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Chemical and sensory quality of fresh pomegranate fruits exposed to gamma radiation as quarantine treatment

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ABSTRACT

The U.S. Department of Agriculture in February 2012 approved the import of fresh pomegranates subjected to irradiation as a quarantine procedure with a minimum absorbed dose of 0.4 kGy against different pests. This study evaluated the application of different gamma-irradiation doses (0.4, 1, and 2 kGy) in fresh pomegranate fruits and their effect on the chemical and sensory characteristics. The total soluble solids, titratable acidity, and pH values remained unaffected up to 1 kGy treatment. Irradiation caused a significant decrease in the total anthocyanins and phenolic content. A strong positive correlation was observed among the antioxidant activities, total phenolics and anthocyanin contents. In general, a stronger preference was shown by sensory panelists for the juice from irradiated fruits. This study provides research-based information about the application of irradiation as a quarantine disinfestation treatment to enhance the marketing and consumer acceptance of pomegranates.

1. Introduction

Pomegranates (*Punica granatum* L.) are one of the important commercial fruits extensively cultivated in many tropical and subtropical regions of the world (Tehranifar, Zarei, Nemati, Esfandiyari, & Vazifeshenas, 2010). The fruit has wide consumer preference as the consumption of fresh arils or juice because of its exceptional and unique sensory and nutritional properties (Varela-Santos et al., 2012). The arils contain a considerable amount of polyphenols, polysaccharides, sugars, acids, vitamins, and important minerals (Al-Maiman & Ahmad, 2002). A growing number of scientific studies have highlighted the potential human health related benefits of pomegranate juice such as antiatherogenic, antioxidant, antihypertensive, etc. (Mena et al., 2011; Rajasekar, Akoh, Martino, & MacLean, 2012; Tehranifar et al., 2010; Varela-Santos et al., 2012; Zaouay, Mena, Garcia-Viguera, & Mars, 2012).

The fresh consumption of pomegranates has increased in Korea but local production, that covers an area of about 161.4 ha, is not enough to fulfil market demand (Shahbaz, Akram, Ahn, & Kwon, 2013). In the past few years, the United States (U.S.) has captured the major market share (97%) of all the imported pomegranates in the Korean market. The fresh pomegranates imported from the U.S. are preferred by consumers because of their uniformity and consistency in quality. The Korea Food and Drug Administration (KFDA) has been authorised to conduct inspections of pomegranate fruits upon arrival at ports in Korea. According to the KFDA established standards and phytosanitary import requirements, the imported fruits must contain proper labelling indicating sufficient information. In addition, pomegranates should not undergo any disinfestation treatment such as fumigation, etc. by importers to qualify for "organic certification" as Korean consumers perceive low-chemical products as healthy products (U.S. Agricultural Trade Office, 2010).

Pomegranate fruits have a high risk of infestation with sucking insects and mite pests during growth which deteriorates their quality and constrain the international trade (Ananda, Kotikal, & Balikai, 2009). According to pest risk assessment prepared by the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA, 2012), 25 quarantine pests including two mites (*Tenuipalpus granati* and *Tenuipalpus punicae*) could follow the pomegranate fruit pathway. The APHIS in February 2012 authorised the import of fresh pomegranates into the U.S. mainland from India to a minimum irradiation dose of 0.4 kGy as quarantine disinfection treatment. The recommended irradiation dose, along with standard postharvest processes, will help to effectively neutralise the concerned insect pests and mitigate the risks of their dissemination (USDA, 2012). The most feasible application of irradiation technology in agricultural products, including fruits, is probably quarantine disinfestation without significantly affecting the chemical or sensory attributes (Fields &

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White, 2002). However, research is required to determine the appropriate irradiation doses and their subsequent effects on different quality attributes in fruits. In general, the FDA restricts the maximum irradiation dose level to 1 kGy for disinfestation and delayed maturation in fresh fruits (Boylston, Reitmeier, Moy, Mosher, & Taladriz, 2002).

The aim of this study was to investigate the effect of gamma-irradiation, as a quarantine disinfestation treatment, on the chemical and sensory qualities of fresh pomegranate fruits. In addition, total polyphenols and antioxidant activities were assessed using two different radical scavenging assays. The results were used to test for correlations between different quality-related parameters.

2. Material and methods

2.1. Pomegranate fruits, irradiation, and juice extraction

This study was done using pomegranate fruits grown in California (California cultivar; U.S. origin) and freshly imported to Korea (December 2012). Seventy commercially available fresh pomegranates, packed in cardboard boxes, were purchased from a local market in Daegu, South Korea. The fruits were divided into four equal portions and labelled with the specific radiation dose. Approximately, 16 fruits were sampled for each irradiation treatment and kept overnight at 5 °C in the laboratory. The packed fruit samples were then irradiated at the Korea Atomic Energy Research Institute (Jeongeup, Korea) with doses of 0, 0.4, 1, and 2 kGy using a Cobalt-60 gamma-ray source (AECL, IR-79, MDS Nordion International Co. Ltd., Ottawa, Ontario, Canada).

