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Effect of gamma irradiation on the physicochemical and structural properties of plant seed gums

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ABSTRACT

The objective of the study was to evaluate the effect of irradiation (0–5 kGy) on the physicochemical properties of two seed gums (guar and locust bean gum). The Hunter color parameters changed upon irradiation, namely "L" value decreased, whereas "a" and "b" values, i.e. redness and yellowness, increased. Irradiation reduced the final viscosity of gums at neutral and acidic pH. Increase in irradiation dose (0–5 kGy) increased the water absorption in the range of 11.75–14.61 g/g and 20.04–23.99 g/g in guar gum and locust bean gum, respectively. Rheological study of the gums revealed their gel behaviour with higher values of G' than G". G' in native guar gum was observed to increase in the range of 880.39–1332.29 Pa while G" increased in the range of 194.21–239.77 Pa as the test frequency was raised from 14.6–100 s^{-1}. In native locust bean gum, the G' and G" varied in the range of 476.50–1230.50 Pa and 300.65–380.30 Pa, respectively, under the applied frequency sweep. FT-IR revealed the presence of —CH, —COOH and —C=O groups in the guar as well as locust bean gum, in addition to the uronic acid and pyranose rings. The absorption of the functional groups declined upon irradiation.

1. Introduction

Seed gums are the viscous biopolymers with high molecular weight and hydrophilic nature extracted from the seeds of certain plants. These hydrocolloids are inexpensive, biodegradable and environment friendly polysaccharides. Chemically, gums are polysaccharides made up of monosaccharide units other than glucose and their composition is closely related to hemicelluloses. In the food industry, they have been used as stabilisers, emulsifiers and thickeners in dairy products, beverages and bakery [1]. They are used as functional ingredients to modify the shelf-life and sensory attributes of foods like texture and flavour [2]. They act as dietary fibre [3], reduce the risk of cardiovascular disease, enhance the immune function and help in management of weight and colonic health [4,5].

Guar gum is obtained from the endosperm of seeds from *Cyamposis tetragonoloba* L. and locust bean gum is obtained from the endosperm of seeds from the carob tree (*Ceretonia siliqua* L.). India is the largest producer of guar gum with an annual production of approximately 2.5–3.5 million tonnes, which is about 80% of the total world production. It is principally grown in India, Pakistan, US, Australia and Africa, that contribute to the total world production of 1.0 million tonnes [6]. Locust bean gum is very abundant in the Mediterranean region. The current production of locust bean gum is high in Cyprus, Greece, Algeria, Turkey, India, Pakistan and other Mediterranean countries including North Africa, South America, and Asia. The main producers include Morocco (38%), Spain (28%), Italy (8%) and Portugal (8%) [7]. Guar and locust bean gum are galactomannans with β-(1 → 4) linked mannopyranosyl backbone and α-(l → 6) linked D-galactopyranosyl side chains. However, the two vary in terms of degree of branching which is higher in guar gum (2:1) and lower in locust bean gum (4:1) [8].

Gamma irradiation is a non-thermal method of preservation and has been extensively studied to extend the shelf-life of various foods. This technique is used in food industry for inhibition of sprouting, growth of food-borne pathogens and spoilage causing microorganisms, and disinfestations [9]. However, the treatment is known to change the molecular structure and degradation of long chain polysaccharide molecules [10]. Such properties are known to affect the functionality of gums. Although effect of irradiation has been thoroughly investigated upon the starch from various plant sources, yet its effect on the seed gum polysaccharides is lacking. Present study was conducted to study the effect of γ-irradiation on the structural, functional and rheological attributes of guar gum and locust bean gum.

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2. Materials and methods

2.1. Materials

Pure gums of analytical grade were obtained from Himedia India. The powder was passed through 125 μm sieve to obtain uniform particle size. All chemicals used were of analytical grade.

2.2. Irradiation treatment

Gum samples at a moisture content of 10.0% were irradiated in a cobalt-60 (^{60}Co Panbit, BRIT, BRC, Mumbai, India) source irradiator at room temperature (20 ± 2 °C). Irradiation was carried at two doses i.e. 2.5 and 5 kGy proceeding with the dose rate of 83 Gy/min while an equivalent lot of gum sample was kept unirradiated in order to analyse the effect of irradiation treatment. To ensure that gum samples received the exact dose, dosimeters were placed along with the samples. Aceric-cerous dosimeter was used to measure the absorbed dose of gamma irradiation by the samples. The samples were stored at 20–40% relative humidity. Irradiation was performed at Bhabha Atomic Research Center (BARC), Zakura, Srinagar, J &K, India. Irradiations were performed in duplicate.

