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An acidic heteropolysaccharide from *Mesona chinensis*: Rheological properties, gelling behavior and texture characteristics

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ABSTRACT

Polysaccharide from *Mesona chinensis* is becoming increasingly attractive focus because of its gelling property and biological activities. In this study, the rheological properties of an acidic heteropolysaccharide from *Mesona chinensis* (MCP) were investigated in dilute and semidilute solutions. Dynamic rheology was systematically conducted to investigate the effects of concentration, temperature, pH values, salts and freeze-thaw variations on the rheological properties of MCP. Results showed that the rheological properties of MCP exhibited pseudoplastic characteristic and "gel-like" behavior by the flow behavior detection. A closed hysteresis loop was formed when the MCP concentration reached 4%, and the Gel was generated when the MCP concentration reached 5%. The storage modulu (G′) and loss modulu (G″) of MCP solution were increased with increasing oscillation frequency at concentration of 4% and 5%. The phase angel (tanδ) was less than 1, indicating MCP was a weak gel in linear viscoelastic region. The gel exhibited favourable textural properties when MCP at concentration 5%. The scanning electron microscope (SEM) verified MCP had a unique lotus leaf-like shape with some small irregular round-like rods surface morphology.

1. Introduction

Mesona chinensis, also named Hsian-tsao, Herb Jelly and *Mesona chinensis* benth, belonging to the *Lamiaceae* family, is an edible and medicinal yearly herbaceous herb plant [1]. It was used by people in the India, Indonesia, Malaysia, the Philippines, Thailand, China, and Southeast Asia for thousands of years. In China, it is widely distributed in Guangdong, Guangxi, Jiangxi, Zhejiang, Taiwan, Yunnan and Fujian provinces. Various types of components, including polysaccharide, campesterol, apigenin, saponins, flavonoid, terpenoid, kaempferol, caffeic acid, protocatechuic acid, and polyphenos have been reported in *Mesona chinensis* [1,2]. It has been demonstrated that the extracts of *Mesona chinensis* has a wide range of biological properties, such as antioxidant, anti-inflammatory [3], hepatoprotective [4], hypouricemic [5], hypolipidaemic [1], and anti-hypertensive activities [6].

As the main component of *Mesona chinensis*, polysaccharide from *Mesona chinensis* had been demonstrated to possess many biological properties, such as anti-oxidant [2], immunoregulation, and anti-diabetic effects [7]. It was an acidic heteropolysaccharide consisting of galactose, arabinose, glucose, galacturonic acid and protein with an average molecular weight (*Mw*) of 1.45×10^6 Da [2]. Structural features of an polysaccharide gum (AMBG) fractionated from *Mesona Blumes* gum might possess a backbone of the average disaccharide of [→4)-a-D-Gal*p*A(1 → 2)-a-D-Rha*p*-(1 →], with h-(1 → 4)-linked Xyl*p* residues, β-(1 → 3) and β-(1 → 6)-linked Gal*p* (galactan) residues as the side chain. It also had a certain degree of methyl esterification [8]. Polysaccharide from *Mesona chinensis* has good gelling properties, it can form good bean jelly by mixing with starches. The mixture of *Mesona chinensis* gum and casein film endowed casein film better texture characteristics and stronger oxidation resistance [9].

The rheological properties and gelling behaviors of food components and their change mechanism under the conditions of flow and deformation are important for design, shelf-life estimation, and evaluation of the stability of food products [10,11]. The extraction, structural properties, product design, storage period, sensory

Abbreviations: MCP, acidic heteropolysaccharide from *Mesona chinensis*; *Mw*, molecular weight; SEM, scanning electron microscope; LVR, linear viscoelastic region; TPA, texture profile analysis; SD, standard deviations; ANOVA, Analysis of variance.

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evaluation and stability during processing of polysaccharides are significantly affected by rheological properties such as apparent viscosity, shear stress and shear rate. Rheological experiments can contribute to understanding chain conformation, conformation transition, and other physical properties of polysaccharides in solution [12,13]. Carrageenan and konjac glucomannan were employed as gelling agent, thickener and emulsifier in various food like jelly, sausage, soft sweets, and ice cream [14]. Rheological properties of polysaccharides are affected not only by their physicochemical properties, but also external factors such as temperature, pH value, shear stress, and salt ion [15].

In recent years, a great deal of interest has been given to the polysaccharide from *Mesona chinensis*. Many studies have reported its extraction optimization, physicochemical properties, structures and biological activities, but few studies have been investigated focused on the rheological properties, gelling behavior and texture characteristics of the polysaccharide. Therefore, the aim of this paper was to investigate the rheological properties of an acidic heteropolysaccharide from *Mesona chinensis* (MCP) comprehensively and verify its gelling behavior and texture characteristics.

2. Materials and methods

2.1. Materials and reagents

The *Mesona chinensis* Benth was purchased from Xiaoshicheng, Ganzhou, Jiangxi, China. A voucher specimen was deposited at the State Key Laboratory of Food Science and Technology, Nanchang University, China. The *Mesona chinensis* samples were identified by Prof. Yuanxing Wang, School of Food Science and Technology, Nanchang University. *Mesona chinensis* was air desiccated and milled by a mechanical grinder for 10 min to get the fine powder before MCP extraction.

