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# Total phenolics, antioxidant activity, and functional properties of 'Tommy Atkins' mango peel and kernel as affected by drying methods

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ABSTRACT

Mango processing produces significant amount of waste (peels and kernels) that can be utilized for the production of value-added ingredients for various food applications. Mango peel and kernel were dried using different techniques, such as freeze drying, hot air, vacuum and infrared. Freeze dried mango waste had higher antioxidant properties than those from other techniques. The ORAC values of peel and kernel varied from 418–776 and 1547–1819 μmol TE/g db. The solubility of freeze dried peel and kernel powder was the highest. The water and oil absorption index of mango waste powders ranged between 1.83–6.05 and 1.66–3.10, respectively. Freeze dried powders had the lowest bulk density values among different techniques tried. The cabinet dried waste powders can be potentially used in food products to enhance their nutritional and antioxidant properties.

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## 1. Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruits consumed in fresh or processed form globally. Storage under ambient or higher refrigerated temperature leads to substantial postharvest losses mainly due to moisture loss and/or microbial activity. Postharvest hot water quarantine treatment also accelerates the ripening process (Krishnamurthy & Subramanyam, 1970). In addition, a large number of non-marketable fruits are typically discarded thereby creating massive amounts of bio-waste. Commercial processing of mango into juice, nectar, pulp, puree, fruit leather, and jam produces 35–60% waste consisting of peel, kernel, and cull fruit (Larrauri, Ruperez, Borroto, & Saura-Calixto, 1996).

Mango waste contains significant amounts of phytochemicals, which makes it suitable to be processed for value-added applications in functional foods and nutraceuticals. Mango peel is rich in pectin, cellulose, hemicellulose, lipids, protein, polyphenols and carotenoids with excellent antioxidant and functional properties (Ajila, Bhat, & Prasada Rao, 2007). Mango peel flour has enormous potential as a functional ingredient in developing healthy food products such as noodles, bread, sponge cakes, biscuits or other bakery products besides using it in baby foods (Aziz, Wong, Bhat, & Cheng, 2012). Mango peel contains various classes of polyphenols, carotenoids, and vitamins with different health-promoting properties, mainly antioxidant activity (Manthey & Perkins-Veazie, 2009; Schieber, Berardini, & Carle, 2003). Mango peel fibre with high hydration capacities has potential in dietary fibre-rich foods preparation (Koubala, Germain Kansci, Catherine Garnier, Jean-François Thibault, & Marie-Christine Ralet, 2013). Mango kernels are rich sources of gallic acid, ellagic acid, ferulic acid, cinnamic acids, tanins, vanillin, coumarin, and mangiferrin, all having potential to act as a source of natural antioxidants (Abdalla, Darwish, Ayad, & El-Hamahmy, 2007a; Soong & Barlow, 2006). Solvent extraction method produces extracts from mango bio-waste with high antioxidant capacity (Dorta, Lobo, & Gonzalez, 2012a). Dried mango peel and kernel products can improve the nutritional, functional and sensory properties, and oxidative stability of oil/oil-rich product (Abdalla, Darwish, Ayad, & El-Hamahmy, 2007b), however, the selection of a suitable drying method is important to minimize quality losses.

Mango waste contains high quantity of water and nutrients, making it susceptible to decomposition. This solid waste can be preserved for further food or other uses by drying. A range of drying techniques are used for dehydration, which have advantages and disadvantages over the others (Dev & Raghavan, 2012). Static or forced hot air oven-drying (70 °C) has been shown to impart the most negative effect on the antioxidant capacity of mango peel and seeds; however, freeze-drying did not cause such losses

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(Dorta, Lobo, & Gonzalez, 2012b). Waste drying needs cost effective techniques for commercially feasible processing without significantly compromising its quality. Our objective was to evaluate different drying methods for mango peel and kernel and assess their impact on nutrients, antioxidants and functional properties.

## 2. Materials and methods

### 2.1. Materials

Market-ripe mangoes (cv Tommy Atkins) were procured from a local market. Fruits were sorted for maturity and defects, followed by washing. The whole fruits were sanitized by dipping in Fruit & Vegetable Wash (3.75 g/L water, SC Johnson Professional, Sturtevant, WI, USA) solution for 5 min. Peel and stones were removed manually using stainless steel knives. The stones were opened to get kernels. Mango peel were cut into 5 mm strips whereas the kernels were cut cross-section wise into 5 mm thick slices before drying.

### 2.2. Chemicals

Analytical grade chemicals ascorbic acid; 2,6 dichloro indophenol sodium salt dye; sulphuric acid; hexane; sodium sulphate; methanol; Folin–Ciocalteu reagent; gallic acid; 2,2′-azinobis(3-ethylbenzo thiazoline-6-sulphonic acid) diammonium salt (ABTS); 2,2-diphenyl-1-picrylhydrazyl (DPPH); 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox); β-carotene; flourescein; 2,2′-azobis(2-amidino-propane) dihydrochloride (AAPH); sodium phosphate (mono, dibasic) were procured from Sigma–Aldrich (St. Louis, MO, USA). Meta-phosphoric acid, sodium carbonate, and potassium persulphate were procured from W.W. Grainger, Inc. (Lake Forest, IL, USA) and glacial acetic acid from EM Science (Gibbstown, NJ, USA). Unless noted otherwise, all extractions/dilutions were made using 80:20 methanol–water (methanol-80).

