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Physico-chemical and functional properties of gamma irradiated whole wheat flour and starch

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ABSTRACT

The present paper describes the studies carried out for effects of gamma irradiation on physico-chemical, thermal and functional properties of the whole wheat flour and the starch extracted post irradiation. The results showed that the proximate composition did not change with dosage. However, pasting properties for both flour and starch showed a significant ($p \leq 0.05$) decrease in peak viscosity, final viscosity, setback with increase in dosage. Amylose content increased significantly with dosage from 25.33 to 36.03%, bulk density of the flour did not change significantly. Swelling, solubility, syneresis and freeze thaw stability were improved with dosage. Water and oil absorption capacity of the flour increased significantly with dosage and was found in the range of 0.85–0.91 and 1.10–1.91 g/g of flour respectively. FTIR spectra pattern did not change with irradiation.

1. Introduction

Wheat (*Triticum* sp.) is an important cereal crop and ranks third in production after maize and rice around the globe. It is the second most important winter cereal in India after rice contributing substantially to the national food security by providing more than 50% of the total calories to the people who mainly depend on it. The annual global wheat production during the year 2014–15 was 717 million metric tonnes and is estimated to reach 720 million metric tonnes during 2015–16, among which India is expected to produce 95 million metric tonnes (International Grains Council, 2014; Sharon, Abirami, & Alagusundaram, 2014; State of Indian Agriculture, 2014–15). In India due to poor post-harvest management the losses account for about 500 billion per year only in case of cereal grains (Sharon, Abirami, Alagusundaram, 2014; Singh, 2010). Although, there are processes available to limit these post-harvest loses like fumigation, but the losses has not been prevented up to the mark, besides having disadvantages like toxic residues and change in organoleptic properties of the products. During past two decades several studies has been conducted on the effects of irradiation technology on the food products. As irradiated food is wholesome and nutritionally adequate, the FAO/WHO/IAEA Joint Expert Committee on Food Irradiation has unconditionally cleared foods irradiated up to 10 kGy as safe for human consumption (Campbell, Classen, & Ballance, 1986; Diehl, 1995, pp. 283–289; Marathe, Machaiah, Rao, Pednekar, & Rao, 2002). Several researchers have carried out work on the effects of gamma irradiation on the physico-chemical, thermal, functional and microbiological properties of the various cereal flours. Aziz, Souzan, and Azza (2006) reported that the gamma irradiation is very effective for reducing the microbial contamination of the cereals, although a significant decrease in the values of the thiamine and riboflavin content was observed, while in case of amino acids no significant decreasing trend was observed except methionine at a dosage of 10 kGy and higher. According to the literature, irradiation up to 70 kGy does not change concentrations of amino acids in various foods and feeds significantly (Diaa & El-Din Farag, 1999; Marathe et al., 2002; Seda, Mahmoud, Ibrahim, & EL-Niely, 2002).

The effect of gamma irradiation on the properties of starch (extracted from cereals, legumes or other underutilized crops) has been studied extensively. Several researchers have proposed that rice starch subjected to gamma irradiation decreases the gelatinization temperature, iodine affinity absolute density of the starch, viscosity (specific and intrinsic), swelling capacity and gelatinization enthalpy while as solubility, formic acid and reducing sugars content increased (Bao, Ao, & Jane, 2005; Lee et al., 2008; Wu, Shu,

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Wang, & Xia, 2002). The effect of gamma irradiation on the maize starch was studied by Bettaïeb, Jerbi, and Ghorbel (2014), Kang et al. (1999), Kollengode, Bhatnagar, and Hanna (1996), Lee, Ee, Chung, and Othman (2013), Liu, Ma, Xue, and Shi (2012), Rombo, Taylor, and Minnaar (2001). They revealed that the gelatinization temperature decreased with dosage along with gelatinization enthalpy, viscosity (peak, trough, final) while as solubility, amylose content, surface cracking of the starch increased with dosage.

Hussain et al. (2014), Sofi, Wani, Masoodi, Saba, and Muzaffar (2013) studied the effect of gamma irradiation on the starch extracted from beans. They found that the carboxyl content, solubility, freeze thaw stability, crystallinity and water absorption capacity increased while as syneresis, pasting properties and pH was reduced significantly.

