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Comparative evaluation of organic and conventional farming on chemical quality parameters and antioxidant activity in fruits

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The aim of this research was to determine some important quality parameters and the antioxidant activity of organic and conventional oranges, limes and apples. Five samples of organic fruits with seal certification, organic fruits without seal certification and conventional fruits were acquired from supermarkets and farm in Rio de Janeiro, Brazil. Organic lime and orange showed higher mean values of acidity, being 4.5 and 34.8% higher, when compared to conventional fruit, respectively. There were no statistical differences (p>0.05) among organic lime and orange with seal certification, organic without seal certification and conventional fruits regarding the values of density and ascorbic acid. Total soluble solids of organic with seal certification and organic without seal certification in lime was 47.4 and 25.8% higher than conventional fruits. Few statistical differences were observed in acidity and total sugar for Sweet orange (*Citrus sinensis* L. Osbeck) and Lime (Citrus aurantifolia (Christm) Swingle). In relation to the apple samples, there is no significant difference between the physico-chemical analyzes of organic and conventional cultivars. Regarding antioxidant activity, an increase in the percentage of reduction of DPPH (1,1-diphenyl-2-picrylhydrazyl) radical was observed in organic with seal certification lime (18.4%) and orange (22.2%) in comparison to conventional fruit. In general, small differences were observed in chemical quality parameter contents of organically and conventionally grown fruits, however, organic fruits, sealed or not, showed higher antioxidant activity than conventional fruits, suggesting that modulation of these parameters due to alterations in the cultivation practice is unique to the specific species and cultivar of vegetables.

Key words: Organic, orange, lime, apple, antioxidant activity, quality parameters.

INTRODUCTION

The development of chronic diseases, such as cardiovascular diseases (CVD), cancer, hypertension and type 2 diabetes involves large production of free radicals leading to oxidative stress. A diet rich in fruits and vege-

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tables has been associated with lower risk of chronic diseases, because in addition to its vitamin and mineral composition, it may also contain other com-pounds with protective effects, in particular antioxidants (Arts and Hollman, 2005).

Polyphenol quantity and quality in plant foods can vary significantly according to different intrinsic and extrinsic factors such as plant genetics and cultivar, soil composition and growing conditions, maturity state and post harvest conditions (Jaffery et al., 2003). The high antioxidant capacity makes polyphenols an important part of a plant's innate defense mechanism, with its synthesis stimulated under stress conditions, such as temperature alterations, UV exposure and pathogenic attacks (Dixon and Paiva, 1995).

Synthetic pesticides and fertilizers are used in the traditional fruit production, whereas the organic agriculture, in general, is characterized by the absence of these products throughout the cultivation period. The literature suggests that organic agriculture could result in foods with higher polyphenol quantity, mainly for two reasons. First, the use of synthetic fertilizers could offer more bioavailable sources of nitrogen, accelerating plant development and plant resources from production of secondary metabolites to growth. Second, the absence of synthetic pesticides could result in higher exposure of the plant to stressful situations leading to an enhancement of natural defense substances such as phenolic compounds (Winter and Davis, 2006; Woese et al., 1997). Both hypotheses would result in foods with higher antioxidant capacity as a consequence of the higher polyphenol composition. The literature showed mixed results regarding the phytochemical composition and antioxidant capacity of organic and conventional vegetables varying according to the bioactive compounds measured and food type (Carbonaro et al., 2002; Lombardi-Boccia et al., 2004).

The debate about the quality parameters superiority of organically and conventionally grown products has been gathering momentum for some time especially in developed countries. The debate has cut across different agricultural produce, animal products inclusive. Organic products are those products which are produced under controlled cultivation conditions with the provisions of the regulation on organic farming. Requirements for organic certification vary from country to country and generally involve a set of production standards for growing, storage, processing, packaging and shipping. There are only few well-controlled studies that are capable of making valid comparison and therefore, compilation of results is difficult and generalization of the conclusions should be made with caution (Masamba and Nguyen, 2008).

