



The influence of temperature, sucrose and lactose on dilute solution properties of basil (*Ocimum basilicum*) seed gum



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ABSTRACT

Hydrocolloid interactions with solvent/cosolutes play a vital role in the resolution of their functional properties. Basil seed gum (BSG) is a plant-derived hydrocolloid which has been found many applications in food formulations as stabilizer, emulsifier, thickener and gelling agents. Sucrose and lactose are the most effective sugars in textural and sensorial properties of bakery and dairy products which adding them to solutions containing hydrocolloids can be helpful to approach a proper formula. In this paper, the effect of temperature (25–65 °C), sucrose (10, 20, 30 and 40%) and lactose (5, 10 and 15%) were investigated through some molecular parameters of BSG. Results revealed high flexible chain (665.35), intrinsic viscosity (11.38 dl/g) and hydrogel content (73%) of BSG, which may be attributed to some extent by its high molecular weight (1.73×10^6 Da). The density and intrinsic viscosity of BSG were diminished by growing temperature from 25 to 55 °C. Among five models, which were applied to estimate intrinsic viscosity, Higo-2 was the most suitable model at varying temperatures and cosolutes concentrations. The sugars showed a significant effect on the molecular parameters of BSG such as swollen specific volume, shape function, hydration parameter, and coil dimensions. The sugars showed more impact on the $[\eta]$ of BSG and its molecular parameters than that of temperature. However, lactose had a more prominent effect on the BSG dimensions than that of sucrose, which can be related to its molecular conformation and spatial orientation. It is feasible to make a proper formula by BSG and explain some phenomena in its applications in food and pharmaceutical systems.

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1. Introduction

Hydrocolloids are extensively utilized in food systems to improve their functionality such as thickening, emulsifying, stabilizing and texturizing. Among all kinds of hydrocolloids, those obtained from plant sources, due to the more abundance and extraction convenience, have achieved a great deal of interest in the industrial sections. In addition, owing to bioavailability and biodegradability of plant hydrocolloids, they can be used successfully in different areas such as food and pharmaceutical industries [1–3]. There are some Iranian endemic plants which their seeds can be exploited as a new hydrocolloid source in food and pharmaceutical systems [4]. Basil seed gum (BSG) is one of them, which can be extracted from the seeds of basil herb and have been recently found many applications in food formulations as stabilizer, emulsifier,

thickener and gelling agents [5–8]. The extraction of BSG was optimized by response surface methodology and the highest yield and viscosity were achieved at 68.71 °C, pH 8.09 and water/seed ratio 65.98:1 [9]. The structural analysis of macromolecular networks of BSG has shown to encompass hydrogel properties, which dissolve in an aqueous environment [10–12]. Moreover, the structural characteristics of BSG at sol-gel states revealed that it has a glucanmannan anionic structure, which has carboxylate salts, probably uronic acids in its structure [7,12]. BSG has also shown interesting gelling and emulsifying properties in which the surface charges on the gum affecting the self-aggregation and ultimately adsorption behavior [6]. Furthermore, some investigations on the rheological and structural properties of BSG were performed in the semi-dilute and concentrate regimes, particularly, in terms of its interaction with other polysaccharides and proteins such as locust bean gum and β -lactoglobulin [10–14], but its interaction with selected solvents or co-solutes have not studied in dilute solution domain so far. It was found that there are commonly the intermolecular hydrogen-bonding interactions with different biopolymers and particularly

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between junction zones of the stabilized gel network of BSG and β -lactoglobulin [14]. However, these interactions can be changed by altering the solvent properties through using the additives like as sugars or salts.

The intrinsic viscosity $[\eta]$ is a molecular parameter, indicating the hydrodynamic volume occupied by the unit mass of macromolecule and depends primarily on the molecular size, conformation and molecular weight as well as solvent quality [15–18]. Since, the viscosity survey in dilute solution regimes can afford proper knowledge concerning the nature and structure of macromolecules separate of intermolecular interaction; and intrinsic viscosity is one of the simplest, most precise and inexpensiveness measurements in polymer science, it has gained many attractions for characterization of various hydrocolloids [19–24]. The dilute solution study is feasible when the macromolecular chains are sufficiently apart. In this situation, there are negligible interactions between the chains such that each isolated molecule occupies a discrete hydrodynamic volume within the solution and contributes individually to the bulk properties of the system [25]. Thus, it provides a deep understanding of the fundamental molecular properties of the macromolecules in solution [26].

The influence of temperature and various types of salts on intrinsic viscosity of hydrocolloids have been studied. It was generally concluded that increase in temperature and ionic strength of the solution generally cause to diminish the intrinsic viscosity [18,27–33]. Only few studies are reported concerning the influence of sugars on intrinsic viscosity of hydrocolloids such as pectin and guar [25,27,34–36]. In fact, the understanding of sugar addition and temperature influence on dilute solution properties of BSG is inevitable, which can be applied as an emulsifier and thickener in food systems [5]. Among the sweeteners used in food industry, the most predominant and effective ones are sucrose and lactose, which play important roles in textural and sensorial properties and can be used for most formulations such as bakery and dairy products.

