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Antioxidant properties, total phenolics, and quality of fresh-cut 'Tommy Atkins' mangoes as affected by different pre-treatments

M. Siddiq [a,*], D.S. Sogi [a,b], K.D. Dolan [a,c]

[a] Department of Food Science & Human Nutrition, Michigan State University, East Lansing, MI 48824, USA
[b] Department of Food Science and Technology, Guru Nanak Dev University, Amritsar 143 005, India
[c] Department of Biosystems & Agricultural Engineering, Michigan State University, East Lansing, MI 48824, USA

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ABSTRACT

Fresh-cut processing of mangoes have not been explored on a scale similar to other tropical fruits. This study assessed the effect of different pre-treatments and storage on total phenolics, antioxidant properties, and selected quality characteristics of mango cubes treated with: ascorbic acid + citric acid + $CaCl_2$ (AA–CA–Ca), sodium acid sulfate (SAS), and 5-min infrared heat (IR-5). Phenolics content of the untreated cubes was 21.16 mg GAE/100 g on day-0, whereas treated samples had higher contents – 70.82, 40.58, and 25.98 mg GAE/100 g in AA–CA–Ca, SAS, and IR-5 samples, respectively. Similarly, antioxidant activities (ABTS, DPPH, FRAP, ORAC) generally increased with all treatments, this effect was more pronounced with AA–CA–Ca. Total phenolics and antioxidant activities were stable during 12-day storage at 4 °C. Cubes treated with AA–CA–Ca showed consistently better color and firmness than the control and other two treatments. Storage time and treatments showed a mixed trend on pH, soluble solids, acidity, and sugar-acid ratio.

1. Introduction

Minimally-processed or fresh-cut fruits and vegetables have been one of the fastest growing sectors of the food industry in recent years (Jang & Moon, 2011; Rojas-Grau, Oms-Oliu, Soliva-Fortuny, & Martin-Bellose, 2009). Currently, melons, apples, pineapples, fruit mixes, and fruit trays are the commonly available fresh-cut fruit options. The share of fresh-cut mangoes in this market segment is relatively very small. The popularity of tropical fruits in North American and European markets presents an excellent opportunity for the introduction and growth of fresh-cut mango products on a greater scale. The market potential is evident from an increase in the U.S. per capita mango consumption in the last two decades, from 0.25 to 0.92 kg (USDA-ERS, 2011).

The use of fruits, such as mangoes, as a source of certain phytochemicals (carotenoids, phenolics, and flavonoids) has health-promoting effects due to their action as natural antioxidants (Saxena, Bawa, & Raju, 2009) by acting against free radicals generated by lipid peroxidation. Phenolics play an important role as aroma constituents in fruits (Saxena et al., 2009). Mango fruit is a good source of many of these health beneficial phytochemicals and devising appropriate fresh-cut processing techniques is critical to optimize better retention of such compounds (Dorta, Lobo, & González, 2012; Vergara-Valencia, 2007).

Fresh-cut processing induces chemical and biochemical changes besides increasing respiration rate of the produce. Cutting and peeling operations also increase surface area per unit volume that can results in solutes losses thereby compromising the quality of the fresh-cut products. Further, these tissue disruptions may enhance microbial proliferation besides accelerating water loss. All of these changes may be accompanied by degradation of bioactive compounds, browning, higher vitamin loss, rapid tissue softening, and a reduced storage life (Rico, Martín-Diana, Barat, & Barry-Ryan, 2007; Vamos-Vigyazo, 1981). Mango pericarp loses protection from physical, enzymatic, chemical and microbial deterioration on processing into the fresh-cut form. Thus, the quality factors for fresh-cut products depend not only on the visual color/appearance, texture/firmness, flavor, and safety but also on minimizing losses of nutritive value, bioactive compounds. Different pretreatments, packaging methods and storage conditions are recommended frequently to reduce or control these quality problems in fresh-cut products (Rico et al., 2007; Rojas-Grau, Tapia, & Martín-Belloso, 2008).

