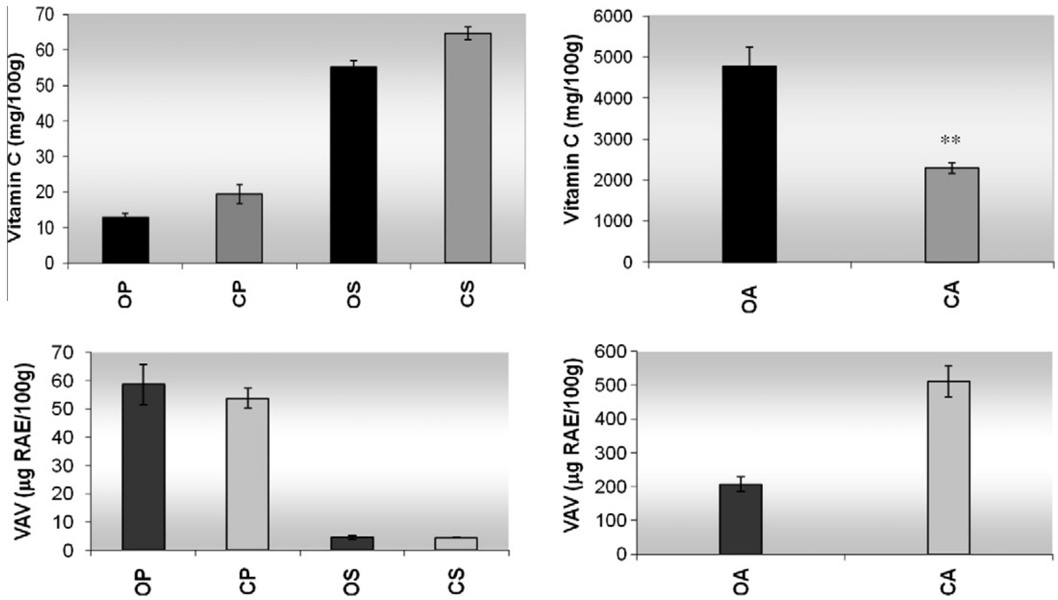

Fig. 2. Comparison of mean total vitamin C content and mean vitamin A value in the edible portion of fruits produced by organic and conventional farming (results are expressed on a wet weight basis). Mean of six repetitions ± standard deviation. ∗∗, Value corresponding to ascorbic acid (AA) content only (mg/100 g). VAV, vitamin A value; OP, organic persimmon; CP, conventional persimmon; OS, organic strawberry; CS, conventional strawberry; OA, organic acerola; CA, conventional acerola.

observed a higher β-carotene content [4060 μg/100 g] in conventionally grown acerola harvested during the rainy season and treated with chemical fertilizers 3 months before harvest. According to Gross (1987), soil fertilisation is one of the factors that affects the biosynthesis of carotenoids in fruits. This fact probably contributed to the higher β-carotene content observed in conventionally grown acerola fruits in this study.

Only β-carotene was detected in strawberries, with no significant difference between the organic and conventional production system.

3.5. Vitamin C content, vitamin A value and nutritional information

Mean total vitamin C content and mean vitamin A value derived from β-carotene of organic and conventional fruits are shown in Fig. 2. Significant differences in total vitamin C content between the two production systems were observed for all fruits ($p < 0.05$) as a consequence of the higher concentration of DHA in conventionally grown persimmons and of AA in conventional strawberries and organic acerola. Vitamin A value was significantly higher in conventionally grown acerola compared to organic fruits ($p < 0.05$).

Table 3 summarises the nutritional information regarding vitamin C content and vitamin A value of organic and conventional fruits and the classification of these fruits as a source of or rich in a given vitamin according to the recommendations of the National Sanitary Surveillance Agency (ANVISA; Decree No. 27 from January 13, 1998). According to these recommendations, solid foods ready for consumption are classified as a "source" when they meet 15% of the dietary reference intake (DRI) and as "rich" when they meet 30% of the DRI (Brasil, 1998).

Ingestion of a portion of 100 g of the organic or conventional fruits analysed partially or completely meets the daily vitamin C requirements of adults and children. The fruits classified as rich in vitamin C for the population groups studied were acerola followed by strawberry. Persimmon was classified as rich in vitamin C for children and as a source of vitamin C for women and men (except for organic persimmon). The consumption of 100 g acerola often exceeds the daily vitamin C requirements of adults and children; for example, 100 g organic acerola meets 5318% and 19,144% of the daily recommendation for adults older than 19 years and for children aged 4–8 years, respectively. Thus, this fruit represents a possible natural supplement in different food products and might be included in dietary programs aimed at risk populations. However, it is important that the daily consumption of acerola does not exceed the tolerable upper intake level of vitamin C for each population group.

With respect to vitamin A, ingestion of a portion of 100 g conventionally grown acerola meets more than half the daily

Table 3
Nutritional information regarding the vitamin C content and vitamin A value of organically (O) and conventionally (C) grown fruits.

