Radiation Physics and Chemistry 92 (2013) 112–120

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

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

# Influence of gamma radiation on the physicochemical and rheological properties of sterculia gum polysaccharides

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## HIGHLIGHTS

- Solubility increased and swellability decreased of gum on increasing the total dose.
- Apparent viscosity of gum solution increased upto 8.1 kGy then decreased.
- Emulsion stability improved for gum irradiated with total dose of 8.1 kGy.
- Flow behavior shifted to Newtonian from non-Newtonian with increasing total dose.

## ARTICLE INFO

*Article history:*
Received 6 December 2012
Accepted 8 June 2013
Available online 29 June 2013

*Keywords:*
Polysaccharides
Gamma radiation
Physiochemical properties
Rheology

## ABSTRACT

Keeping in view the influence of gamma radiation on the physiochemical properties of the polysaccharides and their importance in the food and pharmaceutical industry, in the present study attempt has been made to investigate the effects of absorbed dose on FTIR, XRD, SEMs, absorbance, pH, solubility, water absorption capacity, emulsion stability and rheology of sterculia gum. Increase in solubility and decrease in swellability of gum has been observed on increasing the absorbed dose. The emulsion stability has improved for the gum sample irradiated with total dose of $8.1 \pm 0.2$ kGy. Apparent viscosity of gum solution first increased with increase in dose from 0 to $8.1 \pm 0.2$ kGy than decreased with regular trends with further increase in total absorbed dose. Flow behavior of gum solution shifted to Newtonian from non-Newtonian with increasing the dose.



## 1. Introduction

Polysaccharide gums are used in food and pharmaceutical industries as gelling, thickening, emulsifying, and stabilizing agents (Lai and Lii, 2004) due to their hydrophilicity, highly-branched structure and high molecular weight. These properties also provide a macromolecular barrier against destabilizing mechanisms by increasing the viscosity of the aqueous phase and slowing flocculation and coalescence between dispersed droplets (Dickinson, 2003, 2009; Dickinson and Galazka, 1992). Hence, these are usually added to the aqueous phase of emulsions as thickening agents in order to modify the rheological behaviour of the aqueous phase and thereby to retard instability mechanisms. However, under specific conditions, they can cause phase separation and flocculation. Nature and type of oil and emulsifier used in emulsification affect the droplet growth in emulsions (Dolz et al., 2007; McClements, 2000). Polysaccharide hydrocolloids stabilize emulsions through viscosity effects, steric hindrance and electrostatic interactions (Tan, 1990). Different kinds of hydrocolloids are normally used for this purpose. Chanami et al. (2002) have found that gum arabic has a low interfacial activity and needs to be used at much higher concentrations than other types of emulsifier commonly used to stabilize the emulsions. However, on the other hand physicochemical properties of the polysaccharides can be modified by treating with high energy radiation which influences the viscosity of solution and its emulsification capacity.

Irradiation of polysaccharides with ionizing radiation either in the solid state or in aqueous solution leads to their degradation (Al-Assaf et al., 2007). Radiation degradation is associated with random fissure of the glycosidic linkage in the polysaccharides (Skinner and Kertesz, 1960). The rheological behavior of the irradiated aqueous sodium alginate solutions revealed the influence of irradiation on the rheological parameters. The viscosity and average molecular weight of the irradiated polysaccharides decreased with increase in radiation dose (Mollah et al., 2009; Katayama et al., 2006).These chemical and physical changes induced in acacia gum under the influence of ionizing doses up to 100 kGy. The gamma irradiation has decreased the average molecular weights of polysaccharides and increased the numbers of carboxyl and carbonyl groups, and double bonds in the

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0969-806X/$ - see front matter 
http://dx.doi.org/10.1016/j.radphyschem.2013.06.006

irradiated polysaccharides. The period of exposure has considerable influence on the amount of scission and consequently on the length of polymer in aqueous solution. This in turn decreases the mass, size, extension configuration, solute-solute contact and increases the overlap concentration and solute-solvent interpretation (Choi et al., 2009; King and Gray, 1993; Al-Assaf et al., 2005; Blake et al., 1988; Deeble et al., 1991). In one study it has been observed that gamma radiation has provided the sufficient decontamination without exerting adverse effects on the physical properties of the final products (Zaied et al., 2007). Absorbed dose up to 10 kGy has been approved by IAEA, WHO, and FAO (IAEA, 2003). Even doses as high as 75 kGy have been approved for some products (WHO, 1981). The rheological properties of hydrocolloids are particularly important when they are used in the formulation of any food for their effects on the textural attributes. Dogan et al. (2007) have observed that the increasing dose generally caused a decrease in apparent viscosity (AV) of hydrocolloid solutions; the magnitude of the effect of the irradiation on the AV was different for guar gum, pectin and salep hydrocolloids.

Keeping in view the influence of gamma radiation on the physiochemical properties of the polysaccharides and their importance in the food and pharmaceutical industry, in the present study, attempt has been made to investigate the effects of radiation dose on FTIR, XRD, SEMs, UV absorbance, pH, solubility, water absorption capacity, emulsion stability and rheology of sterculia gum. Sterculia gum is a natural gum exudate of *Sterculia urens* tree belongs to the family *Sterculiaceae*. It is a complex, branched and partially acetylated polysaccharide which has very high molecular mass. It consists of glucuronic acid, galacturonic acid, galactose and rhamnose structural units (Singh and Sharma, 2009). Sterculia gum has emulsifying property for various oils to form stable emulsions (Iyer et al., 2006). Sterculia gum is an important hydrocolloid which has various pharmaceutical and food industries applications due to its high water retention capacity and high viscosity (Cerf et al., 1990).

