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# Phenolic compounds and antioxidant capacity of Brazilian mango (*Mangifera indica* L.) varieties

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**Abstract**

Phenolic compounds and antioxidant activities of four mango varieties cultivated in Brazil were analyzed. The profile of flavonol-*O*-glycosides and xanthone-*C*-glycosides was characterized in pulps from Haden, Tommy Atkins, Palmer, and Ubá cultivars and in the agro-industrial residues from Ubá variety by LC-ESI-MS analysis. The first three varieties were collected from conventional production, whereas Ubá was obtained from organic production. The total phenolic content of the peels and seed kernel extracts was analyzed utilizing Folin-Ciocalteu's reagent. The aqueous-methanolic extracts of pulp, peel and seed kernels were analyzed for antioxidant activity (AA) by free radical-scavenging and reducing power. A total of 12 flavonoids and xanthones were identified in the pulps, peels and seed kernels, with larger amounts of these compounds being present in the organically grown Ubá variety. The Ubá mango pulp presented higher AA and the peel and seed kernel extracts showed higher AA than did a commercial standard.


*Keywords:* Antioxidant capacity; Flavonols; Xanthones; *Mangifera indica* L.; Agro-industrial residues

## 1. Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruits worldwide in terms of production and consumer acceptance (FAO, 2005). It is a rich source of antioxidants (Kauer & Kapoor, 2001; Kim, Brecht, & Talcott, 2007), including ascorbic acid (Franke, Custer, Arakaki, & Murphy, 2004), carotenoids (Godoy & Rodriguez-Amaya, 1989), and phenolic compounds (Berardini, Carle, & Schieber, 2004; Berardini et al., 2005a; Schieber, Ullrich, & Carle, 2000). Among the latter, flavonol and xanthone glycosides, as well as gallotannins and benzophenone derivatives, have been demonstrated to be present mainly in the peels and seeds, and pronounced intervarietal differences have been observed in terms of the quantitative composition of these compounds (Berardini, Knödler, Schieber, & Carle, 2005b; Berardini et al., 2004, 2005a; Schieber, Berardini, & Carle, 2003). The presence of phenolic compounds in the human diet is associated with protective effects against some chronic-degenerative diseases related to oxidative stress (Manach, Williamson, Morand, Scalbert, & Rémésy, 2005). Flavonols have potent antioxidant (Pannala, Chan, O'Brien, & Rice-Evans, 2001), anticarcinogenic (Peng, Dixon, Muga, Smith, & Wargovich, 2006), and antiatherogenic activities (Kim, Liu, Guo, & Meydani, 2006). Mangiferin, a xanthone-*C*-glycoside, has attracted intense interest for its variety of pharmacological properties, including antioxidant (Sánchez et al., 2000), antitumor and antiviral (Guha, Ghosal, & Chattopadhay, 1996) activities.

Brazil is one of the major mango exporting countries (FAO, 2005) and has a great potential for expanding its market, since the climatic conditions allow cultivation

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throughout the year by the use of flower induction techniques. The mango varieties Haden, Tommy Atkins and Palmer are outstanding in the domestic and foreign markets for fresh consumption, as they present the quality attributes demanded by consumers. Apart from these cultivars, some mango varieties grown in Brazil display a fruit size and peel colour that do not meet the required characteristics demanded by the market for *in natura* consumption. However, since some of these varieties show excellent sensorial properties, they are highly valued for processing into products such as juice, nectar and pulp. Among them, the variety Ubá has been used on a large scale by the agroindustry in the state of Minas Gerais in Brazil. A severe problem associated with the mango processing industry is the production of large quantities of by-products, in particular peels and seeds. These by-products have been shown to constitute a rich source of polyphenolics which could be used as nutraceuticals and/or natural antioxidants to replace some synthetic food additives (Balasundram, Sundram, & Samman, 2005; Peschel et al., 2006; Schieber et al., 2003), and as cancer-preventing agents (Okonogi, Duangrat, Anuchpreeda, Tachakittirungrod, & Chowwanapoonpohn, 2007).