The International Federation of Organic Agriculture Movements (IFOAM) fully implemented their standards for organic crop production outlining the criteria that must be met to label agricultural products as "organic" (IFOAM, 2005). Products usually are certified by a third party certification body recognized at international or national level, hence accountable in the case of fraud. Certification is made against the standards of the country where the product is sold. Certified organic food is recognized on the market by the organic label of the certification body (FAO, 2009).

The aim of this research was to determine some important quality parameters and the antioxidant activity of organic and conventional oranges, limes and apples.

MATERIALS AND METHODS

Samples

Samples of sweet orange (*Citrus sinensis* L. Osbeck), lime (*Citrus aurantifolia* (Christm) Swingle) and Apple (*Malus domestica* Borkh) were purchased in supermarkets and farmer's market in Rio de Janeiro, Brazil from August to December 2011. Foods were chosen based on Brazil's Food Acquisiton Database 2002/2003 (POF 2002/2003 IBGE) reflecting the fruits most consumed in Brazil. Cultivars used in this study were selected by the organically grown varieties available, since their production is more restricted. All samples were of the same cultivar and had similar sensory characteristics. Certified samples were obtained straight from the refrigerated shelves, except from the conventional and no certified organic samples. Fruits were purchased and immediately sent to the Laboratory of Nutritional Biochemistry of University of State of Rio de Janeiro, Brazil for analyses.

Sample preparation

All samples were rinsed with tap water to remove adherent contaminants. For the analysis of the ascorbic acid content and antioxidant activity in the samples, determination was done on the same day of purchase to avoid the instability of certain compounds. All fruits were divided into peel and pulp fractions. For each independent analysis, at least 300 g of fruit were put in a commercial juice extractor (Samsom GB- 9001, Greenbison Inc., USA), obtaining a fluid extract which was used in all analyses. All analyzes were determined using five different batches of certified organic, organic (without certification seal) and conventional, each one analysed in triplicate immediately after the fluid extract was obtained.

Quality parameters

All the analyses were performed according to AOAC (2005). Results were expressed as means±SD where all the analysis was done in triplicate.

The inversion of sucrose was carried out by acid hydrolysis, using 20 ml of the sample heated at 90°C, which received the addition of 1 ml of concentrated HCl and remained in a water bath for 30 min. Then, the mixture was cooled until room temperature and neutralized with sodium hydroxide (NaOH) solution 40%, which was verified using litmus paper strips. Subsequently, the solution was transferred to a 100 ml volumetric flask and the volume was completed with distilled water.

Total soluble solids (°Brix) were measured using a refractometer at 25°C accurate to two decimals, making readings on two or three drops of juice from the sample. Results were expressed in °Brix. Density was determined with picnometer at the temperature of 25°C. Total titratable acidity was determined by volumetric neutralization using, typically, 0.01 N NaOH and using phenolphthalein as an indicator (pH = 8.1 to 10.0). For lime and orange samples, it was used as a solution of 10% and for apples as a solution of 5%. The total acidity was expressed as the predominant acid in food.

Vitamin C (ascorbic acid) was determined by N-Bromosuccamide (NBS) method, where the titration flask initially contains some added potassium iodide (KI). The first small excess of NBS oxidizes some iodide ions to molecular iodine, which then reacts with more iodine (I) - to produce the triiodide ion (I^3). The polymeric amylose (starch) molecules wrap themselves around the threaded ions and form a blue colored aggregate to signal the end point. The results were expressed in g/100 g of citric acid.

