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Characterization of nutritional, organoleptic and functional properties of intermediate moisture shelf stable ready-to-eat *Carica papaya* cubes

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ABSTRACT

Papaya fruit is highly perishable resulting in around 25% postharvest losses which is further enhanced during storage and transportation. To prevent these losses intermediate moisture (IM) papaya cubes were developed using a novel combination technology including osmotic dehydration, blanching and infrared drying. These cubes were further hygienized by exposing to gamma radiation dose of 2 kGy. The final processed product could be stored up to 60 days at ambient temperature, whereas, the unprocessed freshly cut samples spoiled within 2 days. Nutritional analysis of IM cubes indicated nearly 5 fold increase in calorie value with significant increase in the per unit dry weight content of carbohydrate, protein, fibre, and functional bioactives such as ascorbic acid, carotenoids, and phenolics including flavonoids. The activity of oxidising enzymes, polyphenol oxidase and peroxidase, was reduced by 88 and 96%, respectively in IM papaya cubes. The functional properties in terms of antioxidant capacity and antimutagenic potential were improved. The processing ensured the microbiological safety of the product. Organoleptically the product was found to be well acceptable by the taste panellists. The findings thus could help reduce postharvest losses in papaya by providing a technology to make ready-to-eat (RTE) nutrient rich product.

1. Introduction

Papaya (*Carica papaya*) is a popular tropical fruit having production share of approx. 15% after mango (approx. 53%), and pineapple (approx. 26%). Annual production of papaya is approx. 11 million tons out of which approx. 86% is contributed by only ten countries (Evans & Ballen, 2012). India is its leading producer having annual production of approx. 4.7 million tons. It ranks fifth in papaya export after Mexico, Brazil, Belize, and Malaysia, and its export quantity is merely approx. 18,000 t. Indian export of papaya is limited to Gulf countries and The Netherlands. The major reason for marginal export is the highly perishable nature of the fruit, which is often susceptible to fungal attack during storage and transportation (Evans & Ballen, 2012). The softness occurring during ripening of the fruit further accelerate the spoilage. The shelf life of ripe papaya is limited to 4–7 days at 25 °C, and 2 weeks at 12 °C (Wu, Wu, & Wei, 2004). Storage below 10 °C causes chilling injury to the fruit. The total

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postharvest loss of papaya has been reported to be approx. 25%. This include losses at field level (approx. 1%), during transit (approx. 4%), ripening (approx. 8%), and at retail (approx. 11%) (Gajanana, Sudha, Saxena, & Dakshinamoorthy, 2010). The stringent selection of fruit for export further results in rejection which could be up to 30%. This results in dumping a large proportion of fruits which are indeed wholesome.

Hence to minimize such losses, there is an urgent need for a method which can extend the shelf life of papaya fruits while maintaining its wholesomeness and functional properties. Appropriate pre- and postharvest treatments, better handling, and storage practices could help in reducing these losses (Gajanana et al., 2010). The storage at modified atmosphere was reported to extend the shelf life of papaya for 14–21 days (Wu et al., 2004). The hot water treatment followed by radiation (750 Gy) treatment was reported to extend the shelf life of papaya by 8 days at 20 °C (Thomas, 1986). Packaging alone was not found to significantly improve the shelf life of the fruit. The minimally processed papaya cubes were reported to have shelf life of 1–2 days at ambient temperature, and 5–8 days at 8–10 °C (Wu et al., 2004; Alam, Kaur, Gupta, & Kumar, 2013). This is too short a period to make the process commercially viable. Processing into intermediate and low moisture value added products such as puree, jam, jelly, marmalade, tutti frutti, candy, pickle, papad, canned papaya, freeze dried papaya, and juice are viable options to reduce the postharvest losses. The United States (Hawaii and Florida), Brazil, South Africa, West Indies, Malaysia, and Taiwan are the major producer of such processed papaya products. However, many of those processing methods drastically modify the appearance, freshness and natural flavour of the fruit. Therefore, development of a process which can help in modify the fruit into a shelf stable ready-to-eat (RTE) product while retaining its quality attributes is an attractive alternative.