Considering the economic importance of Brazilian mangoes, it is surprising that studies on their phenolic composition and antioxidant activities are rather limited. Recently we found significant differences in the total content of ascorbic acid, β-carotene and total phenolics among four mango varieties cultivated in Brazil (Ribeiro, Queiroz, Queiroz, Campos, & Pinheiro-Sant'Ana, 2007). Therefore, the objective of this work was to characterize the profile of phenolic compounds of extracts from pulp, peel and seed kernel of four mango varieties cultivated in Brazil employing sophisticated analytical techniques, and to determine the antioxidant properties of these extracts using the DPPH· assay and the reducing power test. The total phenolic contents for seed kernels and the peels of Ubá variety were determined. Three of the varieties investigated (Haden, Tommy Atkins and Palmer) were obtained from commercial conventional crops, whereas the variety Ubá was obtained from organic production.

## 2. Materials and methods

### 2.1. Chemicals

All chemicals and solvents used were of analytical grade. 1,1-Diphenyl-picrylhydrazyl (DPPH·), butylated hydroxyanisole (BHA), and gallic acid were purchased from Sigma (St. Louis, MO, USA). The Folin-Ciocalteu reagent was obtained from Merck (Darmstadt, Germany). Solvents used for HPLC analysis were of HPLC grade. Ultrapure water was produced using a Milli-Q system (Millipore, USA). All aqueous solutions were prepared in doubly distilled water. Standards used for identification and quantification purposes by HPLC were as follows: quercetin 3-*O*-galactoside, quercetin 3-*O*-glucoside, mangiferin (2-*C*-β-D-glucopyranosyl-1,3,6,7-tetrahydroxyxanthone; Extrasynthese, Lyon, France); quercetin (Roth, Karlsruhe, Germany).

### 2.2. Mango fruits

Four mango cultivars produced in the State of Minas Gerais, in the southeast of Brazil, were used in the study. The varieties Haden, Tommy Atkins and Palmer were collected in mid October, 2003, from commercial plantations in Janaúba city, Minas Gerais State, at the intermediate ripening stage. The fruits were used after they had completed ripening and presented the following indices of pulp quality: total soluble solids ranging from 14 to 16 Brix; colour characteristics ($L^*a^*b^*$ system) from 55.0 to 61.0 ($L^*$), 11.5 to 14.4 ($a^*$) and 40.0 to 50.0 ($b^*$). Pulp from 20 fruits of each cultivar was homogenized and pureed. The ripe pulp and residues (peels and seeds) of cultivar Ubá were purchased directly from the agro-industries (Ubá-Minas Gerais State) in January, 2004. Samples of seeds and peels were obtained from 50 kg of total residue, and were separated manually. Homogenized pulp and kernels were lyophilized. Peels and whole seeds were oven-dried at 65 °C (72 h) and then milled. The material was stored at −20 °C, and protected from light until analysis. The moisture content in the pulp was determined by the gravimetric method.

### 2.3. Determination of total phenolic content in the peel and seed kernel

The extracts containing the phenolic compounds were obtained as described by Bloor (2001). Peel and seed powders (0.5 g each) were extracted with 20 ml of methanol:water (60:40 v/v) as described above. The mixture was centrifuged and the supernatant was adjusted to 25 ml. An aliquot of this extract was used for the quantification of total phenolics.