Total antioxidant capacity of 1,1-diphenyl-2-picrylhydrazyl (DPPH)

The antioxidant activity of the samples was subjected to determination of the ability to scavenge the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical, according to the method described by Brand-Williams et al. (1995) modified by Miliauskas et al. (2004). Aliquots of sample (5, 10, 15 and 25 µL) were placed in different test tubes containing 3 ml of methanol solution of DPPH. Then, the tubes were left to stand under the light, for 30 min and finally, the absorbance was measured at 515 nm in a spectrophotometer (Turner™ model 340). The ability to scavenge the radical was calculated relating to control (no antioxidant) and expressed as a percentage, according to the following expression:

$$\% \text{ scavenging} = \frac{(\text{Absorbance of control} - \text{Absorbance of sample}) \times 100}{\text{Absorbance of control}}$$

Statistical analysis

Data are shown as mean values ± standard deviation of five independent experiments done in triplicate (n = 5). Statistical comparisons were carried out by ANOVA and post hoc Tukey´s test using GraphPad Prism. Differences were considered significant when p<0.05.

RESULTS AND DISCUSSION

Physico-chemical analysis

Lime (Citrus aurantifolia (Christm) Swingle)

The results of total titratable acidity were 5.46 ± 0.05 g% for conventional samples and 5.72 ± 0.14 g% for organic samples. Soluble solids were 6.64 ± 0.20 ºBrix and 8.15 ± 0.10 ºBrix for conventional and organic samples, respectively. These results disagree with those observed by Rangel et al. (2011) that evaluated the contents of ascorbic acid, minerals, sugars, total soluble solids, pH, titrateble acidity, and juice yield of the acid lime juice, cv.*Tahiti,* from conventional and organic biodynamic production systems. In this study the conventional acid lime showed higher values of titratable acidity and soluble solids. Statistical analyses indicated no significant differences between conventional and certified organic samples for total titratable acidity; however, the soluble solids content of the organic group was higher than that of the conventional group (Table 1).

The soluble solids content and titratable acidity of lime conventional samples presented mean values lower than organic samples. This probably is due to the fact the composition and fruit flavor can be modified by the intensity of sunlight and the use of pesticides (Mattheis and Fellman, 1999).Intense sun rays over the fruit can influence total soluble solids, but not total titratable acidity, but phosphorus fertilization, for instance, may lead to a reduction of total acidity and soluble solids (Rangel et al., 2011).

There were no significant differences (p > 0.05) among the values of density and ascorbic acid in lime samples. These results are higher with those observed by Esch et al. (2010) determined by the vitamin C content of conventionally and organically grown fruits by cyclic voltammetry. This study reported values of vitamin C content of 26.2 mg/100 g for conventional and 34.5 mg/100 g for organic lemons.

The vitamin C content in fruit and vegetables can be influenced by some factors such as: genotypic differences, pre-harvest conditions, maturity stage, harvest methods, and post-harvest handling system. In citrus, vitamin C concentration decreases with ripening. However, vitamin C content is higher in mature fruit than in green fruit because the fruit juice volume and fruit size increase in mature fruit. The vitamin C content of citrus juice increases with potassium soil fertilization and decreases with high nitrogen fertilization (Lee et al., 2006).

The total sugar content and °Brix of organic samples differed significantly from the conventional samples. Moreover, this study reported values of vitamin C content of 26.2 mg/100 g for conventional and 34.5 mg/100 g for organic. (Table 1). The results for soluble solids are discordant from those obtained by Rangel et al. (2011), who found higher soluble solids content in fruits from the conventional system.

In general, comparative studies between physical and chemical characteristics of diverse vegetables grown under organic and conventional, have shown variable results, requiring further studies. Therefore, it will be possible to conclusively state whether there are differences in nutritional quality between organic and conventional systems or not (Barret et al., 2007).