Fruit	Edible portion corresponding to 100 g fruit	Production system	Meeting of daily requirements (%)	
			Vitamin C	Vitamin A value
Persimmon Rama Forte	1 Average unit	O	M: 14.2 W: 17.1[s] Ch: 51.2[r]	M: 6.5 W: 8.4 Ch: 14.7
		C	M: 21.7[s] W: 26.0[s] Ch: 78.0[r]	M: 6.0 W: 7.7 Ch: 13.5
Acerola Olivier	8 Average units	O	M: 5317.6[r] W: 6381.2[r] Ch: 19143.5[r]	M: 23.0[s] W: 29.6[s] Ch: 51.8[r]
		C	M: 2549.5[r] W: 3059.4[r] Ch: 9178.1[r]	M: 56.8[r] W: 73.0[r] Ch: 127.7[r]
Strawberry Oso Grande	5 Average units	O	M: 61.2[r] W: 73.4[r] Ch: 220.3[r]	M: 0.5 W: 0.6 Ch: 1.1
		C	M: 71.8[r] W: 86.2[r] Ch: 258.6[r]	M: 0.5 W: 0.6 Ch: 1.1

Daily vitamin C requirements according to dietary reference intake (Institute of Medicine IOM-US, 2000): 90 mg/day for men (M) (>19 years); 75 mg/day for women (W) (>19 years); 25 mg/day for children (Ch) (4–8 years). Daily vitamin A requirements according to dietary reference intake (IOM, 2001): 900 μg/day for men (M) (>19 years); 700 μg/day for women (W) (>19 years); 400 μg/day for children (Ch) (4–8 years).
[s] Source.
[r] Rich.

requirements of adults and 100% of the daily requirements of children, thus representing a source rich in provitamin A. Organic acerola was found to be a good source of vitamin A. For the other fruits, the order of classification regarding their importance to meet daily vitamin A requirements was organic persimmon > conventional persimmon > organic and conventional strawberry.

4. Conclusions

The present study did not provide evidence that would indicate the nutritional superiority of organically grown fruits in terms of the components analysed. However, organic acerola was found to present a higher concentration of AA and total vitamin C. With respect to nutritional value, the organic and conventional fruits studied were considered to be excellent sources of vitamin C for the population. In addition, these fruits contribute to meet the nutritional requirements of vitamin A. Persimmon was considered to be a good source of dietary lycopene, and acerola was the main source of vitamin C and the most important source of provitamin A.

Few studies regarding the nutrient content of organically and conventionally grown fruits are available in the literature and only a small number of fruits produced by these two farming systems have been analysed, a fact demonstrating the need for incentive, investment and concern on the part of research institutions and the federal government in this area. The contribution of the present study was to provide a database of the chemical composition of foods.

With respect to environmental impact and social issues related to the health of farmers and consumers, organic farming seems to increase environmental and socioeconomic viability compared to conventional farming, but this does not necessarily imply a better nutritional value of these foods.

Acknowledgements

The authors thank CNPq for financial support and for granting Master's and research initiation fellowships. We also thank FAPEMIG for granting a research initiation fellowship.

References

Aldrigue, M. L. (1998). *Desenvolvimento e validação de metodologia analítica, utilizando a CLAE, para determinação de vitamina C em frutas e seus principais produtos*. Campinas-SP: Unicamp. 160p [Doctoral thesis].

Araújo, A. S. F., Santos, V. B., & Monteiro, R. T. R. (2008). Responses of soil microbial biomass and activity for practices of organic and conventional farming systems in Piauí state, Brazil. *European Journal of Soil Biology, 44*(2), 225–230.

Barba, A. I. O., Hurtado, M. C., Mata, M. C. S., Ruiz, V. F., & Tejada, M. L. S. (2006). Application of a UV–vis detection-HPLC method for a rapid determination of lycopene and β-carotene in vegetables. *Food Chemistry, 95*, 328–336.

Borges, A. L., & Souza, L. S. (2005). Produção orgânica de frutas – Comunicado técnico. *Embrapa Mandioca e Fruticultura Tropical, 113*, 1–4.

Brasil (1998). *Portaria SVS/MS n° 27, de 13 de janeiro de 1998*. Regulamento técnico referente à informação nutricional complementar (declarações relacionadas ao conteúdo de nutrientes). Diário Oficial da União, Brasília, DF, January 16, 1998.

Campos, F. M., Ribeiro, S. M. R., Della Lucia, C. M., Pinheiro-Sant'Ana, H. M., & Stringheta, P. C. (2009). Optimization of methodology to analyze ascorbic and dehydroascorbic acid in vegetables. *Química Nova, 32*(1), 87–91.

Deutsch, J. (2000). Dehydroascorbic acid: Review. *Journal of Chromatography A, 881*, 299–307.