The total phenolic content of the extract was determined colorimetrically, using the Folin-Ciocalteu method, as described by Singleton, Orthofer, and Lamuela-Raventós (1999). For this purpose, aliquots of 0.5 ml of the extract were added to 0.5 ml of Folin-Ciocalteu reagent, followed by addition of 0.5 ml of an aqueous 7.5% solution of sodium carbonate. The mixture was stirred and allowed to stand for 30 min. The absorbance at $\lambda_{max} = 765$ nm was measured using a model UV/VIS 1601 spectrophotometer (Shimadzu, Kyoto, Japan). A blank sample consisting of water and reagents was used as a reference. The results were expressed as milligrams of gallic acid equivalents (GAE) per kg of dry matter, utilizing a calibration curve of gallic acid in the concentration range 0.005–0.080 mg/l. The ascorbic acid reaction, prior to alkali addition, was monitored and the total phenolic values obtained were corrected.

### 2.4. Identification and quantification of flavonol and xanthone glycosides

The extraction and purification of flavonol and xanthone glycosides were carried out as described previously (Schieber et al., 2003). The separation of phenolic compounds was performed using an Agilent HPLC series 1100 system (Agilent, Waldbronn, Germany) equipped with ChemStation software, a G1322A degasser, a model G1312A binary gradient pump, a G1329/1330A thermoautosampler, a G1316A column oven, and a G1315B diode array detector. The column used was a 150 × 3.0 mm i.d., 4 μm C18 Hydro-Synergy (Phenomenex, Torrance, CA, USA) with a 4.0 × 2.0 mm i.d. C18 ODS guard column, maintained at 25 °C. The mobile phase consisted of 2% (v/v) acetic acid in water (eluent A) and of 0.5% acetic acid in water and acetonitrile (50:50 v/v; eluent B). The gradient programme was as follows: 0–25% B (15 min), 25–30% B (35 min), 30–80% B (10 min), 80–100% B (5 min), 100–0% B (0.5 min). Simultaneous monitoring was performed at 320 nm (xanthones) and 370 nm (flavonols) at a flow rate of 0.6 ml/min. Spectra were recorded from 200 to 600 nm (peak width 0.2 min).

LC–MS analyses were performed with the same HPLC system as described above connected in series with a Bruker (Bremen, Germany) model Esqire 3000+ ion trap mass spectrometer fitted with an ESI source. Negative ion mass spectra of the column eluate were recorded in the range of $m/z$ 50–2000. Nitrogen was used as the dry gas at a flow rate of 10.0 l/min and at a pressure of 60.0 psi. The nebulizer temperature was set at 365 °C. Collision-induced dissociation spectra were obtained with a fragmentation amplitude of 1.2 V (MS/MS) and 1.5 V (MS > 2) for flavonoids, 1.2 V (MS/MS) and 1.7 V (MS > 2) for xanthones, 1.2 V (MS/MS and $MS^3$) and 1.7 V ($MS^4$) for xanthone gallates, 1.5 V (MS/MS) for flavonoid aglycones. Helium was used as the collision gas ($1.2 \times 10^{-5}$ mbar).

### 2.5. Antioxidant activity

#### 2.5.1. General

Quantities of 0.5 g of lyophilized pulps were stirred with 10 ml of methanol: water (60:40 v/v) for 30 min at 180 rpm at 25 °C. Subsequently, the extract was centrifuged at 1000$g$ for 10 min. Peel and seed kernel extracts from the variety Ubá were obtained under conditions identical to those described for the pulps, using 0.05 g of peel or seed kernel powders and 10 ml of extraction solvent. After centrifugation, the extracts were diluted with the extraction solvent in order to obtain solutions of 1.0, 2.0, 3.0, and 4.0 ppm. Solutions (100 ppm) of BHA and gallic acid were prepared immediately before the analyses and were used as a control.

#### 2.5.2. 1,1-Diphenyl-2-picrylhydrazyl (DPPH·) radical-scavenging activity (RSA)

The ability of the extracts to scavenge DPPH· free radicals was determined by the method described by Blois (1958). Aliquots (100 μl) of test sample (pulp extract at 0.05 g/ml, peel and seed kernel extracts at 1000, 2000, 3000, 4000 and 5000 ppm), were mixed with 5.0 ml of 0.1 mM DPPH· in methanol. The control samples contained all the reagents except the extract or positive control antioxidant. After vortexing for 1 min, the reaction mixture was allowed to stand in the dark for 30 min at 25 °C. Subsequently, the absorbance was recorded at 517 nm. The percentage inhibition value was calculated according to the following equation:

$$\text{Scavenging activity } (\%) = \{(\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}})/\text{Abs}_{\text{control}}\} \times 100$$

Gallic acid and BHA were used as positive controls.

