International Journal of Biological Macromolecules 97 (2017) 426–433

Contents lists available at ScienceDirect

International Journal of Biological Macromolecules

journal homepage: www.elsevier.com/locate/ijbiomac

Physicochemical, thermal and functional properties of gamma irradiated chickpea starch

Khalid Bashir*, Manjeet Aggarwal

National Institute of Food Technology Entrepreneurship and Management, Kundli, Haryana 131028, India

ARTICLE INFO

Article history:
Received 25 July 2016
Received in revised form 1 October 2016
Accepted 5 January 2017
Available online 6 January 2017

Keywords:
Chickpea starch
Gamma irradiation
Physicochemical properties
Pasting properties
Gelatinization

ABSTRACT

The study was conducted to evaluate the effect of gamma irradiation (0, 0.5, 1, 2.5, 5 and 10 kGy) on physicochemical, functional and thermal properties of chickpea starch. Results revealed that the pasting properties showed a significant ($p \leq 0.05$) decrease in peak viscosity, final viscosity, setback viscosity, trough viscosity and pasting temperature in dose dependent manner. Swelling, solubility index, oil absorption capacity and water absorption capacity increased significantly with dose, while as syneresis decreased with dose. Gelatinization temperatures T_o, T_p and T_c decreased significantly with dose. X-ray diffraction showed a characteristic C type pattern of the starches and the crystallinity decreased with dose. Scanning electron microscopy revealed small oval shaped starch granules and slight surface fissures were seen in the irradiated starch treated with 5 and 10 kGy.

1. Introduction

Legumes are plants which belong to the family *Leguminosae*. These are important sources of food due to their high protein (20–50%) and starch content (37–58%) [1]. Over the years the consumption of the legumes has increased globally owing to their high nutritive value as well as low glycemic index. There are reports suggesting decrease in cholesterol and triglyceride level by consuming leguminous fibre (containing more amylose content than amylopectin). Interest in the consumption of legume flours is growing [2–4] particularly because of their functional properties viz, foaming, emulsification, texture, viscosity, gelation, water and oil absorption capacities [5,6]. These functional properties of legume flours may be attributed to the proteins, pectins, mucilages and other complex carbohydrates present in the flour [7].

Among the major legumes, chickpea (*Cicer arietinum*) acts as one of the most important legume, in terms of economic importance and a key source of carbohydrates and proteins in the diet of people particularly in India, Pakistan, Afganistan and Turkey [8,9]. The starch from legumes is often overlooked by-product after the isolation of proteins from them. It is because of the high amylose (30%) content present [10], which confer poor functional properties when compared to cereal starches. However, with the advancements in the starch modification techniques, it has become possible to meet the requirements by simply restructuring the starch [11]. Extensive research has been done on the modification of starches from cereal sources. However, there is limited literature available on the modification of legume starch particularly by gamma irradiation. Gamma irradiation modifies the physical and chemical properties of macro-compounds in foods via free radical mechanism. Nene et al. [12] reported that gamma irradiation reduced the gelatinization viscosity of the starch extracted from red gram. Rao and Vakil [13] studied the effects of gamma irradiation on the flatulence causing oligosaccharides (stachyose, verbascose and raffinose) in green gram, they reported that the oligosaccharide content was reduced due to fragmentation in the polymeric chains. Similar results were reported by Rayas-Duarte and Rupnow [14] for northern bean starch with increased maltose content due to the fragmentation and hydrolysis of starch molecules. Abu et al. [10] studied the effect of gamma irradiation on the functional properties of the cowpea and they reported that the swelling and pasting properties decreased while oil absorption capacity increased significantly with dose. Similar findings were reported for bean starch by Gani et al. [11]. Several other studies have revealed a reduction in viscosity, cooking time, increased digestibility and increased amino acid content in various irradiated pulses [12,13,15–19]. However, limited information is available related to the modification of chickpea starch using gamma irradiation. Therefore, the present work was undertaken to explore the effects of irradiation on the physicochemical, thermal and functional properties of chickpea starch in order to exploit them for diverse food and non-food applications.

* Corresponding author.
E-mail address: kbnaik25@gmail.com (K. Bashir).

http://dx.doi.org/10.1016/j.ijbiomac.2017.01.025
0141-8130/

2. Material and methods

2.1. Materials

The chickpea seeds (variety Pusa 547), procured from the local supplier were milled and ground in the flour mill. The flour was packed into airtight food grade polyethylene pouches purchased from the registered supplier. All the chemicals used in this study were of analytical grade.