The physical processes like osmotic dehydration (OD) and blanching result in longer shelf-life of the product due to reduced moisture content (Moreno, Bugueño, Velasco, Petzold, & Tabilo-Munizaga, 2004). The OD treatment reduces the available water, whereas, blanching helps in reducing microbial load and inactivate enzymes responsible for quality deterioration (Levi, Cagel, & Juven, 1983). The OD and blanching can be done together by heating the sugar solution to accelerate dehydration (Saxena, Mishra, Chander, & Sharma, 2009). Among the conventional drying methods, infrared drying (ID) has been reported to be advantageous for better retention of color, texture and flavour of the processed products (Hebbar & Rostagi, 2001). Radiation treatment helps in reducing microbial burden and hence has been proved to be an excellent preservation method for various foods (Thomas, 1986). The current study was aimed to explore the use of combination treatments including osmotic dehydration, blanching and infrared drying to get intermediate moisture papaya cubes, which were packed and subjected to gamma irradiation for extension of shelf life and ensuring microbiological safety. The processed product was analysed for its nutritional qualities (calorie value and content of carbohydrate, protein, fat, ash, sugar and fibre), bioactive compounds (phenolics including flavonoids, ascorbic acid and carotenoid content), functional properties (antioxidant capacity and antimutagenic potential), reduction in activity of oxidising enzymes (polyphenol oxidase and peroxidase), and organoleptic properties.

2. Materials and methods

2.1. *Papaya cube preparation and gamma radiation treatment*

Fresh ripe papaya procured from a local market (4 kg) was washed, peeled, cut into cubical pieces (approx. 3 × 3 × 3 cm) and subjected to osmotic dehydration using sucrose solution at different concentrations (30, 40, or 50%) coupled with blanching at different temperature (70, 85, or 100 °C) for different times (10, 20 or 30 min). The cubes were later rinsed in potable water, air dried on muslin cloth for 1 h and further dried using an infrared dryer (Sakav, Shirsat Electronics, Mumbai, India) to reduce water activity in the range of 0.65–0.85. These intermediate moisture (IM) papaya cubes were packed (20 pieces; approx. 50 g/packet) in low density polythene packets (LDPE, thickness: 700 ga; water vapor transmission rate: 0.4 g/m^2/day; oxygen transmission rate: 1800 cm^3/m^2/day) and subjected to gamma radiation treatment at two doses 1, and 2 kGy in a cobalt-60 based Gamma Chamber at ambient temperature (26 ± 2 °C) (GC-5000, BRIT, Mumbai, India; source strength 60 kCi, dose rate 6.25 kGy/h) at Food Technology Division (FTD), Bhabha Atomic Research Centre (BARC), Mumbai, India. Non-processed fresh samples served as control. The radiation dosimetry was carried out using ceric-cerous sulfate dosimeters (ASTM Standard 51205, 2009). The overdose ratio was 1.25. The final processed samples were stored at ambient temperature and subjected to following wholesomeness analyses periodically during storage as discussed later.

2.2. *Physical and biochemical analyses*

The papaya cubes (10 g) were incubated in a hot air oven (Metlab Scientific Instruments, Mumbai, India) at 100 °C for 16 h and later weighed at every 1 h interval until no further decrease in weight was observed. The percentage decrease in weight was expressed as moisture content (IS7874-1 Indian Standard, 1990). Water activity was measured using a water activity meter (Aqua-labCX2T, Decagon Devices, USA). The moisture free residue was used for total fat determination. The fat was extracted using hexane in a Soxhlet extractor (BTI-41, Bio-technics, India), evaporated to dryness using a flash evaporator (Rotavapor R-205, Buchi, Switzerland), and the residual weight was expressed as percentage fat content (IS7874-1 Indian Standard, 1990). The dry residue left after hexane wash was used for crude fibre determination. It was refluxed with 200 ml of 0.25 N sulphuric acid (H_2SO_4) for 30 min, centrifuged (8000 × g, 10 min), and washed with water until the pH became neutral. The residue was again refluxed with 200 ml of 0.3 N sodium hydroxide (NaOH) solution for 30 min, and centrifuged (8000 × g, 10 min). The residue was washed with water, then with ethanol and finally dried in a hot air oven (105 °C). This dry weight when subtracted from the ash content gave the crude fibre content (IS7874-1 Indian Standard, 1990). The ash content was determined by ignition at 640 ± 20 °C for 6 h using a muffle furnace. The residual dry weight of the remaining grey mass was expressed as percentage ash content (IS7874-1 Indian Standard, 1990). The total protein content was determined by estimating the nitrogen content by Kjeldahl method (Kelplus Distyl EM, Pelican Equipments, India). The hot air oven dried papaya (1 g)