#### 2.5.3. Reducing power test (RP)

The reducing power of the extracts was measured as described by Oyaizu (1986). The reaction mixture contained 1.0 ml of extract (from pulp, peel and seed kernel residues), 1.0 ml of 0.2 M phosphate buffer (pH 6.6) and 1.5 ml of potassium ferricyanide (1%, w/v, in water). The control contained all reagents except the sample extracts. The mixture was incubated at 50 °C for 30 min and the reaction was stopped by addition of 1.5 ml of trichloroacetic acid (10%, w/v, in water), followed by centrifugation at 980$g$ for 10 min. Aliquots of 2 ml of the supernatant were mixed with 2 ml of distilled water and 0.5 ml of ferric chloride (0.1%, w/v, in water) and the absorbance was measured at 700 nm, using a Hitachi U-2000 spectrophotometer, against blanks that contained all reagents except the sample extracts.

### 2.6. Statistical analysis

Tests were run in triplicate. Statistical analyses were conducted using the Statistica software, version 6.0. Differences between sample means for the total phenolic and ascorbic acid concentrations were determined by analysis of variance at $p < 0.05$. Linear regression was used to verify the correlation between the total phenolic and ascorbic acid contents and antioxidant activities in the extracts.

## 3. Results and discussion

### 3.1. Total phenolic content in the peels and seed kernels

The total phenolic contents for seed kernels and the peels of Ubá variety were 82,540 and 57,240 mg/kg of dry matter, respectively (Table 1). These values correspond to approximately 8–6% in relation to the dry matter. The total phenolic content in the peels of Ubá variety peel was higher than amounts described for apple peels (3.3% w/w), analyzed by Folin-Ciocalteu reagent and also expressed as GAE units (Wolfe & Liu, 2003). The concentrations of phenolic compounds in the seed kernels and peels were 4.6 and 7.3 times higher, respectively, than those in the pulp (Ribeiro, Queiroz, Queiroz, Campos, &

Table 1
Total phenolic content in the peel and seed kernels of Ubá variety

| Residue | Total phenolics (mg GAE $kg^{-1}$ dm) | Concentration (%) |
|---|---|---|
| Peel | 57,240 | 5.72 |
| Seed kernel | 82,540 | 8.25 |

GAE, gallic acid equivalents; dm, dry matter.

Pinheiro-Sant'Ana, 2007), making these residues promising sources of polyphenolics.

### 3.2. Identification and quantification of flavonol and xanthone glycosides

The characterization of polyphenolic compounds in the pulps, peel and seed kernel of the mango cultivars was carried out using HPLC–DAD–ESI–$MS^n$ techniques previously described (Schieber et al., 2003). A typical chromatogram of the phenolic compounds extracted from mango peel is presented in Fig. 1. The identities of several compounds were confirmed by comparison of the data with those obtained for standard compounds listed in the experimental part. The corresponding UV–Vis and mass spectrometric data for the 12 compounds identified were obtained and used in the structural characterization (Table 2). The data obtained were in agreement with those reported by Schieber et al. (2003). Mangiferin, isomangiferin, quercetin 3-*O*-galactoside, quercetin 3-*O*-glucoside, quercetin 3-*O*-xyloside, quercetin 3-*O*-arabinopyranoside, quercetin 3-*O*-arabinofuranoside, quercetin 3-*O*-rhamnoside, kaempferol 3-*O*-glucoside and quercetin were unambiguously identified. Compounds **3** and **4** were tentatively identified as mangiferin gallate and isomangiferin gallate. The contents of the flavonol and xanthone glycosides in the pulps, peel and seed kernel are shown in Table 2. Besides the peel sample, only the pulp of the cultivar Ubá showed the complete profile of xanthone and flavonol glycosides; however, their contents were low compared to those found in the peels. The highly characteristic profile of quercetin monoglycosides, which was found in our previous investigations, (Berardini et al., 2004; Schieber et al., 2003) was also confirmed in this study. However, the contents of quercetin 3-*O*-glucoside exceeded those of quercetin 3-*O*-galactoside, which has rarely been found (Berardini et al., 2004).

