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Shear flow behaviour and emulsion-stabilizing effect of natural polysaccharide-protein gum in aqueous system and oil/water (O/W) emulsion

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ABSTRACT

The main objective of the current work was to characterize the shear rheological flow behaviour and emulsifying properties of the natural biopolymer from durian seed. The present study revealed that the extraction condition significantly affected the physical and functional characteristics of the natural biopolymer from durian seed. The dynamic oscillatory test indicated that the biopolymer from durian seed showed more gel (or solid) like behaviour than the viscous (or liquid) like behaviour ($G' > G''$) at a relatively high concentration (20%) in the fixed frequency (0.1 Hz). This might be explained by the fact that the gum coils disentangle at low frequencies during the long period of oscillation, thus resulting in more gel like behaviour than the viscous like behaviour. The average droplet size of oil in water (O/W) emulsions stabilized by durian seed gum significantly varied from 0.42 to 7.48 μm. The results indicated that O/W emulsions showed significant different stability after 4 months storage. This might be interpreted by the considerable effect of the extraction condition on the chemical and molecular structure of the biopolymer, thus affecting its emulsifying capacity. The biopolymer extracted by using low water to seed (W/S) ratio at the low temperature under the alkaline condition showed a relatively high emulsifying activity in O/W emulsion.

1. Introduction

Biopolymers have been widely used in food, cosmetic, pharmaceutical, and biomedical science [1]. In recent years, many studies have been devoted to ascertain the natural plant biopolymers with the potential functional properties. They are usually safe for oral consumption and preferred over analogous synthetic biopolymers due to their nontoxicity, low cost and availability [2]. Plant biopolymers are usually heterogeneous polysaccharide and protein composed of the monosaccharide and amino acid. Plant gums are a group of naturally occurring complex biopolymers commonly used for various industrial applications [3]. They are usually water-soluble biopolymers used to improve the rheological properties, extend shelf-life, and encapsulate flavours. They are also used to enhance the elasticity, modify the texture, retain the moisture, make the gel, and emulsify the oil [3,4].

The physicochemical properties of food emulsions are directly related to their quality and acceptability [5]. It is possible to form a kinetically stable dispersion for a long period, by using 'emulsifiers'. The emulsion stability can be enhanced by using high molecular weight polysaccharides and proteins that protect emulsion droplets against creaming, flocculation and coalescence [6]. The main emulsifying role of the emulsifier in the emulsion system is to adsorb at the surface of freshly formed emulsion droplets to prevent the aggregation and coalescence (Fig. 1) [4]. In addition, the contribution of the emulsifier into the emulsion stability is also related to its significant effect on the rheological properties and viscoelastic behaviour of the continuous phase of the emulsion system. In this regard, the emulsifying capacity is defined as the amount of oil required to reach the inversion point, when the emulsion collapses and the viscosity drops [7].

Many plant gums (e.g. carrageenan, pectin, CMC, starch, guar, and sodium carboxyl methyl cellulose) are used as the thickening agent to modify the rheological properties, viscoelastic behaviour and overall acceptability of food products. The rheological properties and viscoelastic behaviour of plant gums significantly depend on their chemical composition and molecular structure. On the other hand, the extraction and further processing conditions of the plant gum significantly influence its chemical composition and molecular structure, thus affecting its rheological behaviour. The viscoelastic behaviour of various plant gums in the aqueous and dispersion systems have been studied by previous researchers. Chenlo and co-researchers [8] studied the rheological behaviour and viscoelastic properties of tragacanth and guar gum. They observed that the storage and loss modulus (G' and G'') of gum solutions decreased with time. Jafari and co-workers [9] compared the rheological behaviour of Angum gum and gum Arabic in the emulsion system. They illustrated that rheological behaviour of Angum

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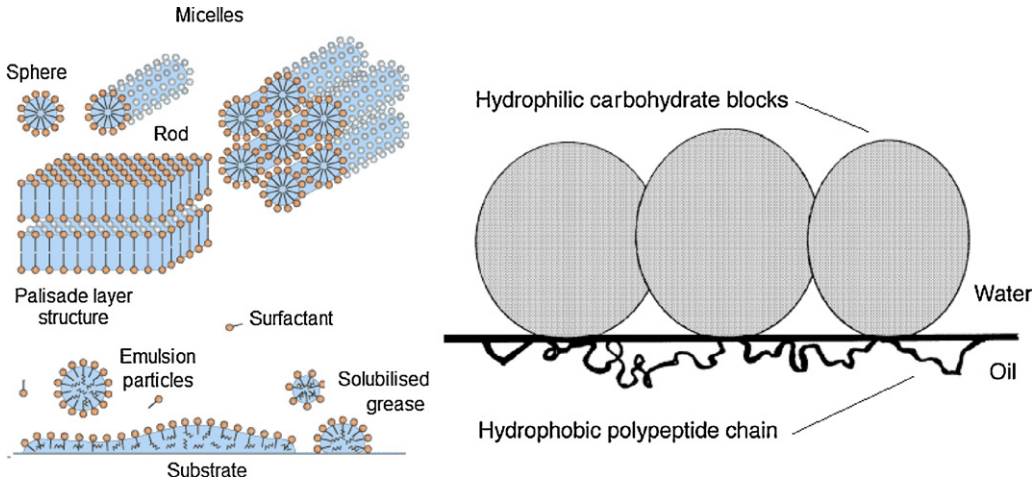

