Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 110 (2008) 620–626
FOOD CHEMISTRY
www.elsevier.com/locate/foodchem

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

S.M.R. Ribeiro [a,*], L.C.A. Barbosa [b], J.H. Queiroz [c], M. Knödler [d], A. Schieber [d,e,*]

[a] *Department of Human Nutrition, Federal University of Viçosa, Av. Peter Rolfs, Viçosa, MG 36571-000, Brazil*
[b] *Department of Chemistry, Federal University of Viçosa, Viçosa, MG 36571-000, Brazil*
[c] *Department of Biochemistry and Molecular Biology, Federal University of Viçosa, Viçosa, MG 36570-000, Brazil*
[d] *Section Plant Foodstuff Technology, Institute of Food Science and Biotechnology, Hohenheim University, Garbenstrasse 25, D-70599 Stuttgart, Germany*
[e] *Department of Agricultural, Food and Nutritional Science, University of Alberta, 410 AgIFor Centre, Edmonton, AB T6G 2P5, Canada*

Received 16 September 2007; received in revised form 18 December 2007; accepted 15 February 2008

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

* Corresponding authors. Tel.: +55 31 3899 3730; fax: +55 31 3899 2545.
E-mail addresses: sribeiro@ufv.br (S.M.R. Ribeiro), schieber@uni-hohenheim.de, schieber@ualberta.ca (A. Schieber).

0308-8146/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2008.02.067

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.