Orange (*Citrus sinensis* (L.) *Osbeck*)

Statistical analyses indicated no significant differences

Table 1. Physico-chemical analysis of conventional and organically grown of Lime (*Citrus aurantifolia* (Christm) Swingle)

Parameter	Sample	Acidity (g%)	Total sugar (g%)	Density (g/cm^3)	Brix (º)	Ascorbic Acid (mg%)
Organic	**O1**	5.76 ±0.05	2.32 ± 1.05	1.215	7.95	29.26 ± 1.58
	O2	6.14 ± 0.19	2.39 ± 0.08	1.226	8.35	37.64 ± 1.99
	O3	5.44 ± 0.06	2.22 ± 0.01	1.28	7.95	48.07 ± 2.49
	O4	5.79 ± 0.27	2.22 ± 0.05	1.01	8.35	20.95 ± 0.78
	O5	5.46 ± 0.13	2.32 ± 0.02	1.22	8.15	42.27 ± 3.95
	Mean ±SD	**5.72 ± 0.14[a]**	**2.29 ± 0.24[a]**	**1.19 ± 0.10[a]**	**8.15 ± 0.10[a]**	**35.64 ± 2.16[a]**
Certified Organic	**O1**	5.44 ± 0.06	2.34 ± 0.12	1.28	9.47	48.07 ± 2.49
	O2	5.79 ± 0.27	2.40 ± 0.63	1.22	8.16	46.78 ± 0.39
	O3	5.46 ± 0.13	2.57 ± 0.08	1.01	9.47	42.27 ± 3.95
	O4	5.47 ± 0.06	2.48 ± 0.16	1.03	8.16	39.75 ± 1.97
	O5	5.46 ± 0.13	2.55 ± 1.01	1.03	9.47	50.90 ± 1.57
	Mean ±SD	**5.42 ± 0.13[b]**	**2.47 ± 0.40[a]**	**1.10 ± 0.13[a]**	**8.95 ± 0.72[a]**	**45.55 ± 2.07[a]**
Conventional	**O1**	5.87 ±0.06	1.07 ± 0.03	1.21	6.83	27.16 ± 1.45
	O2	5.95 ±0.06	1.65 ± 0.03	1.22	6.43	36.19 ± 1.95
	O3	5.13 ± 0.06	1.07 ± 0.03	1.11	6.68	52.53 ± 2.74
	O4	4.76 ± 0.02	1.65 ± 0.03	1.02	6.43	29.74 ± 0.60
	O5	5.57 ± 0.06	1.07 ± 0.03	1.29	6.83	51.81 ± 6.40
	Mean ±SD	**5.46 ± 0.05[b]**	**1.30 ± 0.03[b]**	**1.17 ± 0.11[a]**	**6.64 ± 0.20[b]**	**39.49 ± 2.63[a]**

Data represent mean ± SD values of triplicate experiments. Tukey–Kramer Multiple Comparison test; Different letters indicate statistically significant differences at the 0.05 level.

between orange samples for density and ascorbic acid (Table 2). Masamba and Nguyen (2008) reported values of 43.4 mg/100 g and 51.8 mg/100 g of vitamin C for conventionally and organically grown oranges, respectively. According to Esch et al. (2010), the levels found was approximately half that amount, showing 27.7 mg/100 g in conventionally grown oranges and 26.2 mg/100 g in organically grown oranges. In this study values of 35.49 mg/100 g in conventionally grown oranges and 39.21 mg/100g in organically grown were detected.

Morillas Ruiz (2005) observed that ecological crops of tangerines and lemons presented higher antioxidant activity and vitamin C content than conventional fruit crops. However, the opposite was observed in oranges, in which the conventional crops had higher vitamin C content than the ecological ones. Worthington (2001) find that the vitamin C content of an organic fruit or vegetable is 27% more, on average, than a comparable conventionally grown fruit or vegetable. In other words, if an average conventional fruit or vegetable contains 100 mg of vitamin C, then a comparable organic one would contain 127 mg.

Total sugar content of organic orange showed higher mean values, when compared to conventional fruit and organic certified. Organic orange and organic certified showed higher mean values of acidity, when compared to conventional fruit. According to Camargo et al. (2011), the fruits cultivars presented the highest percentages in the organic system. For fruits to be well accepted for flavor, there must be a positive correlation among the °Brix and titratable acidity contents (Vangdal, 1985; Fellers, 1991).