Silicone oil was purchased from Sigma Chemical Co. (St. Louis, MO, USA). All other chemicals and reagents such as sodium carbonate, NaCl, $CaCl_2$, $ZnCl_2$, and sucrose were of analytical grade and purchased from Xilong Scientific Co., Ltd. (Guangdong, China). The ultra-pure water was provided by a Milli-Q water purification system (Millipore, USA).

2.2. Preparation of MCP solutions

The MCP was extracted by hot alkali extraction method [2]. MCP was accurately weighed, then dissolved in ultra-pure water adequately with stir (60 °C, 0.5 h) to obtain a series of concentrations of MCP solutions ranging from 0.5 to 5.0%. MCP solutions with different pH values were adjusted by using either 0.1 M HCl or 0.1 M NaOH. The effects of different types of salts (NaCl, $CaCl_2$, $ZnCl_2$), sucrose and freeze-thaw variation on the apparent viscosity of MCP were investigated seriatim. The prepared samples were stored (25 °C, 12 h) for adequately hydration in ultrapure water for use in subsequent experiments.

2.3. Rheological analysis

All the rheological analysis including flow behavior, thixotropy, and viscoelasticity were measured by a strain controlled ARES rheometer (TA Instruments, New Castle, USA) equipped with cone-plate (40 mm diameter, gap 0.05 mm). A circulating water system was employed to keep the precise temperature-variation of the bottom plate during tests. Different temperatures were set for studying the effects of temperatures on apparent viscosity of MCP, and every applied sample was covered with silicone oil prior to measurement to avoid evaporation. Other rheological tests were conducted at 25 °C. The ARES rheometer was zero adjusted. 1.5 mL of prepared samples with different concentrations of 0.5–5.0 mg/mL was carefully loaded onto the Peltier plate of rheometer. Before the formal test, the loaded samples were maintained for 2.0 min for waiting the equilibration of stress and temperature. All the experimental rheological data were obtained directly from the TA Rheology Data Analysis software.

2.3.1. Intrinsic viscosity

Huggins empirical expression and an Ubbelohde capillary viscometer (25 ± 0.1 °C, Φ 0.57 mm) were employed to determine the intrinsic viscosity of dilute MCP solutions (0.1–0.5 mg/mL) [16].

$$\frac{\eta_{sp}}{c} = [\eta] + k_H[\eta]^2 \quad (1)$$

Where c is the concentration of polymer solution, $[\eta]$ is the intrinsic viscosity, k_H is the Huggins coefficient, respectively; η_{sp} is defined as $(\eta - \eta_s)/\eta_s$, η and η_s are the viscosity of the polymer solution and the pure solvent, respectively.

2.3.2. Flow behavior

The shear rate ranging from 0.01 to 1000 s^{-1} was run to obtain the flow curves of MCP, and the power–law model was employed to explain the flow behavior of MCP.

$$\tau = k(\gamma)^n \quad (2)$$

Where τ represents the shear stress, γ represents the shear rate, k represents a consistency index and its value is related to the concentration of polymer solution, and n is the index of power–law model.

Besides, the effects of pH, temperature, different salts and freeze-thaw variation on the apparent viscosity of MCP were also investigated at the same shear rate.

2.3.3. Thixotropic property

The shear rate increasing from 0.01 to 1000 s^{-1} and then decreasing from 1000 to 0.01 s^{-1} in the same time were implemented to obtain the upward and downward curves of MCP, and the area of formed hysteresis loop was calculated by calculating the original shear rate (γ_1) to the last shear rate (γ_2) [17].

$$\text{Hysteresis loop area} = \int_{\gamma_2}^{\gamma_1} k_1(\gamma)^{n_1} - \int_{\gamma_2}^{\gamma_1} k_2(\gamma)^{n_2} \quad (3)$$

Where n_1, n_2 and k_1, k_2 are the behavior index and consistency coefficient for upward and downward measurement, respectively.

2.4. Linear viscoelastic region and dynamic oscillatory measurements

The linear viscoelastic region (LVR) of MCP was conducted systematically for latter dynamic oscillatory measurements. Concisely, the storage modulus (G′) was recorded along with the shape changing from 0.1 to 200%, and the frequency was set as 1 Hz.

The dynamic oscillatory measurements of MCP at different concentrations in the linear viscoelastic region were studied seriatim. The storage modulus (G′), the loss modulus (G″) and the phase angle (tanδ) were obtained under the experiment conditions of 1% shape change and 0.1–70 Hz frequency.

Furthermore, the dynamic temperature sweep measurements of MCP under different temperature in the linear viscoelastic region were also performed. The numerical values of G′, G″ and tanδ were acquired under the experimental conditions of 1% shape change, 1 Hz frequency and from 5 to 45 °C with heating rates of 5 °C/min. The applied sample was covered with silicone oil prior to measurement to avoid evaporation.