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Starch digestibility and predicted glycemic index in the bread fortified with pomelo (*Citrus maxima*) fruit segments

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ABSTRACT

The aim of this study was to evaluate the starch digestibility and predicted glycemic index in breads incorporated with pomelo fruit (*Citrus maxima*) segments. Volume of the white and brown breads supplemented with pomelo fresh segments increased, while the crumb firmness decreased. Bread with 20% fresh and 5% dry pomelo segments were sensorily acceptable. Bioactive components such as phenolics, flavonoids, naringin and carotenoids were retained to a greater extent in bread containing dry pomelo segments. The pomelo incorporated bread had higher levels of resistant starch fractions (3.87–10.96%) with low predicted glycemic index (62.97–53.13%), despite their higher total starch (69.87–75.47%) content compared to control bread. Thus pomelo segments in the product formulations lowered the glycemic index probably by inhibiting carbohydrate hydrolyzing enzyme activity which could be attributed to naringin. Hence fortified bread prepared from pomelo fruit segment is recommended to gain nutritional value and to decrease the risk of diabetes.

1. Introduction

Recently, Innovative food products with health benefits are increasingly becoming popular. Functional foods having a wide range of phytochemical profiles exhibit therapeutic activity against various health related disorders (Jenkins et al., 2008). The concept of diet-based therapies is aimed at maximizing the physiological benefits of various functional foods that require product development (Siró, Kápolna, Kápolna, & Lugasi, 2008). Foods having high protein and fiber content are now generally preferred by consumers to maintain their health and to act against many diseases like diabetes, obesity etc. So there is a new trend in the market to develop a product that has health benefits with acceptable sensory characteristics. Fruits are the basic components of human diet. Apart from providing energy for metabolic pathways they also act as precursor for protein synthesis and are a source of micronutrients like vitamins and minerals. Citrus fruits have high economic and medicinal value because of their multiple uses in the pharmaceutical, cosmetics, and food industries. These beneficial effects of citrus fruits are attributed to their chemical constituents like vitamins, dietary fiber, carotenoids, flavonoids, lipids, and essential oils. Citrus fruits are the utmost value fruit crop in terms of international trade and it has been recommended in herbal medicine as the source of diabetic medication (Andrade-Cetto, 1995).

Citrus maxima (Burm.) Merr., commonly known as pomelo is one of the largest underutilized citrus fruits belonging to the family Rutaceae. It has been reported to act as an appetizer, cardiac stimulant, stomach tonic and also as a remedy for fever, insomnia, and sore throat (Merina, Chandra, & Jibon, 2012). Further, it shows various pharmacological activities against oxidative stress (Mäkynen et al., 2013), inflammation (Shivananda, Muralidhara, & Jayaveera, 2013) and diabetes (Abdul, Shenoy, Hegde, Aamer, & Shabaraya, 2014). Even though several reports are available on the medicinal property of pomelo, there is a problem of its availability in large quantities. No commercial cultivation is undertaken due to the bitterness and astringent nature of the fruits. Because of this reason, it is less utilized by common people when compared to other fruits like orange, lime and tangerines.

Baking is a process that has been adopted for centuries and bakery products range from simple ingredients plain pastry to the cake having numerous components. Bread is one of the bakery products priced for its taste, aroma and texture. Bread making is a complex process which includes mixing, proofing and baking (Dewettinck et al., 2008). Bread is considered as a well-liked staple food consumed as part of the daily diet worldwide. Annually ~9 million kg of bread are produced (Heenan, Dutour, Hamud, Harvey, & Delahurry, 2008). The popularity of bakery products has

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contributed to increased demand for ready to eat and convenient food products such as bread, cakes, biscuits etc. So initiative has been taken in this research work to use pomelo as a food fortificant for increasing the consumption of this fruit for health benefits. This study was conducted to develop value added white bread and brown bread using pomelo fruit segments. The prepared products were further analyzed for their glycemic index, retention of naringin and other biofunctional components to ensure health promoting properties of pomelo retained even after processing.

2. Materials and methods

Commercial wheat flour (10.2% moisture, 0.51% ash, 10.6% gluten, 24 ml sedimentation value and 373 s falling number), compressed yeast (Tower brand, Mumbai), sugar powder and vegetable fat (Hindustan Unilever Ltd, Bangalore) were procured from local market.

2.1. Pomelo fruit processing

The *Citrus maxima* (pomelo) fruits were obtained from the local market of Mysuru, Karnataka, India during the month of February 2016. The fresh segments were separated from the fruit manually and dried in hot air oven at 35 °C for overnight to obtain dry fruit segments (residual moisture content of ~5%).