The quality-deteriorating enzymatic and chemical changes can be controlled by the application of innovative processing technologies besides traditional interventions. The past studies on fresh-

* Corresponding author. Tel.: +517 355 8474x151; fax: +517 353 8963.
E-mail address: siddiq@msu.edu (M. Siddiq).

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cut mangoes had focused mainly on anti-browning dips or sanitizer treatments (Gonzalez-Aguilar, Wang, & Buta, 2000; Robles-Sanchez, Rojas-Grau, Odriozola-Serrano, Gonzalez-Aguilar, & Martin-Belloso, 2009), and low-temperature or modified atmosphere storage (Sothornvit & Rodsamran, 2010). Mangoes are a rich source of bioactive compounds (β-carotene, ascorbic acid, and total phenolics) and possess high antioxidant capacity (Dorta et al., 2012; Maisuthisakul & Gordon, 2009; Vergara-Valencia 2007). However, there is limited documentation on the changes in the phenolic contents and antioxidant activity in fresh-cut mangoes.

Recently, sodium acid sulfate ($NaHSO_4$), a pH lowering compound, has been used to improve the quality and shelf life of apple slices (Fan, Sokorai, Liao, Cooke, & Zhang, 2009); these authors reported that unlike the sulfite compounds, SAS does not cause an allergic reaction in humans. Among other processing techniques, mild heat treatment also has shown some potential for application in fresh-cut fruits, either in the form of hot water dips (Lamikanra & Watson, 2007) or infrared surface application (Sogi, Siddiq, Roidoung, & Dolan, 2012). The present study was designed with the main objectives of comparing the effect of sodium acid sulfate and infra-red mild heat treatment with traditionally used ascorbic–citric acid dips on the fresh-cut mango cubes and monitoring changes in total phenolics, antioxidant activity, and selected quality characteristics during storage at 4 °C.

2. Materials and methods

2.1. Materials

'Tommy Atkins' mangoes of large size were procured from a local source at early ripe stage in term of red color development and firmness. Fruits were sorted for any defects, washed in water, and followed by a 5-min sanitizer dip, in Fruit & Vegetable Wash (SC Johnson Professional, Sturtevant, WI, USA), at 3.75 g/l water to give 150 mg/kg free chlorine. Mangoes were cut into 15 × 15 × 15 mm cubes manually using stainless steel knives. Polyethylene film bags (0.0508 mm thick, 150 × 100 mm) with 2 micro-holes were used for packaging the mango cubes after the treatments.

Analytical grade chemicals: methanol; Folin–Ciocalteu reagent; gallic acid; 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS); 2,2-diphenyl-1-picrylhydrazyl (DPPH); TPTZ (2, 4, 6-tripyridyl-s-triazine); ferric chloride; 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox); flourescein; 2,2′-azobis(2-amidino-propane) dihydrochloride (AAPH); sodium acetate; sodium phosphate (mono, dibasic) were procured from Sigma–Aldrich (St. Louis, MO, USA). Sodium carbonate and potassium persulfate were procured from W.W. Grainger, Inc. (Lake Forest, IL, USA) and glacial acetic acid from EM Science/Merck KGaA (Gibbstown, NJ, USA).

2.2. Treatment of mango cubes

Three treatments were used to assess the antioxidants and quality of fresh-cut mangoes during storage: i) ascorbic acid, 1 g/100 ml + citric acid, 1 g/100 ml + $CaCl_2$, 0.5 g/100 ml (AA–CA–Ca); ii) sodium acid sulfate, 1 g/100 ml (SAS); and iii) 5-min infrared treatment (IR-5). For AA–CA–Ca and SAS application, mango cubes were dipped in respective treatment solution for 1 min with gentle shaking for uniform application. Thus treated cubes were allowed to drain in a colander for 2 min before packaging and storage. For the IR treatment, 20 cubes were placed in a custom-made IR heating unit consisting of aluminum housing, with two 40-Watt IR bulbs mounted on a height-adjustable assembly. Fruit cubes were placed in a circle under the IR bulbs in round aluminum trays to allow uniform surface treatment. The distance between IR source and samples was 11 cm and cubes were turned over after 2.5 min for a total treatment time of 5 min.