### 2.3. Drying of mango peels and kernels

The peels were cut into strips of 5 mm width and the kernels were cut into pieces of 5 mm width in a cross-section way. Mango peel and kernel pieces were spread in single layer for drying in different dryers. Four drying techniques were employed to process mango waste until their weight became constant or the product texture became brittle:

*Freeze drying/Lyophilization* – Peel and kernel samples were frozen (−20 °C) and dried in a pilot-scale lyophilizer (Vertis Company Inc., Gardiner, NY, USA) with the condenser temperature and chamber vacuum at −55 °C and 0.03 torr.

*Hot air dying* – Samples were dried in a cabinet convective-air dryer (Proctor and Schwartz Inc., Philadelphia, PA, USA) operated at 60 ± 2 °C with constant air circulation.

*Vacuum drying* – Samples were dried in a vacuum oven (Sheldon Manufacturing Inc., Cornelius, OR, USA) set at 60 ± 2 °C and vacuum was maintained at 500 mm Hg.

*Infra-red (IR) drying* – Samples were dried in a custom-made IR heating unit consisting of aluminium housing, with two 40-Watt IR bulbs mounted on a height-adjustable assembly. The samples were placed under the IR bulbs in round aluminium trays by arranging in a circle to allow uniform surface treatment. The distance between the IR source and the samples was 11 cm. The drying time was variable in different dryers; peels dehydrated in about 2 h in IR, 4 h in cabinet, 7 h in vacuum and 11 h in freeze drying, whereas kernels took approximately 3.5 h in IR, 8 h in cabinet, 13 h in vacuum and 17 h in freeze drying.

The dehydrated samples from all four methods were ground using a grinder (Toastmaster Inc., Columbia, MO, USA) to pass through US Sieve No. 40 (0.5 mm mesh size) and packaged in 3-mil polyethylene bags and stored at −20 °C until analysed.

### 2.4. Ascorbic acid, total carotenoids, and total phenolics

Mango peel and kernel powders (∼2 g) were extracted with 25 mL extraction solution (15 g meta-phosphoric acid: 40 mL acetic acid: 3.7 mL conc. sulphuric acid: 450 mL water) after incubation in a water bath shaker at 22 ± 1 °C for 1 h. Extracted samples were centrifuged at 10,000 × g for 10 min and the supernatant was collected. The residues were extracted twice with 10 mL extraction solution by vortexing and centrifugation (10,000 × g, 5 min). The extracts were titrated against indophenol dye (50 mg dye, 42 mg $NaHCO_3$, and 200 mL water) until a pink colour persisted for 15 s. to determine ascorbic acid content (AOAC, 1991). For total carotenoids, mango powder (1 g) was extracted thrice with 10, 5 and 5 ml of hexane:acetone (7:3) solution using a pestle and mortar. The extracts were combined in a separating funnel and washed twice with sodium sulphate solution (5 g/100 mL). Non-aqueous phase was collected, the volume was made to 25 mL with hexane, and the absorbance read at 450 nm using a spectrophotometer (Milton Roy, Pennsylvania, Ivyland, USA) following Davis et al. (2007). Total carotenoids were determined as β-carotene equivalent using a standard curve prepared with pure β-carotene (0.5–2.5 μg/mL hexane).

The total phenolic content was determined as per the method described by Singleton and Rossi (1965). Briefly, mango peel or kernel powders (1.0 g) were mixed with 20 mL of methanol-80, agitated on water-bath shaker for 1 h followed by centrifugation (10,000 × g for 10 min). The supernatant was collected and the residues were re-extracted twice using 10 mL of methanol-80 by vortexing (1 min) and centrifugation (10,000 × g for 5 min). All three supernatants were combined, analysed for phenolics, and the results expressed as mg gallic acid equivalent (GAE)/100 g.

### 2.5. Antioxidant properties

The sample extraction protocol for antioxidant assays was the same as for total phenolics. The antioxidant capacities were expressed as μmol Trolox equivalent (TE)/g db in all of the following assays.

#### 2.5.1. ABTS Assay

The ABTS antioxidant activity of mango powder was carried out using the $ABTS^+$ radical cation decolourization assay with some modification (Re et al., 1999). Briefly, 7 mM ABTS solution and 2.45 mM potassium persulphate were mixed in 1:1 ratio and allowed to stand in the dark for 12–16 h to produce ABTS radical cation ($ABTS^+$) stock solution. This solution was further diluted with methanol-80 to attain absorbance of 0.700 ± 0.020 at 734 nm. The $ABTS^+$ working solution (3 mL) and 30 μL of blank, standard or sample were mixed and the absorbance was measured at 734 nm after 6 min using a spectrophotometer. The blank was run with methanol-80; a standard curve was prepared using Trolox solution (0.3–1.5 mM).

#### 2.5.2. DPPH Assay

The radical scavenging activity of mango powders was determined using DPPH solution in methanol following the method of Brand-Williams, Cuvelier, and Berset (1995). Briefly, one part of stock solution of DPPH (0.24 g/100 mL methanol) was diluted with ten parts methanol-80 to get working solution having an absorption of 1.10 ± 0.02 at 515 nm. Blank, standard or samples (0.6 mL) and 3.0 mL of DPPH working solution were mixed, kept in the dark

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