Mangiferin was present in the pulps of the varieties Haden, Tommy Atkins and Ubá (2.9, 2.2 and 12.4 mg/kg of dry matter, respectively), whereas it could not be detected in Palmer pulp. It was also found in appreciable amounts in the seed kernel and peel of the Ubá variety (46.5 and 199 mg/kg of dry matter). Isomangiferin was detected only in the pulps of Tommy Atkins and Ubá, and in the peels of Ubá. Quercetin 3-*O*-glucoside was identified in the pulps of Haden and Uba, and in much larger quantities in the peels of Uba. The total contents of quercetin 3-*O*-glycosides (13.4 mg/kg of dry matter) and xanthone-*C*-glycosides (19.3 mg/kg of dry matter) in the pulp of the Ubá cultivar are close to the levels found in the pulp of Haden cultivar originating from Peru (16.2 and 12.2 mg/kg of dry matter, respectively) (Berardini et al., 2005a). Differences in the profile and contents of flavonols and xanthones in the pulp of mango varieties from different countries were also reported in another study, in which mangiferin was detected in five out of nine cultivars analyzed, and quercetin was only found in one of the samples (Berardini et al., 2005a). Other flavonol and xanthone glycosides were identified only in the pulp and peels of the Ubá cultivar. The peels of the Ubá cultivar proved to be a rich source of mangiferin and quercetin glycosides, with contents of 270 and 785 mg/kg of dry matter, respectively. Kaempferol 3-*O*-glucoside was also detected at a concentration of 35.3 mg/kg of dry matter. The amounts of mangiferin and quercetin glycosides found in the peel of Ubá cultivar were within the range observed (32.2–1428 and 180–3600 mg/kg dry matter, respectively) for the lyophilized peels of 14 mango varieties from different regions of the world (Berardini et al., 2005a). The presence of large quantities of flavonols and xanthone glycosides in the peels of Ubá cultivar justifies further studies to evaluate its suitability as a commercial source of such bioactive compounds. The main reason to exploit the potential use of the Ubá mango peel is the environmental consequence caused by

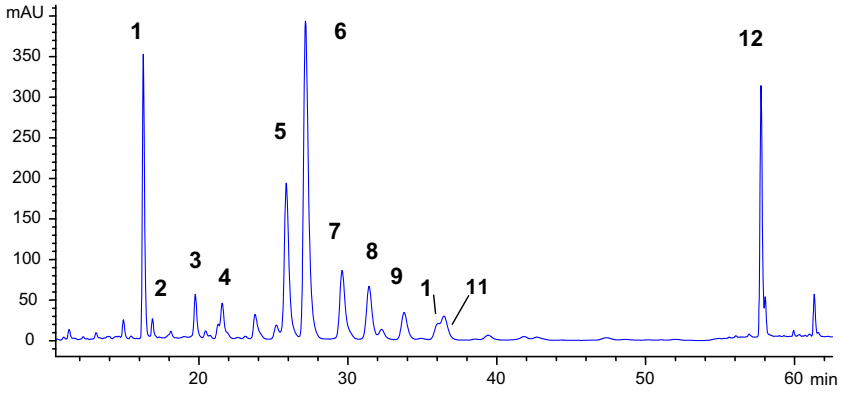


Fig. 1. Separation of xanthone *C*- and flavonol *O*-glycosides extracted from mango peel (cv. Ubá) by HPLC (370 nm). For peak assignment see Table 2.