## 2. Experimental

### 2.1. Material and methods

Sample irradiation was carried out for specific time in $^{60}$Co gamma irradiator obtained from Board of radiation and isotope technology, India. The pH meter was calibrated manually by using pH 4.0, pH 7.0 and pH 9.2 buffer capsules obtained from the Merck specialties Pvt. Ltd., Mumbai—India. Sterculia gum (karaya gum) used in this study was obtained Sigma-Aldrich Co., USA. The grinded fine powder was irradiated, by keeping the powdered sterculia gum in $^{60}$Co gamma irradiator for different time period to have different dose (i.e. $8.1\pm0.2$, $16.2\pm0.3$, $24.3\pm0.5$, $32.4\pm0.6$, $40.5\pm0.8$ kGy), to study the effect of radiation on different properties. Samples were then packed into polyethylene plastic bags for further analysis. All the experiments were carried out in triplicate and uncertainty ($\pm$error) of the results are shown in figures and tables. Further, data thus obtained have also showed reproducibility within the standard deviation. In case of linear fit (i.e Power law, Bingham model and Arrhenius model) the uncertainty ($\pm$error) and correlation coefficient ($R^2$) are given to determine the relative standard deviation of slope and intercept which is also shown in tables. Dosimetry was done using ceric-cerous system and the dose rate of $\gamma$-rays was 1.35 ($\pm$2%) kGy/h. Effect of radiation, on solution form irradiation (1% solution) was also studied.

### 2.2. Characterization of irradiated sterculia gum

FTIR spectra of unirradiated and irradiated samples of sterculia gum were recorded in KBr pellets on Nicolet 5700 FTIR THERMO (USA). Definite amount of dried KBr and sterculia gum was taken to study the effect of irradiation on spectra of gum. XRD measurement of unirradiated and irradiated samples of sterculia gum was made using PAN-analytical X'Pert Pro powder diffraction system (The Netherland). The X-ray generator was operated at 40 kV and 40 mA using the Cu-$K\alpha$ radiation. The definite amount of sample was scanned at 25 °C from 10° to 80° ($2\theta$) and in step size of 0.05 and count time of 1.0 s, using an automatic divergence slit assembly and a proportional detector. To study the effect of gamma rays on surface morphology of sterculia gum SEMs were taken of both irradiated and unirradiated gum powder. FEI SEM Quanta 256, Model D9393 (Singapore) was used to provide information about morphology of the samples. The UV absorption spectra of unirradiated and irradiated samples of sterculia gum solution (1.0% w/v) were recorded by UV visible spectrophotometer (Cary 100 Bio, Varian).

### 2.3. pH measurements

pH of the unirradiated and irradiated samples of sterculia gum solution of (0.5 and 1% w/v) concentration was measured. The solution was prepared in distilled water and kept for overnight to allow complete hydration of gum and pH of aqueous solution of sterculia gum was measured using a glass electrode pH-meter (EI-Model 1012E).

### 2.4. Solubility and water absorption capacity

The effect of the total radiation dose on solubility and water absorption capacity (WAC) was determined by preparing 1.0% (w/v) solution of gum in distilled water. (Dakia et al., 2008; Koocheki et al., 2013; Byun et al., 2008). The percentage of solubility and WAC (g/g) were calculated using the Eqs. (1) and (2), respectively:

$$\text{Solubility } (\%) = \frac{\text{Weight of dried supernatant}}{\text{Weight of initial gum}} \times 100 \quad (1)$$

$$WAC = (ssw - sw)/sw \quad (2)$$

where 'ssw' is swollen sample weight and 'sw' sample weight taken i.e. 0.25 g.

### 2.5. Emulsion stability

Emulsifying stability (E.S.) of sterculia gum and irradiated sterculia gum was determined according to method described elsewhere (Sabah El-Kheir et al., 2008; Wang et al., 2011; Kafi and Sabahalkhair, 2010). Emulsifying stability was measured using UV Visible Spectrophotometer (Cary 100 Bio, Varian) at one hour intervals upto 6 h and then after 24 h at 520 nm. Emulsifying stability (E.S.) was calculated as:

$$E.S. = \frac{First\ reading\ of\ absorbance\ (T=0)}{Reading\ of\ absorbance\ after\ time\ T\ (in\ h)}$$

### 2.6. Rheological properties

Rheological measurements (viscosity) of irradiated and unirradiated sterculia gum solution of different concentration under different shear rate and different temperature were carried out using a Brookfield viscometer (DV-II+ Pro, Brookfield Engineering Laboratories, USA). These measurements were made with the spindle S00 using ULA (ultra low viscosity adaptor having temperature jacket and cylindrical shape) at different stirring speed (within certain range of shear rate) and different temperature (25 to 40 °C) using solution of different concentration (0.1 to 1.5% w/v) of gum solution. Different