To the best of our knowledge, no research work has conducted about the impact of especial factors including temperature and sugars on BSG in the dilute solution domain to characterize its conformational structure and molecular properties. Understanding the effect of sugars and temperatures on BSG molecules can improve our knowledge on some phenomena in food systems such as crystallization and textural changes in dairy products especially ice-cream. Therefore, the aim of current work was to investigate the influence of varying temperatures (25–65 °C) and sugars (sucrose and lactose at different concentrations) on some hydrodynamic parameters i.e. intrinsic viscosity; chain flexibility; shape and hydration parameters; coil radius and volume, density and hydrogel content to shed some light on the behavior of BSG in the dilute solution regime.

2. Materials & methods

2.1. Materials

Basil seeds were purchased from the local markets of Mashhad, Iran. Foreign bodies and matters were separated from basil seeds and then were packed in hermetic sealed plastic bags and kept in dry and cool place till extraction. Sucrose and lactose (monohydrate) were purchased from Merck (Darmstadt, Germany).

2.2. Preparation of solutions

Basil seed gum was extracted, at optimum conditions (65:1 water to seed ratio, pH 8, 68 °C), using the same procedure as described by Razavi et al. [9]. The justification of pH was performed

by NaOH (0.1 N). Dehydration and purification of BSG solution were accomplished by using alcohol 96% and solutions were dried in an oven at 40 °C. The BSG solutions (0.15 g/ml) were prepared by dispersing dried BSG powder in deionized water in presence or absence of cosolutes (sucrose, lactose) under constant mixing (500 rpm) using a magnetic stirrer for 30 min at room temperature. Then, the prepared solutions were left at room temperature for 24 h prior to measurements to complete the hydration. All the solutions were prepared in duplicate.

2.3. Capillary viscometry

Dynamic Newtonian viscosity of the prepared solutions and solvent were determined in triplicate using a No.75 Cannon–Ubbelohde semi micro dilution type capillary viscometer (Witeg Co., Germany) immersed in a thermostated water bath under precise temperature control (± 0.1 °C). The flow time of sample through capillary was measured with an accuracy of 0.1 s using a digital chronometer. The equilibration time for each solution at the bath temperature was 10 min, after loading (5 ml) and each time diluting the sample. The viscosity measurements were carried out at different temperatures (25, 35, 45, 55 and 65 °C) and cosolutes (sucrose, 10, 20, 30 and 40% w/v, and lactose 5, 10 and 15% w/v). In the presence of the cosolutes, the viscosity measurement was performed at 25 °C. The intrinsic viscosity $[\eta]$ was calculated using the well-known Huggins (Eq. (1)) and Kraemer equations (Eq. (2)) by extrapolating the η_{sp}/C [37] and $\ln\eta_{rel}/C$ [38] to zero concentration through a linear regression, respectively.

$$\frac{\eta_{sp}}{C} = [\eta] + k'[\eta]^2 C \quad (1)$$

$$\frac{\ln\eta_{rel}}{C} = [\eta] + k''[\eta]^2 C \quad (2)$$

where η_{sp} , η_{rel} , k' and k'' are the specific viscosity, relative viscosity, Huggins and Kraemer constants, respectively.

In this paper, the slope-based models such as Tanglertpaibul & Rao (Eq. (3)), and Higo-1 (Eq. (4)) and Higo-2 (Eq. (5)) were also used to determine the intrinsic viscosity:

$$\eta_{rel} = 1 + [\eta] C \quad (3)$$

$$\eta_{rel} = e^{[\eta]C} \quad (4)$$

$$\eta_{rel} = \frac{1}{1 - [\eta]C} \quad (5)$$

2.4. Density measurement

Density (ρ) of BSG solutions (0.1, 0.2 and 0.3%) was determined at the temperature range of 25 to 65 °C with 10 °C interval by using Tensiometer instrument (K100, Kruss Company, Germany). Temperature was controlled by a circulator bath (model F12, ED, JULAB, USA). An aliquot of 85 ml of solution was injected in the apparatus and density was measured by applying the following equation:

$$\rho_L = \rho_{MP} \frac{G_{MPA} - G_{MPL}}{G_{MPA}} \quad (6)$$

where, ρ_L , ρ_{MP} , G_{MPA} and G_{MPL} are liquid density, probe density, probe weight and probe weight in liquid, respectively.

2.5. Molecular weight measurement

The solution preparation procedure for molecular weight determination was the same as described in section 2.2, unless the concentration of the stock solution was 0.003 g/ml and the solvent was sodium phosphate buffer to suppress the tendency of forming aggregates. The stock solution was diluted by the same solvent to a series of three lower concentrations ranging from 0.0005 to

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