Table 2
Contents (mg/kg dry matter) of flavonol and xanthone glycosides in peel, pulp and seed kernel of different mango cultivars

| Peak | $[M-H]^-$ ($m/z$) | Compounds | Mango pulp | | | | Seed kernel | Peel |
|---|---|---|---|---|---|---|---|---|
| | | | Haden | Tommy Atkins | Palmer | Ubá | Ubá cultivar | |
| 2 | 421 | Mangiferin | 2.9 ± 0.1 | 2.2 ± 0.1 | ND | 12.4 ± 0.3 | 46.5 ± 4.7 | 199 ± 5.3 |
| 2 | 421 | Isomangiferin[a] | ND[d] | 0.5 ± 0.0 | ND | 1.1 ± 0.1 | ND | 16.4 ± 2.9 |
| 3 | 573 | Mangiferin gallate[b] | ND | ND | ND | 1.3 ± 0.0 | ND | 28.0 ± 1.0 |
| 4 | 573 | Isomangiferin gallate[b] | ND | ND | ND | 4.5 ± 0.0 | ND | 26.9 ± 0.7 |
| 5 | 463 | Quercetin 3-*O*-gal | ND | ND | ND | 2.5 ± 0.2 | ND | 151 ± 12.3 |
| 6 | 463 | Quercetin 3-*O*-glc | 0.6 ± 0.0 | ND | ND | 6.3 ± 0.4 | ND | 370 ± 25.6 |
| 7 | 433 | Quercetin 3-*O*-xyl[c] | ND | ND | ND | 1.7 ± 0.1 | ND | 84.4 ± 6.2 |
| 8 | 433 | Quercetin 3-*O*-arap[c] | ND | ND | ND | 1.2 ± 0.1 | ND | 64.8 ± 5.3 |
| 9 | 433 | Quercetin 3-*O*-araf[c] | ND | ND | ND | 1.2 ± 0.1 | ND | 35.0 ± 2.5 |
| 10 | 447 | Quercetin 3-*O*-rha[c] | ND | ND | ND | 0.5 ± 0.0 | ND | 15.8 ± 1.2 |
| 11 | 447 | Kaempferol 3-*O*-glc[c] | ND | ND | ND | 0.6 ± 0.0 | ND | 35.3 ± 2.7 |
| 12 | 301 | Quercetin | ND | ND | ND | 0.6 ± 0.0 | ND | 64.1 ± 1.6 |
| | | Total | 3.5 ± 0.1 | 2.7 ± 0.1 | 0.0 | 33.9 ± 1.3 | 46.5 ± 4.7 | 1091 ± 67.3 |

[a] Quantified as mangiferin.
[b] Quantified as mangiferin (including molecular weight correction factor).
[c] Quantified as quercetin 3-*O*-galactoside (including molecular weight correction factor).
[d] ND, not detected.

the generation of agro-industrial residue by factories making the juice. Similar to the results obtained for major antioxidant constituents (Ribeiro, Queiroz, Queiroz, Campos, & Pinheiro-Sant'Ana, 2007), the four mango varieties presented differences in composition of the minor antioxidant compounds.

These results are similar to those observed for citrus species that showed differences in the amounts of dietary phytochemicals (Abeysinghe et al., 2007).

### 3.3. DPPH radical-scavenging activity (RSA)

The pulp extracts from the four mango varieties showed significantly different values of DPPH radical-scavenging activities, ranging from 39.6% to 94.2% (Table 3). At a concentration of 0.05 mg/ml, the extract from the variety Ubá scavenged more than 94% of the DPPH radical, showing RSAs 1.8, 2.1 and 2.4 times greater than the extracts from Tommy Atkins, Haden and Palmer varieties, respectively. The antioxidants BHA and gallic acid were used as references. These compounds were tested at 100 ppm, which corresponds to the maximum concentration allowed by the Brazilian legislation for the use of only one synthetic antioxidant in the food industry, and it complies with the range allowed by the FDA for BHA addition in some types of food. Comparison of the radical-scavenging activity (RSA) test of pulp extracts with the antioxidant standards showed that all mango varieties had higher RSA than had gallic acid or BHA (Table 3).

