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Physicochemical and structural evaluation of alkali extracted chickpea starch as affected by γ-irradiation

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ABSTRACT

In this study, starch isolated from chickpea was exposed to gamma-irradiation at 0, 4, 8 and 12 kGy doses. The irradiated starches were evaluated for their physicochemical, morphological and pasting properties. The results revealed significant ($p \leq 0.05$) reduction in apparent amylose content, swelling power, turbidity, syneresis, L (lightness) value, and pasting parameters whereas solubility and b (yellowness) value increased with increase in irradiation dose. X-ray diffraction showed C-type of crystallographic pattern. Relative crystallinity (RC) of irradiated starches was different at different irradiation doses. Prominent changes were recorded in the FT-IR spectra of irradiated starch samples with respect to intensity and shifting of major bands in specific regions. Analysis of O – H and C – H stretches, bending mode of water and glycoside bonds of irradiated starches revealed marked decrease in their absorbance intensities. Scanning electron microscopy revealed cracking and clumping of starch granules at elevated doses of gamma-irradiation. Radiation doses were negatively correlated to swelling power, pasting parameters (peak viscosity, hold viscosity, final viscosity, setback viscosity and pasting temperature), turbidity, syneresis and apparent amylose content except solubility.

1. Introduction

Gamma-irradiation is a high energy, ionizing, physical processing technology used to modify variety of polymers according to their desirable end uses. Long before there was a restricted use of this technology either to extend the shelf life or to ensure the safety of foods by reducing the spoilage or pathogenic microorganisms [1]. It is non-heat processing technique which induces no or negligible damage to the exposed food substance. The scope of gamma irradiation has widened in food applications from the past decade due to its various advantages over other methods of modification of biopolymers especially starches from different botanical sources. Modification by gamma irradiation among other physical methods is preferred because it is fast, low cost, environmental friendly and safe [2]. Wholesomeness and nutritional adequacy of foods is not compromised in case of this processing technology. The mechanism underlying the modification of starch is attributed due to the free radial species produced during the process of irradiation. These radical species thereby cleave the glycosidic bonds leading to the decomposition of starch component polymers to macromolecules with comparatively shorter chain lengths than their parent polymer chains [3]. The extent of their degradation is determined by irradiation dosage. Growing demand for modified polymers is gaining wider acceptance in the existing market scenario and therefore new sources of starches are being exploited to increase the spectrum of applications in this direction.

Chickpea (*Cicer arietinum* L.), an important legume, is a rich repository of starch. It contains on an average 17% protein, 70% carbohydrate, 5.3% fat and 3.9% fibre [4]. Carbohydrates (52.4–70.9%) represent the main fraction of chickpea of which major proportion (37.5–50.8%) is contributed by starch [5]. India stands first in the production of chickpea, followed by Australia, Turkey and Myanmar, with its total production of 988000 Mt [6]. Many studies have been conducted so far on gamma-irradiation of starch from different legume sources but to the best of our knowledge there is no such information available till now pertaining to the modification of chickpea starch by gamma-irradiation. The abundant production of chickpea in Indian subcontinent and non-availability of any report regarding irradiated chickpea starch were the two main factors responsible for drawing our attention towards the irradiation of chickpea starch. In this study, starch isolated from chickpea was irradiated at different doses and characteristics of the irradiated samples, preferably physicochemical, structural, and pasting as influenced by irradiation treatment were determined.

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The study was primarily intended to provide a firm base for further research with regard to chickpea starch and to elucidate its applications in wide variety of food systems in future.

2. Materials and methods

2.1. Materials

The grains of chickpea, for starch extraction, were purchased from the local market of Pondicherry. The grains were cleaned from damaged grains and other impurities manually prior to their use.

2.2. Starch preparation

Starch from chickpea grains was isolated using the modified method of Sun et al. [7]. Chickpea grains (250 g) were steeped in water containing 0.1% sodium sulphite for 12 h at 25 °C. The steeped water was drained off, and the soaked grains were ground in a laboratory blender. The slurry obtained was then diluted with sufficient distilled water, and the pH was adjusted to 10 using 0.5 M NaOH. The slurry was continuously mixed using magnetic stirrer for 1 h and then filtered through a 100 mesh sieve to separate the fibre. The filtered slurry was then centrifuged at 3000*g* for 30 min at 10 °C (Eppendorf Centrifuge 5810R made in Germany) and starch was obtained as white sediment.

