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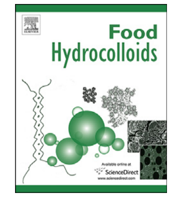

Effects of gamma irradiation on some physicochemical and rheological properties of Persian gum and gum tragacanth

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ABSTRACT

In the present study, the effect of various levels of gamma irradiation (0, 4, 8, 16, 30 kGy) on some physiochemical and rheological properties (FTIR, color, pH, water absorption capacity, solubility, stabilizing capability, flow behavior, apparent viscosity, intrinsic viscosity, molecular weight) of powder form of Persian gum (PG) and gum tragacanth (*Astragalus campatus* gum: ACG) was evaluated. FTIR analysis, intrinsic viscosity and molecular weight were determined to provide more structural information. Based on our FTIR findings, the functional groups were not significantly affected by gamma irradiation. However, it induced significant changes in color, solubility and water absorption capacity (WAC). In terms of PG, the increase in irradiation dose of (4 kGy) almost doubled its apparent (from 19.9 to 33.4 mPa s) and intrinsic viscosity (from 3.72 ± 0.04 up to 8.22 ± 0.17 dl/g), whereas at higher irradiation doses (>4 −8 kGy), these parameters decreased. Nevertheless, for GT, significant decrease for apparent and intrinsic viscosity was seen by increasing the irradiation doses, likely due to decreasing of molecular weight and the reduction of side branches and radiolysis of the glycosidic bonds. In addition, the flow behavior of the dispersions shifted from non-Newtonian to Newtonian one. Furthermore, the highest stabilizing capability of PG was seen at 4 kGy in milk sour cherry mixture whereas no significant effect was seen on ACG. Consequently, one can conclude that gamma irradiation could be potentially used at certain dose, as an effective method, to improve some functional properties such as stabilizing ability of PG but not for ACG.

1. Introduction

Hydrocolloids, due to their hydrophilicity, highly branched structure and high molecular weight are used for various purposes (gelling, thickening, emulsifying, and stabilizing) (Dickinson, 2009). Persian gum (PG) and gum tragacanth (GT) are two Iranian natural hydrocolloids. This country exports a large amount of these gums for use in food, medicinal, and industrial applications (Abbasi & Rahimi, 2015; Abbasi & Mohammadi, 2013; Azarikia & Abbasi, 2010).

PG and GT are natural shrubs exudates for which they normally can be highly contaminated. Consequently, it is recommended to be sterilized before being used in food industry. Therefore, irradiation can be a potential technique for sterilization of natural gums to provide the sufficient decontamination with or without exerting adverse effects on their functional properties (Singh & Sharma, 2013; Alijani, Balaghi, & Mohammadifar, 2011; Farkas & Mohácsi-Farkas, 2011; Diehl, 2002). On the other hand, many studies have shown that treatments such as irradiation can change the structure and functional properties of the polysaccharides as well as their end products (Abd Alla, Sen, & El-Naggar, 2012; Gupta, Shah, Sanyal, Variyar, & Sharma, 2009; Byun et al., 2008; Kyung, Jo, park, & Woobyun, 2008; Sen, Yolacan & Güven, 2007; Katayama, Nakauma, Todoriki, Phillips, & Tada, 2006; Aliste, Vieira, & Del Mastro, 2000; Blake, Deeble, Phillips, & Du Plessy, 1988).

PG is relatively unknown hydrocolloid with little research yet presented. Keeping in viewing to investigate and find out different properties of PG, in the present study, the effect of irradiation on some physiochemical properties of the PG and its influences on stabilizing properties was studied. To the best of our knowledge, there is no study regarding the effects of irradiation on physicochemical and rheological properties of PG as a natural hydrocolloid. In the case of GT, previous studies have investigated the effect of gamma irradiation on the GT with different botanical sources

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(Alijani et al., 2011). In addition, its effects on some properties of GT like solubility, water absorbing capacity (WAC), stabilizing capability and intrinsic viscosity have been not studied. Therefore, this study was carried out to evaluate the effect of different doses of radiation on some physicochemical (color, solubility, pH, WAC), structural (FTIR, molecular weight), rheological (apparent and intrinsic viscosity, consistency and flow behavior) properties and specially focused on stabilizing capability of irradiated PG and GT. Furthermore, since the intrinsic viscosity provides information about fundamental properties of solute such as hydrodynamic volume occupied by a macromolecule, molecular entanglement and molecular weight, so it was measured to provide a comprehensive insight into the fundamental properties of macromolecules in solution.