The treated fruit cubes were packaged in polyethylene bags (30 g each), sealed, and stored at 4 ± 1 °C for 12 days. Samples were analyzed for total phenolics, antioxidative properties (ABTS, DPPH, FRAP, ORAC), pH, soluble solids, acidity, color, and firmness at 4-day intervals during storage.

2.3. Total phenolics and antioxidant analysis

2.3.1. Samples extraction

Homogenized 2.5 g mango cubes were mixed with 20 ml of 7:3 ethanol–acetone solution, kept on water-bath shaker for 1 h and centrifuged at 10,000×*g* for 10 min. Supernatant was collected and residues were re-extracted twice using 10 ml of extraction solution by vortexing (1 min) and centrifugation at 10,000×*g* for 5 min. All three supernatants were combined for final analyses of total phenolics and antioxidant properties. All analyses were done using 4 replicates unless noted otherwise.

2.3.2. Total phenolics

Total phenolic content were determined following Singleton and Rossi (1965). Briefly, 0.5 ml of blank, standard or extracted sample from step (2.3.1.) and 0.5 ml Folin–Ciocalteu reagent (1:10) were mixed in test tubes by vortexing for 15–20 s. After 3 min, 1 ml saturated sodium carbonate (75 g/l) and 1 ml of distilled water were added. The reaction mixture was incubated in the dark for 2 h and its absorption was measured at 725 nm against de-ionized water using spectrophotometer. The blank was run with ethanol–acetone (7:3) and gallic acid (10–100 μg/ml) for the standard curve to calculate the total phenolics. The data was reported as mg gallic acid equiv. (GAE)/100 g fresh-weight (FW).

2.3.3. Antioxidant activity assay (ABTS, DPPH, FRAP, and ORAC)

ABTS assay: The trolox equivalent antioxidant capacity (TEAC) was carried out using $ABTS^+$ radical cation decolorization assay (Re et al., 1999), with some modification. Briefly, 7 mmol/l ABTS solution and 2.45 mmol/l potassium persulfate were mixed in 1:1 ratio and allowed to stand in the dark for 12–16 h to produce ABTS radical cation ($ABTS^+$). This solution was diluted with methanol (800 ml/l) to attain absorbance of 0.700 ± 0.020 at 734 nm. The $ABTS^+$ diluted solution (3 ml) and 30 μl of blank, standard or sample were mixed and the absorbance was measured at 734 nm after 6 min reaction using a spectrophotometer. The blank was run with ethanol–acetone (7:3). The standard curve was prepared using Trolox solution (0.3–1.5 m mol/l) for calculating antioxidant capacity. The antioxidant capacities of the samples were expressed as m mol Trolox equivalents (TE)/100 g FW for all assays (ABTS, DPPH, FRAP, and ORAC).

DPPH assay: Radical scavenging activity was determined using DPPH solution in methanol following Brand-Williams, Cuvelier, & Berset (1995). Briefly, stock solution of DPPH (2.4 g/l methanol) was diluted with methanol (800 ml/l) to get working solution (A_{515} ~ 1.1). Blank, standard or samples (0.6 ml) and 3.0 ml of DPPH working solution were mixed, kept in the dark for 20 min and absorbance was recorded. Blank (ethanol–acetone, 7:3) was used to calculate radical scavenging activity. Standard curve was constructed using 50–250 μmol/l Trolox solution.

FRAP assay: Ferric-reducing antioxidant power (FRAP) assay was carried out following Benzie and Strain (1996), with some modifications. Briefly, the FRAP reagent was prepared fresh for each analysis from 300 m mol/l acetate buffer (3.1 g $C_2H_3NaO_2.3H_2O$ + 16 ml $C_2H_4O_2$ per liter, pH 3.6), TPTZ (2, 4, 6-tripyridyl-s-triazine) solution (10 m mol/l in 40 m mol/l HCl) and ferric chloride ($FeCl_3.6H_2O$) solution (20 m mol/l, in distilled water) in the proportion of 10:1:1 (v/v), respectively. Extracted samples (3 ml) were taken in test tubes