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Effect of sugars and salts on rheological properties of Balangu seed (*Lallemantia royleana*) gum

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ABSTRACT

The effect of different sugars (sucrose, glucose, fructose, and lactose) and salts (NaCl and $CaCl_2$) at various concentrations on rheological properties of Balangu seed gum (BSG, 1% w/w) was investigated. The apparent viscosity was influenced by the sugars and salts concentration and shear rate. Synergistic interaction between BSG gum and sugars improved the viscosity of solutions, whereas addition of salts decreased viscosity of gum solutions. The Power law and Herschel–Bulkley models were fitted to shear stress–shear rate data to obtain the consistency coefficient (K) and flow behavior index (n) for BSG solutions. Power law model well described non-Newtonian pseudoplastic behavior of BSG. Both K and n were sensitive to sugars and salts concentration. Highest values (0.45–0.49) of flow behavior index were observed for glucose at all concentrations. Addition of sucrose, fructose, lactose and salts to BSG led to more pseudoplastic solutions, whereas glucose decreased pseudoplasticity of solutions.

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1. Introduction

Hydrocolloids are high-molecular weight hydrophilic biopolymers used in food systems for various purposes, for example as thickeners, gelling agents, texture modifiers, and stabilizers [1–5]. Balangu seed (*Lallemantia royleana*) is mucilaginous endemic plant which is grown in different regions of Asia, Europe, and Middle East, especially in various regions of Iran. The extracted Balangu seed gum (BSG) has a high molecular weight and rather flexible chain [6,7]. There has been some research into the effect of BSG on the properties of ice cream, desserts and emulsions [1,2]. Also, there are many valuable studies that investigate the effect of BSG on quantitative and qualitative of sorghum gluten free bread [4].

At an industrial scale, real food formulations will usually involve the addition of other ingredients. Despite the great potential of the impact of sugar or salts on functionalities of this rarely investigated hydrocolloid, no extensive study has been reported on its rheological properties when commonly used sugars (sucrose, glucose, fructose, and lactose) and salts (NaCl and $CaCl_2$) are present [8,9].

The viscosity of Tamarind seed xyloglucan solution increases by the addition of a sugar such as sucrose, glucose or starch syrup. The degree of synergism varies to some extent, depending on the type of sugar [9].

At or below about 0.25% xanthan gum concentration, sodium chloride causes a slight decrease in viscosity. At higher gum concentrations, viscosity increases with added salt. At a sodium chloride level of 0.1%, a viscosity plateau is reached, and further addition of salt has little effect on viscosity. Many divalent metal salts, including those of calcium and magnesium, have a similar impact on viscosity [10]. It is reported that electrolytes increase the viscosity of algin and guar, but decrease the viscosity of Arabic and carrageenan gums. Carrageenan is very sensitive to potassium, ammonium, rubidium and cesium salts [11]. Salts also affect the chain stiffness of various microbial polysaccharides like gellan, rhamsan and welan gums [12]. Ionic gels are formed when divalent ions such as Ca^{2+} are added to alginate or pectin [13–15].

Among the additives generally used in food systems, the most abundant low molecular ones are NaCl, sucrose, glucose and fructose, afterwards the $CaCl_2$ and lactose are also the most important constituents present in dairy systems, which along with salts and sugars play a viral rule in taste and texture of various food products. Literature review shows that there is no recorded data about the rheological interaction between Balangu seed gum, sugars and salts. Therefore, the purpose of the present paper was to investigate the influence of different sugars (sucrose, glucose, fructose and lactose) and salts (NaCl and $CaCl_2$) on rheological properties of BSG. The results of this study will be helpful to understand and analyze the effect of BSG on the rheological properties of different products such as ice cream, desserts, dough and emulsions.

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2. Materials and methods

2.1. Balangu seed gum

Balangu seeds were purchased from a local market in Gorgan, Iran. The cleaned Balangu seeds were soaked in distilled water (water/seed ratio 20:1) at 50 °C, pH = 7, for 20 min. Separation of the hydrocolloid (BSG) from the swollen seeds was achieved by passing the seeds through an extractor equipped with a rotating plate that scraped the gum layer on the seed surface. The extracted solution was then filtered and dried in an air forced oven at 50 °C (convection oven, Memmert Universal, Schwabach, Germany) and finally the powder was milled, packed and kept at cool and dry condition.

2.2. Sample preparation

In this study different solutes including sucrose, D(+)-glucose (monohydrat), lactose (Merck, Darmstandt, Germany), fructose (Scharlau, Barcelona, Spain), sodium chloride and calcium chloride (Panreac, Barcelona, Spain) were used.

BSG solutions, 1% (w/w), were prepared by dispersing the gum powder in distilled water in presence or absence of solutes; sucrose, glucose, fructose and lactose (1, 2, 3 and 4% w/w), and NaCl and $CaCl_2$ (0.1, 0.25, 0.5 and 1% w/w) under constant mixing using a magnetic stirrer for 20 min at room temperature (magnetic stirrer, Falc Stirrer, UK). The solutions were kept on mixer (Memmert Universal, Schwabach, Germany) for 24 h to complete hydration, for evaluation of shear rate dependency.