2. Materials and methods

2.1. Preparation of gums

PG and GT were purchased from a local herbal store (Tehran, Iran), pulverized, sieved, and the collected powders (mesh size < 60) were used. In order to determine the botanical species of GT, its soluble and insoluble fractions were separated. Then the weights, volumes and dry matters of separated fractions were measured (Abbasi & Mohammadi, 2013; Azarikia & Abbasi, 2010). In order to prepare dispersion of PG and GT, 3 and 0.5 g of their powders, gradually added to 100 ml water and mixed thoroughly and allowed to stand overnight to reach the maximum hydration. In order to separate soluble and insoluble fractions, the suspensions were centrifuged (Eppendorf centrifuge, 5810R model, Germany) at 14000 rpm for 30 min at 4 °C. The proportion of soluble (SFGT) and insoluble (IFGT) fractions of the GT was 40 and 60 (% w/w). The comparison of these data with previous reports confirmed that the GT more likely belonged to *Astragalus compatus* gum (ACG). Furthermore, the PG contained 30 and 70 (% w/w) of soluble (SFPG) and insoluble (IFPG) fractions.

2.2. Irradiation

After preparation of PG and GT powders, they were filled in a sterile glass bottle (50 ml) and subjected to gamma irradiation (4, 8, 16, and 30 kGy) using a Gamma cell-220 irradiator (Nordion, Canada). The gamma source strength was approximately 12,470 Ci with the dose rate of 3.05 Gy/s calibrated using Fricke dosimetry standard method. After gamma irradiation, the samples were immediately stored at room temperature for the analysis. All measurements were performed in triplicate.

2.3. Fourier transform IR (FTIR) spectra measurements

Definite amounts of un-irradiated and irradiated PG or ACG powders were mixed with KBr and pellets were prepared. Then, the FTIR spectra were recorded (Bruker, Tensor 27 FT-IR, Germany).

2.4. Color measurements

The L^* a^* b^* values of PG and ACG powders were determined using hunter-lab Colorometer (ColorFlex, Model NO. 45/0, Reston, VA, USA).

2.5. pH measurements

The un-irradiated and irradiated powders (PG or ACG, 0.5% w/w) were dispersed in distilled water and kept for overnight to allow complete hydration. Then, the pH of dispersions was measured using a pH-meter (Model NO. 827, Metrohm, Swiss).

2.6. Solubility and water absorption capacity

The effect of radiation doses on the solubility and WAC (g/g) was calculated using the Eqs. (1) and (2), respectively (Singh & Sharma, 2013; Koocheki, Taherian, & Bostan, 2013; Byun et al., 2008):

$$Solubility\ (\%) = \frac{dried\ supernatant(wt)}{initial\ gum(wt)} * 100 \quad (1)$$

$$WAC = \frac{ssw - sw}{sw} \quad (2)$$

ssw: swollen sample weight sw: sample weight *i.e.* 0.5 g.

2.7. Milk–sour cherry mixture preparation

To prepare milk–sour cherry juice mixture, dry matter content and pH level of mixtures were fixed at 12 (% w/w) and 4, respectively. Consequently, the mixtures contained 57 (% w/w) full fat milk, 7 (% w/w) sour cherry juice concentrate (Brix = 69), 36 (% w/w) water and other ingredients such as gums. Therefore, for preparation of milk–sour cherry juice mixtures, the PG or ACG were gradually mixed with milk while stirring. After that, sour cherry juice concentrate was added to milk-gum mixture (stirred for 15 min). Sodium azide (0.04% w/w) was added to prevent microbial contamination. Finally, samples were filled in sterile tubes, sealed and stored at 5 °C, during which their serum separation were measured (Abbasi & Mohammadi, 2013; Azarikia & Abbasi, 2010).

2.8. Rheological measurements

2.8.1. Dynamic viscosity

The rheological measurements (viscosity and flow behavior) of irradiated and un-irradiated ACG and PG dispersions (0.5% w/w) were carried out using a Brookfield viscometer (LV-, Brookfield Engineering Laboratories, USA). For performing the experiments, some 20 ml of dispersions were placed in the geometry. The shear stress and viscosity were measured as function of shear rate (upward 0.1–250 s^{-1} and downward 250 to 0.1 s^{-1} regimes within 8 min). Then, the fitting rate of the collected data with Newtonian, Bingham, Power law, Herschel–Bulkley models were evaluated.

2.8.2. Intrinsic viscosity

The viscosity measurement of PG (0.2 g/dl) and GT (0.05 g/dl) dispersions were performed using a capillary viscometer (Cannon Instruments Co., No. 150 Cannon-Ubbelohde, Germany; $k = 0.04137\ mm^2/s^2$) immersed in a thermostatic water bath at 25 °C. The intrinsic viscosity was calculated using well-known Huggins and Kraemer models.

2.9. Molecular weight measurement

The molecular weight of irradiated and un-irradiated PG powder was determined by means of a Zetasizer (Nano ZS, Malvern Instrument, UK) with the following specifications: refractive index, 1.330; scattering angle, 117°; temperature, 25 °C; hydration time, 24 h. Data analysis was performed using the DTSNANO software. Furthermore, for calculating the molecular weight of irradiated and un-irradiated GT, the Mark-Houwink constants were used as reported by Mohammadifar, Musavi, Kiumarsi, & Williams, 2006.