Apple (*Malus domestica* Borkh)

According to statistical analysis there is no significant differences between conventional, certified organic and organic samples for total titratable acidity. According to Amarante et al. (2008), apples organic orchard had lower titratable acidity than fruit from conventional orchard. It can be stated that the fruits rapidly lose acidity with ripening, but in some cases there is a small increase in the values as ripeness advances (Camargo et al., 2011), and this might explain the low variation in acidity among the samples assessed.

No significant difference between samples of apple for density and ascorbic acid. Gazdik et al. (2008) reported apples to have a vitamin C concentration range of 11 to

Table 2. Physico-chemical analysis of conventional and organically grown of sweet orange (*Citrus sinensis* L. Osbeck).

Parameter	Sample	Acidity (g%)	Total sugar (g%)	Density (g/cm^3)	Brix (º)	Ascorbic Acid (mg%)
Organic	**O1**	0.60 ± 0.02	15.55 ±1.73	1.03	10.12	50.85±1.86
	O2	0.95 ±0.02	15.55 ±1.73	1.03	10.73	33.44±2.79
	O3	0.90 ± 0.05	12.85 ±0.00	1.04	8.15	32.65±1.13
	O4	0.42 ± 0.04	17.13 ± 0.00	1.05	10.12	39.92±0.91
	O5	0.42 ± 0.04	9.83 ± 0.00	1.01	10.73	38.81±0.68
	Mean ±SD	**0.66 ± 0.03^a**	**14.18 ± 0.69^a**	**1.03 ± 0.01^a**	**9.97 ± 1.06^a**	**39.13±1.47^a**
Certified Organic	**O1**	0.96 ± 0.01	7.47 ± 0.69	1.05	10.73	49.28±3.83
	O2	0.68 ± 0.02	10.46 ±0.31	1.04	10.11	38.24±1.39
	O3	0.62 ± 0.02	12.09 ± 0.00	1.03	9.46	33.64+0.91
	O4	0.45 ± 0.01	9.67 ± 0.00	1.03	8.15	35.49±1.52
	O5	0.68 ± 002	5.91 ± 0.13	1.05	8.81	39.8±1.34
	Mean±SD	**0.69 ± 0.01^a**	**9.12 ± 0.23^b**	**1.04 ±0.01^a**	**9.45 ±1.02^a**	**39.29±1.79^a**
Conventional	**O1**	0.63 ± 0.04	5.16 ± 0.42	1.05	10.73	43.88±1.86
	O2	0.76 ± 0.01	8.57 ± 0.36	1.02	10.12	45.68±0.92
	O3	0.96 ± 0.01	7.47 ± 0.69	1.05	10.73	49.28±3.83
	O4	0.68 ± 0.02	10.46 ± 0.31	1.04	10.11	38.24±1.39
	O5	0.62 ± 0.02	12.09 ± 0.00	1.03	9.46	33.64+0.91
	Mean ±SD	**0.45 ± 0.01^b**	**9.67 ± 0.00^b**	**1.03 ± 0.02^a**	**10.23 ± 0.52^a**	**35.49±1.52^a**

Data represent mean ± SD values of triplicate experiments. Tukey–Kramer Multiple Comparison test; Different letters indicate statistically significant differences at the 0.05 level.

19 mg/100 g. This is not comparable to our results which showed the average value of organic apples to be 39.14 mg/100 g and 26.58 mg/100 g for conventional apples. According to Esch et al. (2010), results found in the current literature regarding the ascorbic acid present in conventional and organic fruit are ambiguous. Other external factors such as the conditions of storage and transport, has considerable influence on the vitamin C content of fruit.

The total sugar content of most cultivars ranged between 24.67 and 17.90 g/100 g, but cultivars from organic growing reached higher values (Table 3). The acid content of organic and conventional cultivars were similar. The higher sugar content does not automatically mean sweeter taste of apples, because the amount of organic acids is also important for perceiving the sweetness (Veberic and Stampar, 2005).