The DPPH radical-scavenging capacity of peel and seed kernel extracts was dose-dependent in the concentration range used in the study (1000–5000 ppm), as presented in the Table 4. At concentrations $\geqslant$2000 ppm the peel extract showed significantly higher activities (minimum 1.3 times) than the seed extract. The higher activity of the peel extract can be attributed to a more elevated concentration of the antioxidant compounds (Table 2). Considering only the two groups of analyzed compounds, it is verified that the peel presented contents of xanthones and the flavonol

Table 3
Radical-scavenging activity (RSA) and reducing power (RP) of four mango pulp extracts and standard compounds

| Sample | RSA (%) | | RP ($A_{\lambda 700\ nm}$) |
|---|---|---|---|
| Ubá | 94.2 A | Ubá | 1.27 A |
| Tommy Atkins | 52.6 B | Palmer | 0.88 B |
| Haden | 44.3 C | Haden | 0.52 C |
| Palmer | 39.6 D | Tommy Atkins | 0.42 D |
| Gallic acid | 18.8 E | Gallic acid | 0.67 F |
| BHA | 7.70 F | BHA | 0.33 E |

Means in the column followed by the same letter are not significantly different by the Duncan test at 5% probability ($n = 3$); BHA, butylated hydroxyanisol.

Table 4
Radical-scavenging activity (RSA) and reducing power (RP) of peel and seed extracts (Ubá variety) at five concentrations, and of reference compounds

| Concentration (ppm) | Sample | RSA (%) | RP |
|---|---|---|---|
| 1000 | Peel | 23.0 ns | 0.60* |
| | Seed | 24.0 ns | 0.81* |
| 2000 | Peel | 53.3* | 0.79 ns |
| | Seed | 24.2* | 0.88 ns |
| 3000 | Peel | 60.3* | 0.88* |
| | Seed | 45.7* | 0.99* |
| 4000 | Peel | 89.0* | 0.95* |
| | Seed | 60.7* | 1.02* |
| 5000 | Peel | 89.1* | 0.97* |
| | Seed | 67.7* | 1.05* |
| 100 | Gallic acid | 18.8 | 0.63 |
| 100 | BHA | 7.70 | 0.33 |

For each concentration, * is significantly different by the $F$-test ($p < 0.05$); ns, differences not significant.

23.5 times greater than the kernel. The radical-scavenging activities of the extracts were higher than those of the commercial synthetic antioxidant BHA at all concentrations tested. At 1000 ppm, both extracts from the peel and seed kernel showed RSA activities similar to that of gallic acid at 100 ppm.

### 3.4. Reducing power (RP)

The RP of the mango extracts was measured by direct electron donation in the reduction of $[Fe(CN)_6]^{3-}$ to $[Fe(CN)_6]^{4-}$. The product was visualized by addition of free $Fe^{3+}$ ions after the reduction reaction, by forming the intense Prussian blue colour complex, $(Fe^{3+})_4[Fe^{2+}(CN^-)_6]_3$, and quantified by absorbance measurement at 700 nm (Oyaizu, 1986).

The values of absorbance at 700 nm for the pulp extracts of all four mango varieties (Table 3) revealed that all samples had a capacity to reduce iron(III), and the RP values of the four mango varieties were significantly different, ranging from 0.42 to 1.27. The RP of the extract from the Ubá cultivar was significantly higher than the other varieties.