The irradiation process was accomplished at room temperature with a dose rate of 1.5 kGy/hr. The absorbed doses (±5.6%) were calibrated by alanine dosimeters with a 5 mm diameter (Bruker Instruments, Rheinstetten, Germany) in which the free-radical signals were determined with a Bruker EMS 104 EPR analyzer (Bruker Instruments, Rheinstetten, Germany) (Shahbaz et al., 2013). After irradiation processing, the pomegranate fruits were taken to the laboratory and manually cut with a sterile sharp blade to separate the fleshy arils. Juice was extracted from the isolated arils using a solid fruit juice extractor (Juice Extractor, Model Le Duo, Magimix, France). The extracted juice was pour into labelled sterile glass bottles and immediately analysed or stored at 4 °C. The experimental juice samples were filtered with Whatman qualitative filter paper, Grade 4, before the chemical analyses. The pure juice samples were diluted at different proportions with distilled water for different analyses until the absorbance was within the linear range of the spectrophotometer (Optizen 2120UV, Mecasys Co. Ltd., Daejeon, Korea). All the analyses were independently repeated three times to ensure accuracy. All the chemicals used were of analytical grade and purchased from Sigma–Aldrich.

2.2. Chemical analyses

The titratable acidity (TA) of the juice was measured by titrating it against 0.1 N NaOH to the end point of pH 8.1, monitored with a pH meter. The results were expressed as percentage of citric acid. The pH measurements were performed using a digital pH meter (Orion 3 star, Thermo Electron Co., Waltham, MA, USA) at 21 °C. The total soluble solids (TSS) in the juice were determined with a digital refractometer (Master-M, ATAGO, Brix 0–32%, Tokyo, Japan) at 20 °C. The instrument was calibrated with distilled water before the analysis. TSS values were expressed as °Brix (Rajasekar et al., 2012).

The total anthocyanins content in juice samples was determined with the pH differential method using two buffer systems: potassium chloride buffer, pH 1.0 (0.025 M) and sodium acetate buffer, pH 4.5 (0.4 M) according to Giusti and Wrolstad (2001). Briefly, 1 mL of diluted juice was mixed with 4 mL of corresponding buffers. Absorbance was measured at two wavelengths, 510 nm and 700 nm, after 15 min of incubation in a spectrophotometer against distilled water as a blank. The total anthocyanins content was calculated by applying the standard formula. The values, three replications per sample, were expressed as mg cyanidin-3-glucoside per 100 mL of juice.

The juice colour measurements were done in a colorimeter (CM-3600d, Konica Minolta, Osaka, Japan) using the Hunter Lab scale ('L^*': Lightness; 'a^*': redness; 'b^*': yellowness) previously described by Rajasekar et al. (2012). The instrument was calibrated against a white reference plate provided with the chromameter between different readings. The quartz cell was filled with filtered juice and colour data were recorded with the Minolta Software Chroma control data system. The average values of 3 measurements were reported.

The amount of total sugars in the fruit juice was determined using a modified version of the phenol–sulphuric acid assay recently described by Nielson (2010). Accurately 1 mL of the diluted juice sample was mixed with 1 mL of 5% phenol solution and 5 mL of 96% sulphuric acid (rapidly added) in each tube. The tubes were vortexed and allowed to stand at room temperature for 20 min. The concentrated sulphuric acid converts all non-reducing sugars to reducing sugars, so the method determines the concentration of the total sugars present in the sample. A blank was prepared by substituting distilled water for the juice sample. The absorption of the characteristic yellow-orange colour produced as a result of the interaction between the sugars and the phenol was measured at 490 nm using a spectrophotometer. The typical colour of this reaction is stable for several hours. The concentration of the total sugars present in each sample was calculated by referring to a standard sucrose curve.

The content of the reducing sugars was measured with the Nelson–Somogyi method (Somogyi, 1952) with minor modifications. The method is widely used for the quantitative determination of reducing sugars in biological materials. Four types of required solutions were prepared according to standard procedures with high accuracy. Arsenomolybdate reagent was incubated at 37 °C for 24 h prior to use. The diluted juice sample (0.5 mL) was mixed with the different solutions as previously described. The absorbance of the blue colour was read at 520 nm with a spectrophotometer. The amount of reducing sugars present in the fruit juice sample was calculated from a standard curve graph drawn using a glucose solution as the standard. The average results for triplicate determinations were expressed as g/100 mL of juice.

2.3. Total phenolics content and antioxidant capacities

The concentration of the total phenolics was measured by the Folin–Ciocalteu reagent method recently described by Rajasekar et al. (2012). To each 50 μL of diluted juice, 0.5 mL Folin–Ciocalteu reagent and 1.5 mL of 7.5% sodium carbonate were added. The samples were allowed to stand at room temperature for 30 min incubated under dark conditions. The wavelength of spectrophotometer was fixed at 765 nm for the absorbance reading. Results were expressed as mg of Gallic acid/100 mL of juice using a gallic acid (0–0.1 mg/mL) standard curve.

Several assays were done to estimate the antioxidant activity in fresh fruits and their products. Most of the natural antioxidants are multifunctional; therefore, for a more reliable evaluation, it is important to perform different antioxidant activity assessments to give proper consideration to the various mechanisms of antioxidant action. In this study, DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid) methods were used to measure the antioxidant activity of