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Effect of gamma irradiation on the physicochemical properties of alkali-extracted rice starch

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HIGHLIGHTS

- Irradiation significantly decreased swelling power, syneresis and pasting properties of starch.
- Increase in water absorption capacity, carboxyl content and light transmittance took place with irradiation.
- SEM images revealed surface cracking of starch granules with increasing irradiation dose.
- No significant difference was observed in the X-ray diffraction pattern of irradiated starches when compared with non-irradiated starches.

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ABSTRACT

Starches isolated from two newly released rice varieties (K-322 and K-448) were subject to irradiation at 0, 5, 10, and 20 kGy doses. Comparative study between native (not irradiated) and irradiated starch samples was carried out to evaluate the changes in physicochemical, morphological and pasting properties due to gamma irradiation. Significant decrease was found in apparent amylose content, pH, swelling power, syneresis, and pasting properties, whereas carboxyl content, water absorption capacity, and transmittance were found to increase with the increase in irradiation dose. Granule morphology of native and irradiated starches under scanning electron microscope revealed that granules were polygonal or irregular in shape. The starch granules were somewhat deformed by gamma irradiation. X-ray diffraction pattern showed A type of pattern in native as well as irradiated starches.

1. Introduction

Rice (*Oryza sativa*) is the major cereal crop cultivated in the world and constitutes a staple food for several countries including India, China, Thailand, Philippines etc. In 2010, the total world rice production was estimated as 69,6324,394 t; India being one of the major producers has a major contribution of about 129,349,631 t (FAOSTAT, 2012). Starch is the main component of rice grains and is the major constituent of endosperm, the largest part of the grain. Starch is one of the most important functional biopolymers. The functional roles of starch in food products could be as a thickener, binding agent, emulsifier, clouding agent, or gelling agent. Native starches have certain limitations like low shear resistance, high retrogradation and syneresis thus, limiting their industrial use (Betancur and Chel, 1997). Therefore, starch is often modified by physical, chemical and enzymatic methods or a combination thereof, in order to obtain desirable functional properties for certain uses (Liu et al., 1997). Most of the modification techniques, such as pregelatinization, chemical crosslinking, oxidation etc., are often complex and time consuming. However irradiation treatments require minimal sample preparation, are fast, do not induce a significant increase in temperature and have no dependence on any type of catalysts (Farkas, 1998; Diehl, 2002). Irradiation has been shown to cause some structural and physicochemical changes in starchy foods such as rice, potato, cassava, and so on. It has been shown that the chemical bonds of starch can be hydrolyzed by gamma irradiation leading to degradation of the polymeric chain. Irradiation treatment of potato starch resulted in an increase in amylose content, increase in transition gelatinization temperatures (onset gelatinization temperature, peak temperature and conclusion temperature) and a decrease in pasting properties (peak viscosity, trough viscosity, break down viscosity

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and final viscosity) (Singh et al., 2011). Solubility increases and swelling power decreases were also reported in the study on corn and potato starches subjected to X-ray and electron beam irradiation treatment (De Kerf et al., 2001). Gamma irradiation treatment induced an increase in the proportion of small size starch granules in stored potato (Ezekiel et al., 2007) and the occurrence of deformed rice starch granules (Wu et al., 2002).

Although much work has been done in assessing the physicochemical and other functional and rheological properties of rice starch, but very less information on γ-irradiation treatment of rice starch to alter the properties of native starches is available. Modification of starches is an ongoing process as there are numerous possibilities resulting from these modifications. The purpose of the present work was to evaluate the effect of gamma irradiation on the physicochemical and functional properties of starch isolated from newly released rice varieties.

2. Materials and methods

2.1. Materials

Two newly released rice varieties (K-322 and K-448) were procured form Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar, Srinagar, J&K, India. Paddy samples were dehusked and polished utilizing the locally available milling facilities.

2.2. Starch extraction

Alkaline steeping method was used for extraction of starch (Song et al., 2006). The rice was soaked in distilled water for 4 hours and the softened rice grains were drained and soaked with 0.3% NaOH solution for 1 h. The grains were blended with alkaline solution for 5 min. The rice slurry was passed through screens. The starch suspension was allowed to stand until the crude starch precipitated. The supernatant was drained off and the sediment remaining was washed to remove the protein using 0.2% NaOH, until the yellow layer disappeared. The starch residue was then washed with distilled water, neutralized by 1 N HCl, again washed with distilled water, and centrifuged at $10{,}000 \times g$ for 10 min. Purified rice starch was dried at room temperature, finely powdered and stored in a desiccator until used.