The RP of the pulp extract from the Ubá cultivar was, respectively, 1.9 and 3.8 times higher than those of the synthetic antioxidants BHA and gallic acid. The extracts from the other three varieties had RP values higher than BHA at 100 ppm (1.2 and 2.7 times greater). Haden and Tommy Atkins had lower scores than gallic acid (0.6–0.8 times), whereas the variety Palmer showed a RP value significantly higher than that of gallic acid (1.3 times greater; Table 3).

Except for the variety Ubá, which had higher scores for radical-scavenging activity and RP as well as a higher phenolic content, a direct relationship between RSA and RP and total phenolic content of the mango pulps was not found. For example, Tommy Atkins presented the lowest total phenolic contents and had higher RSA activity than did the Palmer variety. Other high redox potential compounds could be present in the Tommy Atkins pulp, contributing to its antioxidant activity. The correlation coefficient ($R^2$) between antioxidant activity and total phenolics and ascorbic acid contents in the pulp was determined (0.66 in the RSA test and 0.38 in the RP test). These weak correlations could in part be explained by the fact that, not only is the total phenolic content important, but also the type of the compounds present could influence the results (Milos, Matelic, & Jercovik, 2000). RSA was strongly correlated with the ascorbic acid content ($R^2 = 0.94$). The RP of pulp extracts also showed stronger correlation ($R^2 = 0.72$) with the ascorbic acid content than with the total phenolic content. There was a difference in the classification order of varieties between the two antioxidant tests, as they evaluate different antioxidant properties (Table 4).

The reducing power of the peel and seed extracts of Ubá mango variety increased with the concentration (Table 4). For all tested concentrations, both extracts presented a RP significantly higher than BHA at 100 ppm. Seed kernel extracts also had higher scores (from 0.81 to 1.05) than had gallic acid (0.33) at the five tested concentrations. The RP of the peel extract at concentrations above 2000 ppm was significantly higher than the RP of both standard antioxidants; at 1000 ppm, the RP was similar to that of gallic acid at 100 ppm.

The different antioxidant potentials of mango varieties found in this work can be attributed, not only to genotype differences (Scalzo, Politi, Pellegrini, Mezzetti, & Battino, 2005), but also to agricultural practices (Wang, Zheng, & Galletta, 2002). The Ubá variety is organically cultivated using simplified management techniques (Ramos et al., 2005). Such conditions enable plants and fruits to use their own natural defence against biotic and abiotic stress, resulting in enhanced synthesis of secondary metabolites. This could increase the content of phenolic compounds, resulting in a fruit with better functional properties.

A comparative study involving yellow plums (*Prunus domestica* L.) from conventional and organic productions, provided evidence of higher concentrations of some antioxidant vitamins and phenolic compounds in the organically grown plums (Lombardi-Boccia, Lucarini, Lanzi, Aguzzi, & Cappelloni, 2004). Cultural system affected fruit quality and antioxidant capacity in strawberries (Wang et al., 2002). In the present work, a preliminary GC–MS qualitative analysis of extracts from the pulp of the cultivar Ubá revealed the presence of shikimic acid, a precursor of flavonoids, and also of protocatechuic acid (data not shown), which is considered a plant defence metabolite against fungi (Ghosal, Biswas, & Chattopadyay, 1978).

To the best of our knowledge, this is the first study to raise the question of possible differences in the antioxidant potential of mangoes proceeding from different agricultural systems.

## 4. Conclusions

In summary, the investigation of four mango varieties has demonstrated that the secondary metabolites content varies with the variety. A total of 12 flavonoids and xanthones were identified in the pulps, peels and seed kernels, with larger amounts of these compounds being present in the organically grown Ubá variety. Although the Ubá variety has a commercial value limited to Brazil, it proved to be particularly promising as a source of bioactive antioxidants. Its peels and seed kernels, rich in flavonoids and xanthones, could be industrially processed for the recovery of phenolic compounds, or they could be used in the formulation of animal food. Further studies aiming at the characterization of their physiological effects are required.

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