2.2. Bread making characteristics

Effect of fresh pomelo fruit segments (0%, 10%, 20% and 30%) and dried pomelo fruit segments (0%, 2.5%, 5% and 7.5%) on white bread and brown bread making characteristics was studied (Sudha & Leelavathi, 2008). The formulation used was flour: 100%, pomelo fruit segments, compressed yeast: 2.0%, vegetable fat: 1%, salt: 1.0%; sugar: 2.5% and water. All the ingredients were mixed in a Hobart mixer (Model N-50, Hobart, GmbH, Germany) with a flat blade for 4 min at 61 rpm. The dough obtained was fermented in a chamber maintained at 30 °C and 75% relative humidity (RH) for 90 min. After 90 min, the dough was remixed and relaxed for 25 min, molded, proofed for 55 min at 30 °C, 85% RH and baked for 25 min at 220 °C, cooled for physical and sensory evaluation. Part of the bread samples were dried at 45 °C for 5 h, cooled, homogenized and stored in poly propylene bags for various estimations.

2.3. Evaluation of breads

Weight of the breads was taken and volume of the loaves was measured by rapeseed displacement method (Sudha & Leelavathi, 2008). Bread crumb firmness, the objective measurement of texture was carried out in a texture analyzer (TAHDi, Stable Micro Systems, Godalming, UK) by the standard AACC (2000) (74–09) and 2.0 $mm.s^{-1}$ of pre-test speed and 1.67 $mm.s^{-1}$ of test speed were used. Force required to compress 25% of the bread slice was recorded using 35 mm diameter aluminium cylinder probe P-35. Objective evaluation of color of bread crumb was measured using the Hunter Lab Colour Measuring System (Colour Flex-EZ Hunter Lab, USA) with a reflectance attachment of illuminant G against a standard white board made of barium sulphate (100% whiteness). Bread slice (3 cm × 3 cm) was placed in the sample holder and the reflectance from the surface measured.

2.4. Sensory evaluation

A scorecard containing the description for the desirable (creamish white – color; crisp –texture; wholesome sweetish – taste) and undesirable (dull or dark color; soft or hard – texture; unpleasant taste) quality characteristics for various sensory attributes viz. color of crust and crumb, texture, mouthfeel and overall quality were given to the panelist consisting of men and women of 35–50 age group. The panelist was then asked to assign scores for each parameter as against the maximum scores given in the parenthesis using a 7-point hedonic rating scale: excellent – 7, very good – 6, good – 5, satisfactory – 4, fair – 3, poor – 2 and very poor – 1 (Rathi, Kawatra, & Sehgal, 2004).

2.5. Estimation of total sugars

The total sugars estimation in the samples was carried out using the method described by Albalasmeh, Berhe, and Ghezzehei (2013). An aliquot of 10 µl of sample was mixed with 300 µl of 5% aqueous solution of phenol. After 5 min of incubation 1.8 ml of concentrated sulfuric acid was added rapidly to the mixture. The test tubes were cooled and absorption read at 490 nm. Total sugar content of the sample was expressed as equivalent to mg glucose/g extract.

2.6. Estimation of reducing sugars

Reducing sugars were estimated based on the modified method of Miller (1959). The sample (150 µl) was mixed with 1 ml of DNS (3,5-Dinitrosalicylic acid) reagent in a test tube. The tubes were placed in a boiling water bath for 10 min and cooled for ten to fifteen minutes at room temperature. Each solution was then diluted with 2 ml of water, mixed thoroughly and absorbance was recorded at 540 nm using spectrophotometer (Helios Alpha, Thermo Electron Corporation, England, UK). Total reducing sugar content of the samples was expressed as equivalent to mg glucose/g extract.

2.7. Bioactive components

2.7.1. Estimation of total phenolic content

It was evaluated using a modified colorimetric method described by Henríquez et al. (2010). The reaction mixture was prepared by adding 100 µl of sample, 1.0 ml of Folin-Ciocalteau reagent and 2.0 ml of 10% sodium carbonate solution. The mixture was incubated for 60 min at room temperature, and the absorbance read at 765 nm using an UV–Vis spectrophotometer. The measurement was compared with standard gallic acid solution. The total phenolic content was expressed equivalent to mg gallic acid/g extract.

2.7.2. Estimation of flavonoids

Flavonoids were estimated by a modified method of Lallianrawna, Muthukumaran, Ralte, Gurusubramanian, and Senthil Kumar (2013). To 0.9 ml of sample, 75 µl of 5% $NaNO_2$ solution was added. After 5 min, 150 µl of 10% $AlCl_3{\cdot}6H_2O$ was added to the mixture, which was kept at room temperature for 5 more minutes. This was followed by the addition of 0.5 ml of 1 M NaOH and the total volume was made up to 2.5 ml with the addition of deionised water. The resulting solution was mixed well and immediately, the absorbance was measured at 510 nm on a UV–VIS spectrophotometer. For the blank, the extracts were replaced with an equal volume of deionised water. Total flavonoid content of the samples was expressed as the mg equivalent to catechin/g of extract.

2.7.3. Estimation of carotenoids

The experiment was carried out by the modified procedure of Carvalho et al. (2012). The sample (1 g) was homogenized in the dark (to avoid photolysis of carotenoids) with 20 ml of acetone.