Fig. 1. The surface activity of an emulsifier containing auxiliary hydrophobic and hydrophilic groups [4].

gum-emulsions followed Herschel–Bulkley model with higher viscosity than the viscosity induced by gum Arabic. Srichamroen and Chavasit [10] investigated the influence of different extraction variables (i.e. pH, ionic strength, and co-solutes addition) on the viscoelastic properties (i.e. storage modulus (G') and loss modulus (G“)) of Malva nut gum (MNG). They reported that MNG exhibited more gel-like behaviour rather than viscous like behaviour ($G' > G$“).

The main objective of the current work to investigate the effect of three extraction variables namely water:seed (W/S, 20:1–60:1, w/w) ratio, temperature (25–85 °C) and pH (4–10) on the physical and functional properties of durian seed gum. While the behaviour of many plant gums (such as gum Arabic, flaxseed gum, tragacanth) in the emulsion system has been extensively deliberated, the emulsifying properties of the biopolymer from durian seed have not been studied on date.

2. Experimental

2.1. Sample preparation

In this study, Durian fruit (*D. zibethinus*) cultivars were purchased from the local market (Selongor, Malaysia). Ripened durian fruits were selected based on the size uniformity and free of visual defects. Fruits were de-husked, and seeds were removed, cleaned and rinsed thoroughly with sterile distilled water. Fruit seeds were placed in front of air circulation to reduce the moisture content, thus resisting the germination during storage. Then, they were packed in plastic bags, and stored in a dry and cool place (10 ± 2 °C) until the extraction.

2.2. Gum extraction process

Durian seed gum was extracted out according to the method described in our previous study [11] with minor modification. Dried durian seeds were chopped and milled into the flour. Gum extraction process was carried out by using deionized water from the durian seed flour under different experimental conditions (i.e. water to seed (W/S) ratio (20:1–60:1 w/w, x_1), temperature (25–85 °C, x_2) and pH (4-10, x_3)). During the extraction process, pH was continuously adjusted by 0.1 mol/L NaOH and HCl; while the temperature of the adjustable water bath ranged from 25 to 85 ± 1 °C. The seed-water slurry was stirred throughout the entire extraction period (1 h, based on our preliminary tests). The seed was separated from the slurry by using a Beckman centrifuge (Avanti J-25 Centrifuge, Fullerton, CA, USA) at approximately 1200 rpm for 10 min [11]. The mucilage was recovered from the extract via precipitation in three volumes of 95% ethanol. Subsequently, 5 g of the mucilage was dissolved in 1 L of water and placed at 70 °C water bath for 6 h. Then, the mixture was stirred at ambient temperature overnight and centrifuged for 15 min at 4000 rpm. The supernatant was precipitated by using 1 L of 99% ethanol, and collected by the vacuum filtration on a glass filter (No. 2). The precipitate was washed successively with acetone and diethyl ether. After keeping in a fume hood at room temperature overnight, the gum was dispersed in deionized water and dried in a vacuum oven drier at 40 °C.

2.3. Analytical test

2.3.1. Emulsion stability

The creaming stability of oil in water (O/W) emulsions containing durian seed gum was assessed according to the method described by Huang and co-researchers [12]. Initially, O/W emulsion was prepared by using durian seed gum (20% w/w), orange oil (10% w/w), sodium benzoate (0.1% w/w), and citric acid (0.5% w/w). The continuous phase was prepared by adding gradually durian seed gum into the deionized water (50 °C) containing sodium benzoate and citric acid. Then, it was mixed for 3 min and kept overnight at room temperature to facilitate the hydration. Finally, 10% oil was gradually added into the continuous phase and mixed for 5 min to make a coarse emulsion. The coarse emulsion was then passed through a high pressure homogenizer (APV, Crawley, UK) for three passes (30, 28 and 25 MPa). For the stability test, 10 ml of the prepared emulsion was transferred into a test tube (internal diameter 15 mm and height 125 mm), and then stored for 4 months at the room temperature (25 ± 1 °C). The prepared emulsions were separated into an optically opaque ‘cream’ layer at the top and a transparent (or turbid) ‘serum’ layer at the bottom. The percentage of stability was determined from the ratio volumes of wholesome emulsion over volumes of initial emulsion samples. Emulsion stability index (ESI) was calculated as percentage of the initial emulsion height (HE), height of cream layer (HC) and height of the sedimentation phase (HS) by the following equation: ESI (%) = 100 × (HE − (HS + HC))/HE [12]. The stability index provides the indirect information on the extent of droplet aggregation in an emulsion. The stability measurement was performed in duplicate for each sample.

2.3.2. Average droplet size

The surface-weighted mean (or average droplet size) of O/W emulsions containing durian seed gum was measured by using