



Studies on the steady shear flow behavior and chemical properties of water-soluble polysaccharide from *Ziziphus lotus* fruit



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ABSTRACT

The extraction of water-soluble polysaccharide from *Ziziphus lotus* fruit (WPZL) was performed by ultrasonic-assisted extraction method. A Box–Behnken design (BBD) was applied to evaluate the effects of three independent variables (ultrasonic power (X_1 : 70–100 W), extraction time (X_2 : 10–30 min), extraction temperature (X_3 : 55–95 °C), and water to raw material ratio (X_4 : 5–25)) on the extraction yield of APH. The effect of temperature and concentration on flow behavior of gum solution was studied. WPZL solutions exhibited shear-thinning non-Newtonian flow behavior for concentrations above 0.5% (w/v). The viscosity of fully hydrated gum solutions decreased as temperature increase. The correlation analysis of the mathematical-regression model indicated that quadratic polynomial model could be employed to optimize the extraction of WPZL. The optimal conditions to obtain the highest extraction of WPZL ($13.398 \pm 0.019\%$) were as follows: ultrasonic power, 88.77 W; extraction time, 29.96 min, extraction temperature, 77.73 °C and water to raw material ratio 24.44 mL/g.

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1. Introduction

Ziziphus lotus belongs to the genus *Ziziphus* (Rhamnaceae) and is widely distributed in Iran, China and South Korea. Its fruits are used as edible food and traditional Chinese medicine (Fig. 1). The fruits are claimed to purify the blood and aid digestion [1]. Among the bioactive constituents, polysaccharides may play an important role. Yamada et al. reported polysaccharides from the fruits had anti-complementary activities [2].

Plant polysaccharides, long chain high molecular weight polymers that dissolve or disperse in water to give a thickening, stabilizing or gelling effect, are generally polyuronides composed of more than one type of monosaccharide unit [3].

Polysaccharides can be used as dietary fiber, texture modifiers, gelling agents, thickeners, stabilisers as well as emulsifiers, coating agents, and packaging films. The physicochemical and functional properties of plant based gum are influenced by the chemical composition, molecular structure, extraction, and further processing conditions [4]. In recent years, the demand for hydrocolloid from plant sources has been considerably increased because they are the most notable ingredient in liquid and semisolid foods [5]. Various

parts of plant (e.g. plant cell walls, tree exudates, seeds, tuber/roots, and seaweeds) have surface cells containing gums, mucilage, fiber, and protein compounds. In fact, plant gum exudates are produced by plants as a result of the protection mechanisms against mechanical or microbial injury [6].

Response surface methodology (RSM) is a collection of mathematical and empirical techniques useful for establishing models, and for optimizing processes even in the presence of complex interactions [7]. This procedure not only determines the interaction between parameters, but also reduces the number of experimental trials, development time and overall cost [8].

The objectives of this study were 1- to investigate the effect of process parameters (ultrasonic power, extraction time, extraction temperature and water to raw material ratio) on the extraction yield of water-soluble polysaccharide from *Z. Lotus* fruit (WPZL), 2- to optimize the extraction yield of WPZL by response surface methodology, 3-to study the rheological and chemical properties of extracted polysaccharide.

2. Materials and methods

2.1. Chemicals and plant materials

The fresh fruits of *Z. lotus* were collected during March 2014 from Mollasani, Khuzestan province, Iran, washed with tap water, rinsed

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Fig. 1. *Ziziphus lotus* fruits used in present work.

with deionized water, and then air-dried at ambient temperature (30 °C). The samples were then pulverized using a laboratory grinding machine, sieved and the collected powders (mesh size 200–300) were used. All other reagents used were of analytical grade.

2.2. Extraction process of water-soluble polysaccharide

The extraction of water-soluble polysaccharide from *Z. lotus* fruit (WPZL) was performed using a method described by Samavati and Manoochehrizadeh [9] (Fig. 2).

