Food Hydrocolloids 39 (2014) 1–9

Contents lists available at ScienceDirect

Food Hydrocolloids

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

Physicochemical, rheological and antioxidant potential of corn fiber gum

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ARTICLE INFO

Article history:
Received 20 September 2013
Accepted 12 December 2013

Keywords:
Corn fiber gum
Effective pore radius
Surface free energy
Antioxidant activity
Swelling index
Rheology

ABSTRACT

Corn fiber gum (CFG) is extracted from corn bran which is the by-product of corn dry milling process. Therefore, an attempt was made to understand various properties of CFG to promote its uses for food and pharmaceuticals. The extraction of CFG using alkaline hydrogen peroxide method yielded 25% w/w of destarched corn fibers. A good flow property was indicated from the results of % compressibility (12.9%), Hausner ratio (1.14) and angle of repose (35.45°) in comparison to beal fruit gum [% compressibility (17.65%), Hausner ratio (1.21) and angle of repose (37.2°)]. Further, $R_{eff.p}$ (1.97 mm), dynamic advancing contact angle (74.18°) and surface free energy (22.55 mJ/m^2 polar component and 4.0 mJ/m^2 dispersive component) suggested highly porous and polar nature of CFG. The intrinsic viscosity and molecular weight of CFG were 1.746 dl/g and 3.18 × 10^5 g/mol, respectively. The instrumental texture studies indicated direct correlation between different concentrations of CFG and firmness, cohesiveness, consistency or index of viscosity. CFG exhibit good antioxidant activity in concentration dependent manner. The antioxidant activity was 5–6 folds higher as compared to guar gum, sulfated guar gum, xanthan oligosaccharides and hemicelluloses derived from wood and rice husk. Overall, the physicochemical, rheological and antioxidant potential of CFG could be utilized as an excipient for food and pharmaceutical industry.

1. Introduction

Corn fibers are by-products of corn wet and dry milling process. These fibers are mostly utilized as low protein animal feed. However, the abundant production of corn fibers could also be utilized for various other processes as well. Starch free corn fibers contain more than 50% of hemicelluloses (Doner, Chau, Fishman, & Hicks, 1998). The alkali or alkaline hydrogen peroxide solution treatment could easily isolate arabinoxylans. This highly branched polymeric material is also known as corn fiber gum. Chemically, it consists of α-1,4 linked D-xylopyranosyl backbone with α-L-arabinofuranosyl substituents attached at positions 2 and/or 3 and with glucuronic acid substituents attached primarily at position 2. The ferulic acid and other hydroxycinnamic acids are linked at 5 position of arabinose (Doner & Hicks, 1997; Yadav, Moreau, Hotchkiss, & Hicks, 2012). There is enough evidence to suggest that corn arabinoxylan polymers in intact corn kernels are cross-linked to each other and/or other cell wall polymers through dehydrodiferulate ester bridges (Chanliaud, Saulnier, & Thibault, 1994; Saulnier, Crepeau, Lahaye, & Thibault, 1999; Saulnier, Marot, Chanliaud, & Thibault, 1995; Saulnier, Vigouroux, & Thibault, 1995) and/or dehydrotriferulate ester bridges (Funk, Ralph, Steinhart, & Bunzel, 2005). CFGs isolated from both coarse and fine corn fiber contain functional protein, lipid and also nutraceutical phenolic compounds (Yadav, Moreau, & Hicks, 2007). Corn fiber gum is an excellent emulsifier in oil-in-water beverage emulsion systems (Yadav, Johnston, Hotchkiss, & Hicks, 2007). In addition, it could also be utilized as a new food gum, additive in plastics, dietary fiber, polymer for chemical and pharmaceutical applications, etc. (Gaspar, Juhasz, Szengyel, & Reczey, 2005; Gaspar, Kalman, & Reczey, 2007). The stabilities of orange oil emulsions stabilized with various concentrations of two different types of corn fiber gum (CFG-1 and 2) isolated from coarse (pericarp) and fine (endosperm) fiber from corn wet milling have been studied (Yadav, Moreau, et al., 2007). Further, the detail emulsifying properties and the structure function relationship of CFG was also studied (Yadav, Fishman, Chau, Johnston, & Hicks, 2007; Yadav, Johnston, & Hicks, 2007; Yadav, Johnston, Hotchkiss, et al., 2007; Yadav, Moreau, et al., 2007). In another report Fishman, Doner, Chau, and

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http://dx.doi.org/10.1016/j.foodhyd.2013.12.015

Hoagland (2000) isolated corn fiber gum and evaluated its intrinsic viscosity, molar mass and *Z*-average root mean square radius of gyration R_{gz}.

Various investigations have been conducted to understand the chemical compositions and functionality of plant hydrocolloids. The purpose of current investigation was to isolate and characterize a gum from corn fibers. Further, this study will shed some light on understanding physicochemical, rheological as well as antioxidant potential of CFG and its applications in food and pharmaceutical industry.

2. Material and methods

Corn fibers were procured from local flour mill, Patiala, India. Sodium hydroxide was used as supplied by LobaChemie, India. n-Hexane was supplied by Merk Specialities, Mumbai, India. Hydrogen peroxide solution and hydrochloric acid were procured from Thermo Fischer scientific, India. All other chemicals used were of analytical grade and used as received.