Total soluble solids (°Brix) represent a group of substances present in apple juice, with a predominance of sugars, which are directly related to the density. In addition, other factors affect the production of sugar in the apple juice, especially the variables participating in photosynthesis as heat intensity, solar radiation and soil moisture. So warm climates during maturation apple favor production of sugar and therefore soluble solids (RIzzon et al., 2005).

Antioxidant activity

Regarding the antioxidant activity (Figure 1) there was an increase in the percentage of reduction of DPPH in samples of organic lime and oranges compared to conventional, with no statistical difference ($p > 0.05$) between no certified organic and certified organic fruit. Regarding the apple, conventional samples showed a higher percentage of reduction of DPPH. According to Tarozzi et al. (2005), the protective effect against oxidative damage was higher for organic oranges, probably due to higher levels of phenolic compounds, anthocyanins and ascorbic acid. Thus, it is recommended additional studies to confirm that the practice of organic farming is favorable to increase antioxidant activity of other varieties of fruits and vegetables. Blueberries produced from organic culture contained significantly higher amounts of phytonutrients than those produced from conventional culture (Wang et al., 2008).

Increase of phenolics in fruits of organic production was noticed in various fruit species. For example, there was a parallel increase in polyphenol content of organic

Table 3. Physico-chemical analysis of conventional and organically grown of Apple (*Malus domestica* Borkh).

Parameter	Sample	Acidity (g%)	Total sugar (g%)	Density (g/cm^3)	Brix (º)	Ascorbic Acid (mg%)
Organic	**O1**	0.32±0.03	26.33±4.10	1.05	14.581	62.37±7,44
	O2	0,32±0,02	27,23±1,18	1,01	13,953	35,21±3,10
	O3	0.26±0.01	24.26±0.89	1.05	13.953	69.01±9.14
	O4	0.26±0.01	20.69±1.15	1.01	8.155	45.73±4.65
	O5	0.28±0.00	24.85±1.66	1.01	8.155	39.82±3.56
	Mean ±SD	**0.29±0.01[a]**	**24.67±1.79[a]**	**1.02±0.02[a]**	**11.75±3.30[a]**	**39.14±5.57[a]**
Certified Organic	**O1**	0.39±0.01	11.48±2.18	1.1	15.207	64.38±4.33
	O2	0.35±0.00	22.38±0.96	1.05	15.207	18.04±3.67
	O3	0.34±0.00	24.81±1.13	1.04	11.407	17.48±2.23
	O4	0.21±0.01	18.81±1.71	1.04	12.048	42.88±5.79
	O5	0.29±0.00	17.41±3.27	1.01	12.686	25.58±2.42
	Mean ±SD	**0.32±0.00[a]**	**19.97±1.85[a]**	**1.04±0.03[a]**	**13.31±1.78[a]**	**33.67±3.68[a]**
Conventional	**O1**	0.21±0.00	11.48±2.18	1.1	15.207	59.88±1.57
	O2	0.26±0.00	23.60±1.82	1.04	11.407	14.23±2.02
	O3	0.35±0.01	18.81±1.71	1.05	13.953	18.40±1.33
	O4	0.33±0.02	18.10±1.96	1.03	12.686	22.15±1.81
	O5	0.38±0.00	17.54±2.59	1.02	15.829	18.25±2.53
	Mean ±SD	**0.30±0.00[a]**	**17.90±2.05[a]**	**1.04±0.03[a]**	**13.81±1.80[a]**	**26.58±1.85[a]**

Data represent mean ± SD values of triplicate experiments. Tukey–Kramer Multiple Comparison test; Different letters indicate statistically significant differences at the 0.05 level.

peaches and pears when compared to the corresponding conventional samples (Carbonaro et al., 2002). Veberic and Stampar (2005) observed that cultivars of organic production showed significantly higher contents of total phenolic compounds analyzed in the apple pulp compared to the apples of integrated production and resistant cultivars.