2.3. Methods

2.3.1. Proximate composition

Moisture, protein, fat, ash and crude fibre content of unirradiated samples were determined according to AOAC [11] methods. Carbohydrate content excluding crude fibre was obtained by the difference (100 minus percentage moisture, protein, fat, ash and crude fibre).

2.3.2. Least gelation concentration (LGC)

Least gelation concentration was determined according to the method of Sathe et al. [12]. Samples solutions of different concentrations in centrifuge tubes were heated for 1 h in a boiling water bath at 90 °C. The heated dispersions were cooled rapidly under running cold water and then stored at 4 °C for 1 h. Gelation was determined by its ability to either flow or not in the test tube when slanted.

2.3.3. pH determination

pH of the 1% w/v gum solution was measured using a digital glass electrode pH-meter (HANNA Instruments, USA). The aqueous solutions were prepared in double distilled water and allowed to stand for 2 h to complete the hydration of gums before the pH of solutions was measured.

2.3.4. Functional properties of gums

2.3.4.1. Emulsion capacity (EC) and emulsion stability (ES). Emulsion capacity of samples was determined by the method of Neto et al. [13]. The emulsion with 2 g sample, 20 mL distilled water and 20 mL oil was prepared in a graduated centrifuge tube using homogeniser (WiseTis Homogenizer, Wisd Laboratory Instruments, Korea) at maximum speed (equivalent to 27,000 rpm) for 5 min. The emulsion was centrifuged at 1100*g* for 5 min. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as the emulsion capacity and expressed in percentage. The procedure was repeated by centrifugation at 1100*g* for 5 min after heating the sample for 30 min at 80 °C to determine emulsion stability.

2.3.4.2. Foaming capacity (FC) & foam stability (FS). Foaming capacity and stability was determined according to the method of Narayana and Rao [14]. Two grams of flour sample was added to 50 mL distilled water at 30 ± 2 °C in a 100 mL measuring cylinder. The suspension was mixed and homogenised at maximum speed using homogeniser for 5 min to produce foam. Foaming capacity was calculated as the percent increase in volume of the flour dispersion. The foam stability was determined by measuring the foam volume with time and computing half-life.

$$\text{Foaming capacity}\,(\%) = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

$$\text{Foaming stability}\,(\%) = \frac{\text{Foam volume after standing time}\,(60\ \text{min})}{\text{Initial Foam volume}} \times 100$$

2.3.4.3. Water absorption capacity (WAC). Water and oil absorption capacity was determined according to the modified method of Wani et al. [15]. Sample (0.5 g) on dry weight basis-db (W_1) was mixed with distilled water in controlled amount till saturation point was achieved and then stirred for 30 min at 25 °C. The saturation point was the one at which water no longer was imbibed by the aqueous gum mixture during mixing. The slurry was centrifuged at 10,000*g* for 10 min (5810R, Eppendorf, Hamburg, Germany) and the supernatant was decanted. The sediment was weighed (W_2). The gain in weight was expressed as water absorption capacity (g/g), as per the formula given below:

$$\text{WAC}\,(\text{g/g}) = \frac{\text{W2} - \text{W1}}{\text{Weight of the sample}\,(\text{g})}$$

In order to determine the oil absorption capacity, similar procedure was used while replacing water with oil.

2.3.4.4. Swelling power (SP) & solubility index (SI). Swelling power and solubility index was determined according to the method described by Wani et al. [16] with slight modifications. Gum sample (0.2 g) were mixed with 20 mL distilled water in a centrifuge tube and heated at different temperatures (50 °C, 60 °C, 70 °C, 80 °C and 90 °C) for 30 min in a water bath. After cooling the samples to room temperature, the tubes were centrifuged at 5000*g* for 15 min. Supernatant was decanted in preweighed moisture dishes. The gain in weight of centrifuge tubes was expressed as swelling index. Moisture dishes were dried at 110 °C for 12 h and then cooled in a desiccator to room temperature. The gain in weight of moisture dishes was expressed as solubility index.

2.3.5. Color

Color of the gums was determined using Color Flex Spectrocolorimeter (Hunter lab colorimeter D-25, Hunter Associates Laboratory, Ruston, USA) as per the method of Wani et al. [15].

2.3.6. Rapid visco analysis (RVA)

RVA was performed using 70 min profile on Rapid Visco Analyzer (RVA Tech Master, Perten Instruments, Warriewood, Australia). An aqueous dispersion of gum at 14% moisture basis (1.0%, w/w; 25.25 g total weight with 0.25 g of gum) was equilibrated at 80 °C for 5 min. The sample was then cooled constantly at the rate of 1.0 °C/min from 80 °C to 20 °C for 60 min and then held at 20 °C for 5 min. A constant paddle rotational speed (160 rpm) was used throughout the entire analysis. Analysis was carried at native pH of gums and at pH 3.

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