2.3. Rheological measurements

The rheological measurements were carried out using a rotational viscometer (Model RVDV-II, Brookfield, Inc. USA). Solution samples were loaded into the coaxial cylindrical chamber (16 ml capacity; ULA-31Y, Brookfield, Inc. USA) for all experiments and were allowed to equilibrate at the desired temperature using a circulating water jacket (Model ULA-40Y, Brookfield, Inc. USA). The rheological parameters of BSG at different logarithmic shear rate of 6.12 to 245 s^{-1} were studied using spindle YULA-15 at 20 °C (±0.1 °C). All experiments were conducted at two replications and the data was presented as a mean of each experiment.

The shear rate ($\dot{\gamma}$) dependency of steady shear rheological properties of gums solutions may be described by different flow models such as Newtonian, Power law, Herschel–Bulkley, Casson, and other models [16]. The experimental shear stress (τ)–shear rate (γ) data was fitted with the different rheological models, to find out the best equation to relate shear rate to shear stress data. Power law and Herschel–Bulkley flow models were used to fit the experimental shear stress–shear rate data of Balangu seed gum solutions (Eqs. (1) and (2), respectively)

$$\tau = K\dot{\gamma}^n \quad (1)$$

$$\tau = K\dot{\gamma}^n + \tau_0 \quad (2)$$

where τ is shear stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency coefficient (Pa s^n), τ_0 is the yield stress and n is the flow behavior index (dimensionless). Modeling of data was performed with non-linear and multiple regression analysis functions and parameters associated with different models estimated from the experimental data using Curve Expert program version 1.34 [17].

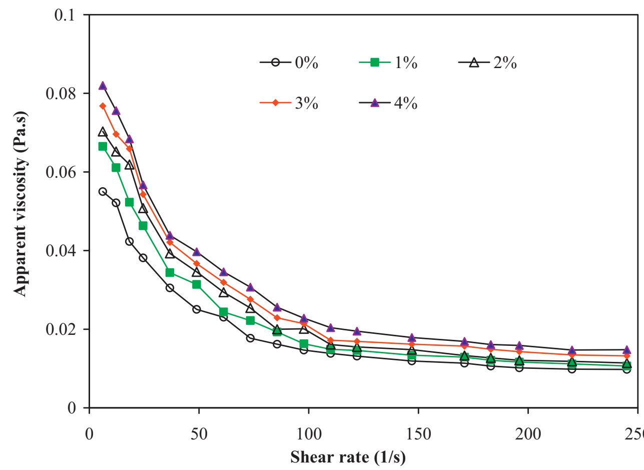

Fig. 1. Effect of different sucrose concentrations on apparent viscosity of Balangu seed gum solution.

3. Results and discussion

3.1. Effect of sugars

Solutions of hydrocolloids are usually known to be a non-Newtonian pseudoplastic fluid which means the apparent viscosity decreases when the shear rate increases or that the fluid is shear thinning in nature [3]. In this research the rheological properties of 1% (w/w) BSG in the presence of some sugars were studied. The flow curves of different sugars (sucrose, glucose, fructose and lactose) concentration (1–4% w/w) on the rheological properties of BSG solutions are presented in Figs. 1–5. Solutions of BSG exhibited interesting pseudoplastic behavior with the viscosity decreasing rapidly with increasing shear rate (from 5 to 50 s^{-1}) but less rapidly at higher shear rate range (from 50 to 245 s^{-1}). A clearly shear-thinning behavior was observed for all concentrations. Similar behavior was obtained at other sugar concentrations. The viscosity of solutions decreased with increasing shear rate. Such behavior has been observed for many hydrocolloid solutions [2,5,16,18–25].

Apparent viscosity clearly increased from 0.023 to 0.034 Pa s with increasing sucrose concentration from 0 to 4% w/w (shear rate = 61.2 s^{-1}, Fig. 1).

The presence of sucrose in the aqueous phase of liquid food systems containing hydrocolloids can change their rheological properties: the effect can be either an increase or a decrease in the

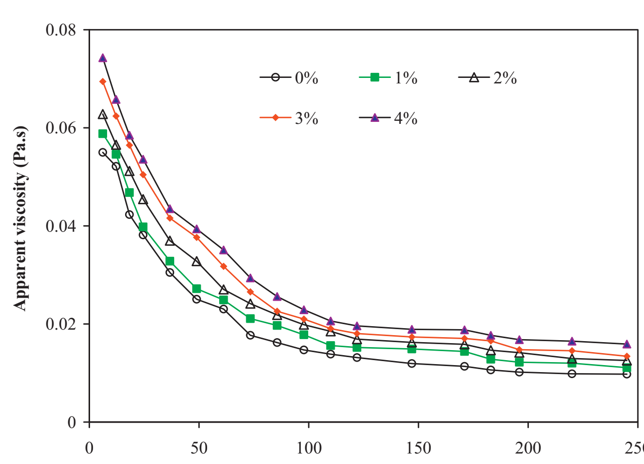

Fig. 2. Effect of different glucose concentrations on apparent viscosity of Balangu seed gum solution.

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