FAO/OMS (1999). *El Codex Alimentarius: Directrices para la producción, elaboración, etiquetado y comercialización de alimentos producidos orgánicamente*. Available at: <http://www.codexalimentarius.net> Accessed 5.11.07.

Gross, J. (1987). *Pigments in fruits*. London: Academic Press.

Guzmán Casado, G. I., & González de Molina, M. (2009). Preindustrial agriculture versus organic agriculture: The land cost of sustainability. *Land Use Policy, 26*, 502–510.

Hernández, Y., Lobo, M. G., & González, M. (2006). Determination of vitamin C in tropical fruits: A comparative evaluation of methods. *Food Chemistry, 96*(4), 654–664.

Hoefkens, C., Sioen, I., De Henauw, S., Vandekinderen, I., Baert, K., De Meulenaer, B., et al. (2009). Development of vegetable composition databases based on available data for probabilistic nutrient and contaminant intake assessments. *Food Chemistry, 113*, 799–803.

Institute of Medicine (IOM-US) (2001). Food and Nutrition Board. In *Standing committee on the scientific evaluation of dietary reference intakes. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc*. Washington, DC: National Academy Press.

Institute of Medicine IOM-US (2000). Food and Nutrition Board. In *Standing committee on the scientific evaluation of dietary reference intakes. dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids*. Washington, DC: National Academy Press.

Ismail, A., & Fun, C. S. (2003). Determination of vitamin C, β-carotene and riboflavin contents in five green vegetables organically and conventionally grown. *Malaysian Journal of Nutrition, 9*(1), 31–39.

Kumpulainen, J. (2001). Organic and conventional grown foodstuffs: Nutritional and toxicological quality comparisons. *The International Fertiliser Society, 472*, 1–20.

Lee, S. K., & Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology, 20*, 207–220.

Lima, V. L. A. G., Mélo, E. A., Maciel, M. I. S., Prazeres, F. G., Musser, R. S., & Lima, D. E. S. (2005). Total phenolic and carotenoid contents in acerola genotypes harvested at three ripening stages. *Food Chemistry, 90*, 565–568.

Magkos, F., Arvaniti, F., & Zampelas, A. (2006). Organic food: Buying more safety or just peace of mind? A critical review of the literature. *Critical Reviews in Food Science and Nutrition, 46*(1), 23–56.

Matsuura, F. C. A. U., Cardoso, R. L., Folegatti, M. I. S., Oliveira, J. R. P., Oliveira, J. A. B., & Santos, D. B. (2001). Avaliações físico-químicas em frutos de diferentes genótipos de acerola (*Malpighia punicifolia* L.). *Revista Brasileira de Fruticultura, 23*(3), 602–606.

Miller, N. J., Sampson, J., Candeias, L. P., Bramley, P. M., & Rice-Evans, C. A. (1996). Antioxidant activities of carotenes and xanthophylls. *FEBS Letters, 384*, 240–242.

Odriozola-Serrano, I., Hernández-Jover, T., & Martín-Belloso, O. (2007). Comparative evaluation of UV-HPLC methods and reducing agents to determine vitamin C in fruits. *Food Chemistry, 105*, 1151–1158.

Pinheiro-Sant'Ana, H. M., Stringheta, P. C., Brandão, S. C. C., & Azeredo, R. M. C. (1998). Carotenoid retention and vitamin A value in carrot (*Daucus carota* L.) prepared by food service. *Food Chemistry, 61*(1–2), 145–151.

Rios, M. D. G., & Penteado, M. V. C. (2003). Vitamina C. In M. V. C. Penteado (Ed.), *Vitaminas: Aspectos nutricionais, bioquímicos, clínicos e analíticos* (pp. 201–225). São Paulo: Manole.

Rodriguez-Amaya, D. B. (1989). Critical review of provitamin A determination in plant foods. *Journal of Micronutrient Analysis, 5*, 191–225.

Rodriguez-Amaya, D. B. (1999). Latin American food sources of carotenoids. *Archivos Latinoamericanos de Nutrición, 49*, 74S–84S.

Rodriguez-Amaya, D. B., Raymundo, L. C., Lee, T., Simpson, K. L., & Chichester, C. O. (1976). Carotenoid pigment changes in ripening *Momordica charantia* fruits. *Annals of Botany, 40*, 615–624.

Saba, A., & Messina, F. (2003). Attitudes towards organic foods and risk/benefit perception associated with pesticides. *Food Quality and Preference, 14*, 637–645.

Shami, N. J. I. E., & Moreira, E. A. M. (2004). Licopeno como agente antioxidante. *Revista de Nutrição, 17*(2), 227–236.

Stahl, W., & Sies, H. (2005). Bioactivity and protective effects of natural carotenoids. *Biochimica et Biophysica Acta, 1740*, 101–107.

Van Duyn, M. A., & Pivonka, E. (2000). Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. *Journal of the American Dietetic Association, 100*, 1511–1521.