Although, there has been work done to prove that low dose gamma irradiation prevent insect infestation in cereals, the aim of the present research was to explore the changes occurring in the physico-chemical, thermal, functional properties of the whole wheat flour (*Triticum aestivum* var WH-1021) and starch extracted post irradiation. The knowledge gained via this research is expected to be very useful for the wheat based industries.

2. Materials and methods

2.1. Materials

The wheat grains (*Triticum aestivum* var WH-1021) were procured from the local supplier and were then milled and ground in the local flour machine. The flour was then packed into airtight 300 g polyethylene pouches of food grade, purchased from the registered suppliers. All the chemicals used in this study were of analytical grade.

2.2. Gamma irradiation treatment

The packed whole wheat flour was subjected to five different doses of gamma irradiation viz, 0.5, 1, 2.5, 5 and 10 kGy using cobalt-60 as source irradiator at room temperature of 23 ± 2 °C. The non-treated sample was taken as control. The irradiation treatments were performed at Shri Ram Institute for Industrial Research, New Delhi, India.

2.3. Starch isolation

Starch was extracted post irradiation as per the method described by Sofi et al. (2013).

2.4. Physicochemical properties

2.4.1. Composition

Moisture, Ash, Fat, Protein and Crude fibre content were determined as per the AOAC standards (1990).

2.4.2. Color

Color of the samples was determined by Colorimeter (D25 LT Hunter Associates Laboratory, USA) on the basis of L, a and b values, where L value indicates the lightness, its value range from 0 to 100, a value gives the degree of the red–green color, with a higher positive a value indicating more red. The b value indicates the degree of the yellow–blue color, with a higher positive b value indicating more yellow (Kaur & Singh, 2007). The equipment was calibrated each time the irradiation dosage changed using white color standard tile.

2.4.3. Bulk density

The flour samples were gently filled into 10 ml graduated plastic cylinders. The bottom of the cylinder was gently tapped on a laboratory bench covered with foam several times until there was no further diminution of the sample level. The weight of the sample was calculated and the bulk density was calculated as weight of sample per unit volume of sample (kg/m^3).

2.4.4. Swelling index and solubility index

Pre-weighed centrifuge tubes were filled with flour samples (2.5 g) (M_0), dispersed in 30 ml of distilled water, while for starch 0.2 g (db) (M_0) was taken and dispersed in 10 mL distilled water. The suspension was vortexed for 1 min. All the suspensions were then heated in water bath for 30 min at 50 °C with regular vortexing after every 5 min. The samples were then cooled to room temperature and centrifuged at 4500 rpm for 15 min. The supernatant was decanted and the swollen starch was weighed (M_1). The supernatant was dried in pre-weighed moisture dishes at 110 °C for 12 h until constant weight (M_2) and then cooled to room temperature in desiccator, the gain in weight of the moisture dishes represents the solubility index (solid content). The gain in weight of the centrifuge tubes was expressed as swelling index. Similarly, solubility and swelling index were calculated at 60, 70, 80 and 90 °C for all the samples.

$$\text{Swelling index}(g/g) = M_1/M_0$$

$$\text{Solubility index}(g/100g) = M_2/M_0 \times 100$$

2.4.5. Light transmittance (%)

1% (w/w db) of the sample was cooked in the water bath for 30 min with continuous stirring using magnetic stirrer. The suspensions were then cooled and the samples were stored at refrigerated conditions for five days and the transmittance was calculated after every 24 h at 640 nm against the distilled water as blank using UV-spectrophotometer (Sican 2301, Inkarp Instruments Pvt. Ltd. Japan).

2.4.6. Syneresis

Syneresis was determined by the modified method of Wani et al. (2014). 6% (w/w db) of the sample for flour and 5% (db) for the starch were taken and heated at 90 °C for 30 min in a water bath (Khera Instruments Pvt. Ltd.) with constant stirring. The heated samples were stored in centrifuge tubes at refrigerated conditions (4 °C) for 5 days. Each day one sample from each treatment was subjected to centrifugation (3-18KS, Sigma Laborzentrifugen GmbH, Germany) at 4500 rpm for 10 min and the per cent of the water released represented the syneresis.

$$\text{Syneresis } \% = \frac{\text{Weight of water released}}{\text{Weight of gel}} \times 100$$

2.4.7. Freeze thaw stability

Freeze thaw stability of the starch extracted from the gamma irradiated flours were determined according to the procedure of Sofi et al. (2013).

2.4.8. Total amylose content

Total amylose content of the starch samples were determined according to the procedure described by Morrison and Laignelet (1983).