2.1. Extraction of corn fiber gum

The CFG was extracted following the method reported by Yadav et al. (2012) with slight modification. In brief, corn fibers were de-oiled with n-Hexane at 50 °C. The deoiled fibers were size reduced to 44 mesh size. The deoiled, size reduced fibers (100 g) were suspended in α-Amylase solution (0.2% w/v; 1000 ml) and boiled for 1 h to remove starch. The fibers were separated from hot solution using white muslin cloth, washed twice with hot water and dried in oven (50 °C for 24 h). The dried fibers were suspended in 1 L of 2 meq/g of sodium hydroxide solution and 21 ml of 30% v/v H_2O_2. This suspension was mechanically agitated for 1 h with simultaneous boiling. The fibers were separated and filtrate was mixed with hydrogen peroxide and raises the pH to 11.5 with sodium hydroxide. The hemicellulose A was precipitated when pH of solution decreased to 4.5 (with 0.1 N HCl). Hemicellulose A was separated by centrifugation (3000 rpm). The hemicellulose B was obtained after precipitation of supernatant with ethanol. The hemicellulose B precipitates were separated and dissolved in water, centrifuged to remove undissolved material and freeze dried to obtain pure Corn fiber gum. The extraction procedure of Corn fiber gum is summarized in Fig. 1.

2.2. Characterization of corn fiber gum

2.2.1. Spectral attributes

2.2.1.1. ATR-FTIR spectroscopy. ATR-FTIR spectra of CFG were recorded on an ATR-FTIR spectrophotometer (Alfa, Bruker, Berlin, Germany). The lyophilized dry powder was used for spectral analysis. The ATR-FTIR spectra were obtained between wavelengths of 4000 and 400 cm^{-1}.

2.2.1.2. ^1H NMR. ^{1}H NMR spectra was recorded on a Bruker AMX 500 FT spectrometer at 25 °C in D_2O. The spectral widths employed in NMR experiments were typically 6000 Hz (^{1}H). The purified hemicelluloses (15 mg/ml in D_2O) were placed in the sample probe and the resonance spectrum was obtained. The chemical shifts of ^{1}H-NMR spectra were calibrated with reference to D_2O, used as an internal standard at 4.70 ppm. The acquisition and relaxation times were of 3.9 s and 1.0 s, respectively.

2.2.2. Thermal analysis

A sample of CFG was hermetically sealed in aluminum pan and heated over temperature range of 40–350 °C in an atmosphere of nitrogen at a constant heating rate of 10 °C/min. The peak transition as well as enthalpy of fusion was estimated from the DSC (Setaram, Lab Sys Evo, France) thermogram.

2.2.3. Powder X-ray diffractometry

Diffraction patterns were obtained using X'pert-PRO High Resolution Powder Diffractometer (PANalyticals, Almelo, Netherlands) equipped with a scintillation counter detector and a divergent beam. This beam employed a Cu Kα radiation source with a wavelength of λ 1.5418 containing 10 mm slits over a range of 10–90° 2θ. X-Ray diffraction data were collected at 25 °C temperature and scanned with a step size of 0.001 2θ and a scan time of 20 min at each step.

2.2.4. Morphological characterization

A CFG powder was mounted on to a sample holder and then sputter coated with gold particles in the presence of argon gas. Pictures of the prepared samples were taken by a JSM-6610LV (Jeol, Tokyo, Japan) scanning electron microscope using a 15 KV accelerating voltage, a 1 μm–10 μm working distance, and a probe current of 3×10^{-11} A°.

2.2.5. Powder flow properties

Powder flow properties (bulk density (ρ_b), tapped density (ρ_t), % compressibility (Carr's index), Hausner ratio and angle of repose) were determined according to the procedure reported by Jindal, Kumar, Rana, and Tiwary (2013a).

2.2.6. Swelling index (SI)

The sample (50–250 mg) was filled into micropipette tips (white, 2 ml, Aldrich) for estimating swelling index. The tip outlet was first blocked with a tiny swab of Nylon fiber to avoid any leakage of the powder during the experiment. After placing the solid sample into the tip, it was tapped 10 times by dropping on a hard surface from a 10 cm height to obtain possibly the same packing of the bed. The plastic tip was weighed (Wa) and then dipped into a 2–3 mm layer of deionized water. When the bed became wetted with liquid, the tip was again weighed (Wb) to find the amount of the liquid taken in by the powder. The swelling index was estimated as

$$\mathrm{SI} = (\mathrm{Wb} - \mathrm{Wa})/\mathrm{Wa} \times 100$$

The experiments were repeated 6 times and average values were taken for calculation.

2.2.7. Electrical performance: zeta potential and conductivity studies

The zeta potential and conductivity studies of CFG were conducted by using Zetasizer (Malvern Instrument Ltd., UK). The temperature of the samples was maintained at 25 °C. The zeta potential measurements were performed by using an aqueous dip cell in an automatic mode. Samples were diluted with triple distilled water and placed in capillary measurement cell.

2.2.8. Effective pore radius

The $R_{\mathrm{eff.p}}$ of powder was estimated according to the method reported by Goel, Kaur, Tiwary, and Rana (2010). In brief, plastic tip used for micropipette was filled with CFG powder and weighed (W_A). Then n-hexane (surface tension, (γ) 18.4 N/m, $\theta = 0°$) was added dropwise to the top of packed bed till the solvent filtered out at the bottom of the tip. The tip was weighed again (W_B). The $R_{\mathrm{eff.p}}$ was calculated using formula:

$$R_{\mathrm{eff.p}} = \frac{(W_B - W_A)}{2\pi\gamma}$$

2.2.9. Surface free energy components of pure CFG

The surface free energy components of CFG were estimated as per the method reported by Singh, Tiwary, and Rana (2013). The dispersive