Organically, grown cultivars also showed higher contents of total phenolics in apple peel, although there were no significant differences between organically grown and intensively grown cultivars. The higher content of phenolics in apple pulp and peel is not only the consequence of the fact that organically grown apples are more exposed to biotic and abiotic stressors (diseases, pests, lack of mineral nutrients), but it appears also to be due to the selection of modern cultivars towards less tough fruits with not such astringent taste. The consumers prefer fruits with gentler taste (Lattanzio, 2003), which leads to choosing those modern cultivars that exhibit lower contents of some groups of phenolics.

Conclusion

Although the literature suggests differences in content of nutrients and other nutritionally relevant substances (nutrients and other substances) in organically and conventionally production, comparing fruits from both types of agriculture, few statistical differences were observed in acidity and total sugar for sweet orange (*Citrus sinensis* L. Osbeck) and lime (*Citrus aurantifolia* (Christm) Swingle). The differences detected in content of nutrients and other substances between organically and conventionally produced crops and livestock products are biologically plausible and most likely relate to differences in crop and soil quality. However, antioxidant capacity tended to be higher in plants grown using organic agriculture, with higher concentrations in the plant fractions most exposed to the environment. The literature suggests that the exposure of plant foods to stressful situations could modulate the synthesis of defense substances such as polyphenols, that reflects in a higher antioxidant capacity. However, the results showed distinct profiles according to the plant food analysed, suggesting that modulation of these parameters due to alterations in the cultivation practice is unique to the specific species and cultivar of vegetables.

Authors' contributions

CBDS and RLS, performed experiments and summarized

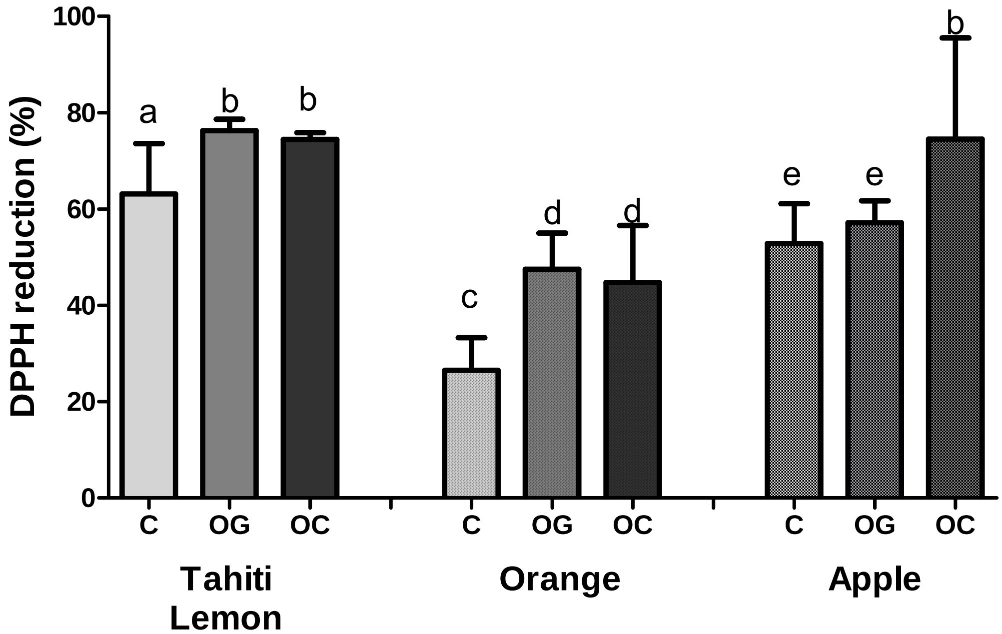

Figure 1. Comparison of the antioxidant activity of Tahiti lemon, orange and apple conventional (C), organic (OG) and certified organic (OC). Tukey–Kramer Multiple Comparison test; Different letters indicate statistically significant differences at the 0.05 level.

the data; TAJ, BDS, RLS and MSEM designed experiments; TAJ, BDS and RLS, MSEM, wrote the paper; all authors have read and approved the final manuscript.

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