2.3. Gamma-irradiation

Irradiation doses were given at Baba Atomic Research Centre, Srinagar, J&K, India using Panoramic Batch Irradiator. The starch samples (12% moisture content) were packed in polyethylene bags and irradiated using ^{60}Co gamma source at ambient temperature (20 ± 0.5 °C).The doses were controlled at 0 (control), 5, 10, and 20 kGy with a dose rate of 2 kGy/h. Irradiations were performed in duplicate.

2.4. Moisture content and apparent amylose content

Moisture content was estimated using moisture analyzer (Model MA 100, Sartorius Germany). Apparent amylose contents of the starch samples were determined by the method of Williams et al. (1970). A starch sample (20 mg) was taken, 10 ml of 0.5 M KOH was added and the suspension was mixed thoroughly. The dispersed sample was transferred to a 100 ml volumetric flask and the volume was made up to the mark with distilled water. An aliquot of the test starch solution (10 ml) was pipetted into a 50 ml volumetric flask and 5 ml of 0.1 M aq. HCl was added followed by 0.5 ml of iodine reagent. The volume was diluted to 50 ml and the absorbance was measured at 625 nm (UV–visible Spectrophotometer, Model U-2900 2JI-0003, Hitachi, Japan). The content of amylose was determined from a standard curve developed using standard amylose and amylopectin blends from potato starch.

2.5. Carboxyl content and pH

The carboxyl content was determined as per the procedure of Mattison and Legendre (1952). To 0.5–1.0 g of starch, 25 ml 0.1 N HCl was added and the mixture was allowed to stand for 30 min with occasional stirring. The slurry was filtered through a fritted glass crucible and washed with distilled water until it was free from chlorine. The starch was then transferred to a 500 ml beaker to which 300 ml distilled water was added. It was then boiled for 5–10 min for complete gelatinization, followed by titration with 0.1 N NaOH solution with phenolphthalein as indicator. A blank test was also performed with unmodified starch. Carboxyl content was calculated as follows:

$$\text{Milli} - \text{Eq. of acidity}/100\text{ g starch} = (A\text{–}B) \times N \times 100/W$$

where

A = titrate value for sample.
B = titrate value for blank.
N = normality of NaOH.
W = weight of dry sample in grams.

$$\text{Apparent \% carboxyl} = \text{milli-equivalents of acidity}/100\text{ g starch} \times 0.045$$

The pH of starch slurry (40% w/v) was determined using a digital pH meter calibrated at 25 °C.

2.6. Amylose leaching and swelling power

The amylose leaching of starch at 60 °C was measured according to the procedure of Chung et al. (2008). Swelling power of the starch samples were determined by using the modified method of Subramanian et al. (1994). Starch sample (M0) 0.6 g was mixed with 30 ml of distilled water and stirred at 90 °C on a magnetic stirrer. After 30 min stirring, the mixture was centrifuged at $1500 \times g$ for 30 min. The supernatant was carefully removed, and the swollen starch sediment was weighed ($M1$).

Swelling power was calculated from the equation given below:

$$\text{Swelling power (g/g)} = M1/M0$$

2.7. Water absorption capacity

Water absorption capacity (WAC) of the starches was determined as described by Mishra and Rai (2006) in triplicate using 2.5% starch suspensions at a temperature of 25 °C. Dried starch samples (0.125 g) were weighed into pre-weighed centrifuge tubes and 5 ml of distilled water was added. The samples were heated at the above temperature for 1 h with constant shaking and thereafter centrifuged for 15 min at $1500 \times g$. The free water was decanted and the tubes were allowed to drain for 10 min at a 45° angle. Subsequently the sample tubes were weighed, and the gain in weight was used to calculate the water absorption capacity.

2.8. Light transmittance

An aqueous starch suspension (1 g/100 g dry weight basis) was prepared by heating at 90 °C in a water bath for 30 min with constant stirring. The suspension was cooled for 1 h at 30 °C. The samples were stored for 5 days at 4 °C in a refrigerator and