Ground *Z. lotus* fruit (50 g) was refluxed with 95% ethanol at 60 °C in a water bath for 3 h to deactivate the endogenous enzymes and remove some soluble materials, including free sugars, amino acids and some phenols. The ethanolic mixture extract was centrifuged (4000 × g, 10 min). The remaining solids were vacuum-dried at 50 °C for 12 h, and suspended in the water at the temperature of 60 °C and for 3 h. The supernatant was concentrated in a rotary evaporator under reduced pressure at 55 °C, and then mixed with 4-fold volumes of ethanol 95% and kept at 4 °C for 24 h. After centrifugation at 5000 rpm/min for 15 min, the precipitate was washed acetone in a ratio of 1:10 (wt/wt) at the boil for 2 h to further remove lipids and pigments. After filtration, the treated material was washed three times with anhydrous ethanol and then lyophilized to yield WPZL sample. The percentage gum yield (%) is calculated as follows:

$$\text{WPZL extraction yield \% (w/w)} = \frac{W_0}{W} \quad (1)$$

W_0 (g) is the dried WPZL weight; W (g) is the dried powder of *Z. lotus* fruit weight.

2.3. Experimental design and statistical analysis

Response surface methodology (RSM) was used to estimate the effect of independent variables (ultrasonic power, A—extraction time, B—extraction temperature, C—and water to the raw material ratio—D) on the extraction yield of WPZL (%). A Box–Behnken design (BBD) was employed for designing the experimental data.

The RSM was applied to the experimental data using a commercial statistical package, Design-Expert version 8.0.7.1 (Minneapolis, USA). Experiments were randomized in order to minimize the effects of unexplained variability in the observed responses due to extraneous factors. The experimental design included star points, and six center points to calculate the repeatability of the method [10]. After determining the preliminary range of the extraction

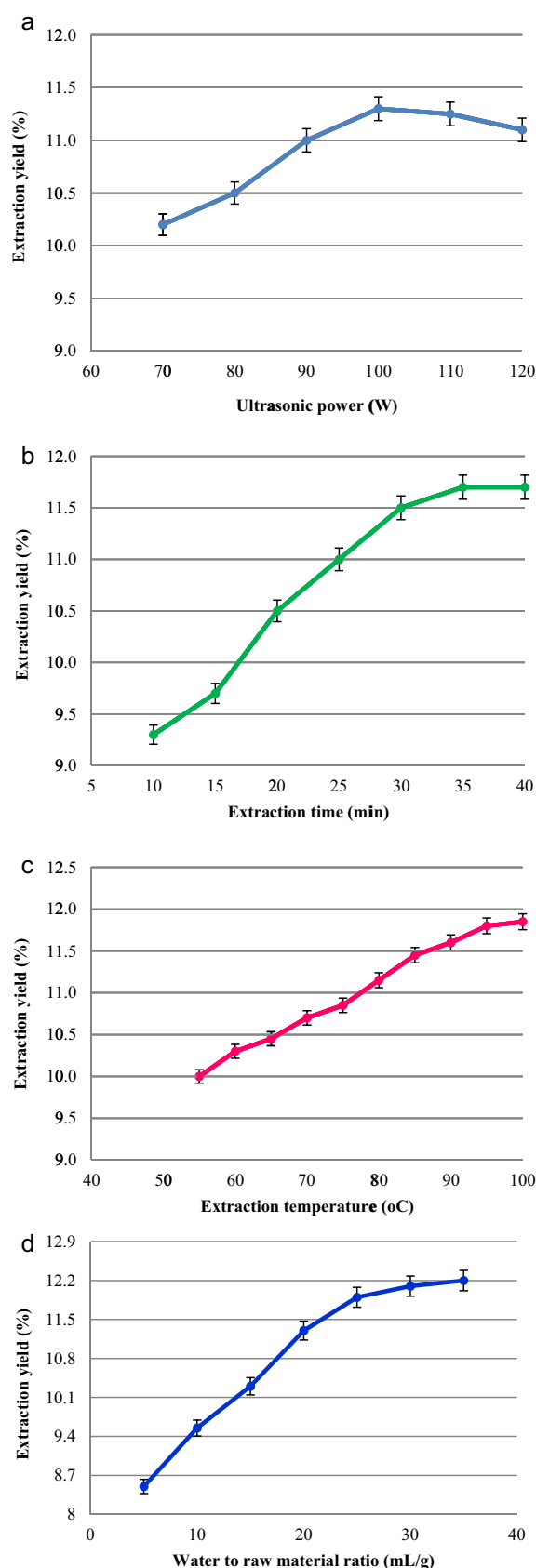


Fig. 2. Effects of ultrasonic power (a), extraction time (b), extraction temperatures (c) and water to raw material ratio (d) on the extraction yield of WPZL (%). Data are mean ± SD for three measurements.

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