2.3. Gamma-irradiation

The starch samples were packed in a polyethylene bags and irradiated using a ^{60}Co gamma source at ambient temperature (25 ± 0.5 °C). The doses were controlled at 0 (control), 4, 8, and 12 kGy with a dose rate of 2 kGy/h [8]. The doses were confirmed by Ceric-Cerous dosimeter. The maximum uncertainty of the dosimeter used was ± 3.5% at 95% confidence level.

2.4. Physicochemical properties

2.4.1. Chemical composition

Moisture, protein, fat, and ash were determined according to the methods of AOAC [9].

2.4.2. Color

Color of the starch was determined using Hunter Lab Colorimeter (D-25, Hunter Associates Laboratory, Ruston, USA) after being standardized using Hunter Lab color standards and L (lightness), a (redness to greenness) and b (yellowness to blueness) values were measured.

2.4.3. Amylose content

Apparent amylose content of the starch samples was determined by the method of Williams et al. [10].

2.4.4. pH of starch suspension

The pH of each starch suspension was determined using a digital pH meter (Hanna, USA). Starch samples for pH measurements were prepared by suspending 1 g of starch in 25 mL of water at 25 °C and agitating for 5–10 min [11].

2.4.5. Solubility and swelling power

Swelling power and solubility of the starch samples were determined by using the modified method of Subramanian et al. [12]. Starch 0.6 g (M_0) 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*g* for 30 min. The supernatant was carefully removed, and the swollen starch sediment was weighed (M_1). The supernatant was evaporated and dried at 105 °C in an oven until constant weight (M_2). Swelling power and solubility was calculated from the equations given below.

$$Swellingpower\ (g/g) = \frac{M_1}{M_0}$$

$$Solubility\ (\%) = \frac{M_2}{M_0} \times 100$$

2.4.6. Turbidity

Turbidity of starches from chickpea was measured in triplicate, as described by Perera and Hoover [13].

2.4.7. Syneresis

Syneresis was determined by the modified method of Singh et al. [14]. It was recorded in triplicate using 3% aqueous starch suspension made by adding 25 mL of distilled water to 0.75 g (db) starch in a screw capped centrifuge. The suspension was heated in a boiling water bath for 30 min with constant stirring and then cooled to room temperature. After cooling, the starch pastes were reweighed to determine the amount of starch paste and then placed in freezer at −20 °C for 48 h. After the freezing period, the samples were placed in 25 °C for 1.5 h to thaw and equilibrate. Syneresis was measured in triplicate as percentage water released after centrifuging at 6000*g* for 10 min.

$$Syneresis\ (\%) = \frac{Weight\ ofwater\ released}{Weight\ of\ gel} \times 100$$

2.5. Pasting properties

Pasting characteristics of starch were determined by the method as described by Gani et al. [8] using a rapid visco-analyzer (RVA Starch Master TM, Newport Scientific, Warriewood, Australia).

2.6. X-ray diffraction and crystallinity

X-ray diffraction analysis of samples was performed using X-ray diffractometer (Shimadzu, XRD 7000) operated at 30 mA (tube current) and 40 kV (target voltage) with Cu Kα filtered radiation. The scanning range for 2θ values was set from 10° to 75° to cover all significant diffraction peaks of sample crystallites with a scan speed of 2°/min. The total area under the curve and the area under each prominent peak was determined using Origin Pro software package and the percentage crystallinity was estimated by using the following formula:

$$Relative\ crystallinity\ (\%) = \frac{Area\ under\ peaks}{Total\ area} \times 100$$

2.7. Fourier transform infrared (FTIR) spectroscopy

The FTIR spectra of native and irradiated chickpea starches were recorded on an FT-IR Spectrophotometer ALPHA (BRUKER Optics Inc, MA, USA) at room temperature. The starch powder was blended with potassium bromide (KBr) powder and pressed into tablets before measurement. Calibration was carried out using KBr as a blank and the spectra were recorded within the range of 400–4000 cm^{-1}

2.8. Scanning electron microscopy

Morphology of the starch samples was analyzed by scanning electronic microscopy (Hitachi, S-3400N, and Tokyo, Japan). The samples were mounted on aluminium stubs using double sided adhesive tape to which the samples were fixed and afterwards were