2.2. Gamma irradiation treatment

Chickpea flour packed in polyethylene pouches 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 with dose rate of 0.5 kGy/h. The untreated sample was taken as control. The irradiation treatments were performed in duplicate at Shri Ram Institute for Industrial Research, New Delhi, India.

2.3. Starch isolation

Starch was extracted from the flour after irradiation as per the modified method of Gani et al. [11]. Chickpea flour (200 g) from each of the treated flour was soaked into 600 mL, 0.1% aqueous NaOH at room temperature (22 ± 3 °C) for 12 h. The samples were then blended for 5 min and passed through 100 mesh sieve. The slurry was then centrifuged (3–18KS, Sigma Laborzentrifugen GmbH, Germany) at 4500 rpm for 10 min and the top yellow layer was carefully drained off. The white residue left was washed five times with double distilled water and was recovered as starch. The starch was then dried in hot air oven (Macro Scientific Works Pvt. Ltd. India) at 40 °C for 48 h. The starch samples were packed into air tight low density polyethylene pouches and stored at 4 °C in refrigerator (FKG 311, Vestfrost Solutions, Denmark) for further analysis.

2.4. Physicochemical properties

2.4.1. Composition

Moisture, ash, fat and protein content of the native starch were determined as per the AOAC standards [20].

2.4.2. Color

Colour of the native and gamma irradiated chickpea starch was determined by Colorimeter (Chromameter, CR-400, Konica Minolta Optics, Japan) on the basis of L*, a* and b* values. The total color difference (ΔE) was calculated by applying the equation:

$$\Delta E = \sqrt{(Ls - L^*)^2 + (as - a^*)^2 + (bs - b^*)^2}$$

where the 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 [8].

2.4.3. Swelling and solubility index

Swelling and solubility index of the starch samples were determined as per the method described by Bashir et al. [2], with slight modifications. Starch, 0.2 g (db) (M0) was taken in pre-weighed centrifuge tubes and dispersed with 10 mL of 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 gentle shaking after every 5 min to minimise fragmentation of swollen starch granules. 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 aluminium 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.

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

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

2.4.4. Light transmittance (%)

Starch sample 1% (db) was cooked in the water bath for 30 min with continuous stirring. The suspensions were then cooled and the samples were stored at refrigerated conditions (4 °C) for five days and the transmittance was determined after every 24 h at 640 nm against the distilled water as blank using UV-spectrophotometer (Sican 2301, Inkarp Instruments Pvt. Ltd. Japan).

2.4.5. Syneresis

Syneresis was determined by the modified method of Wani et al. [21]. Starch slurry (5% – db) was 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 at 4500 rpm for 10 min and the per cent of the water released represented the syneresis.

2.5. Pasting properties

Pasting properties of starch were studied by using a Rheometer (MCR 52, Anton Paar, Austria). Viscosity profiles of starch were recorded using starch suspensions (11%, w/w; 28 g total weight). Initially the suspension was equilibrated at 50 °C for 1 min and then heated from 50 to 95 °C at 6 °C/min, then holding it at 95 °C for 5 min, followed by cooling to 50 °C at the rate of 6 °C/min and finally holding it at 50 °C for 2 min. A constant stirrer speed (160 rpm) was kept throughout the experiment for all the samples, except initially when the speed was 960 rpm for 10 s in order to disperse the sample uniformly.

2.6. Thermal properties

The thermal properties of the native and irradiated starch were investigated by using Differential Scanning Calorimetry (DSC 200, NETZSCH, Germany) as per the method described by Singh et al. [22], with slight modifications. Starch samples (3 mg) were weighed in an aluminium pan and deionized water was added to obtain 70% moisture content. The pan was then sealed and kept for 2 h, to obtain equilibrium and proper moisture migration within the sample and then heated from 25 to 130 °C at the rate of 1 °C/min. The instrument was calibrated using indium and an empty aluminium pan was used as a reference. Onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and enthalpy of gelatinization (ΔHgel) were determined.

2.7. Scanning electron microscopy

The morphological properties of the native and irradiated starches were observed by scanning electron microscopy. The starch samples were placed on an adhesive tape attached to a circular aluminium specimen stub and coated with a thin layer of gold.