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Rheological properties of low fat yogurt containing cress seed gum

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ABSTRACT

Yogurt—a milk based mix fermented by lactic acid bacteria is a valuable health food for both young and old. Milk is the main ingredient of yogurt. However, most yogurts contain additional solids such as milk solids nonfat to boost the nonfat milk solids. Stabilizers such as natural gums are added to improve and maintain gel firmness and consistency, while also for many people to improve appearance and mouth feel. Hydrocolloids specifically stabilize gel structure, increase viscosity and either from networks with milk constituents and establish a separate gel structure. In current research, a natural local plant Iranian hydrocolloid, cress seed gum, is added to yogurt formulation and its rheological properties are evaluated using a rotational viscometer. Different famous rheological models have been used to fit shear stress-shear rate data's. The results demonstrated that cress seed gum has a good potential to be used as a stabilizer in yogurt formula.

Keywords: Yogurt; Hydrocolloids; Cress Seed Gum; Rheological Properties; Viscosity

1. INTRODUCTION

The growing awareness of the relationship between diet and health has led to an increased demand for food products that support health above and beyond providing basic nutrition. One of these products is yogurt that is made from milk. Yogurt essentially has all the nutritive components of milk [1]. Yogurts are prepared by fermentation of milk with bacterial cultures consisting of a mixture of *Streptococcus* subsp. *Thermophiles* and *Lactobacillus delbrueckii* subsp. *Bulgaricus* [2]. Recently, consumption of whole dairy products (e.g. full fat yogurt) has declined due to the awareness of the probable harmful effect of fat on consumer's health, thus dietary habits of consumers have been changed and market interest has tended to change in favor of low or nonfat dairy products [3]. According to the Code of Federal Regulations of FDA, low fat yogurt and nonfat yogurt are similar in description to yogurt but contain 0.5% to 2% and less than 0.5% milk fat, respectively [4,5]. Milk fat has an important role in the texture, flavor and color development of dairy products [6]. Because of reduction of fat and subsequently reduction of total solids content in low fat and nonfat yogurts, they exhibit weak body, poor texture, and whey separation unless various stabilizer blends or ropy strains of yogurt bacteria are used [7]. It is a big challenge for many food scientists to produce a suitable fat substitute to provide the functionality of the missing fat [8]. Therefore, manufacturers have followed different strategies including the milk solid nonfat in yogurt milk, in addition of nondairy based stabilizers, and usage of milk proteins as fat substitutes [9]. Although, enhancing the total solid content of skim yogurt similar to full fat products is a traditional and common method which leads to improvement in viscosity and water binding in yogurt [10]. Hydrocolloids are used in food products as thickeners, stabilizer, gelling agents and emulsifiers. They improve the texture of the products, increase water retention while enhancing lower energy value; they are often employed in low-calorie foods [11]. Stabilizers are used to produce a thick, cohesive body, smooth texture and to prevent wheying off [12] and to improve consistency (increase viscosity) and reduce syneresis [13]. Stabilizers such as pectin or gelatin are often added to the milk base to enhance or maintain the appropriate yogurt properties including texture, mouth feel, and appearance viscosity/consistency and to prevent whey separation [2]. The effects of some stabilizers such as waxy maize starch, gelatin, xanthan gum, low methoxy pectin, guar gum, locust bean gum, and λ-carrageenan on the microstructure and rheology of yogurt have been studied [14,15]. Reference [16] was the first research on cress seed gum. The researches on this area were continued by the same author [17-20]; however, literature review still shows the lack of complete and sufficient information about this new Iranian hydrocolloid and its possible use in food formulations. Thus, the objectives of this study were first to evaluate the physicochemical properties of yogurt containing different concentrations of the gum and second to evaluate the rheological properties of this food formula using different rheological models.

2. MATERIALS AND METHODS

2.1. Yogurt Treatments

Five yogurts treatments were made as follows: control low fat yogurt; low fat yogurt fortified with 0.05, 0.07, 0.1 and 0.15 g/100mL of cress seed gum.

2.2. Materials

Skim milk with 0.5% fat content and Starter culture were obtained from Pegah Dairy Company (Mashhad, Iran). Cress seeds were provided by a medical plant supplier in Mashhad, Iran. All impure matter such as dust, dirt, stone, chaff and broken seed were manually removed from the seeds.

Extracts of dry cress seeds were prepared according to the method presented in [17]. Briefly, cress seed was soaked in preheated de-ionized water at a water/seed ratio of 30:1. 0.1 mol/L NaOH solution was used to adjust the pH to 10. The slurry was stirred continuously for about 15 minutes in constant temperature (35˚C). An extractor with a rotating rough plate was employed to cut the gum layer off the seed. This degummed seeds were discarded; finally, the slurry was dried with the 60˚C air forced oven and milled to powders. They were kept in cool and dry condition.

2.3. Preparation of Yogurt Starter Culture

The yogurt culture combination of *Lactobacillus delbrueckii* ssp. *Bulgaricus* and *Streptococcus thermophiles* was weighted (10 g) and added to 100 mL of sterile skim milk. One milliliter of this mixture was inoculated per 100 mL of yogurt mix.

2.4. Preparation of Yogurt Mixes

In this experiment, low fat yogurt samples were made by adding different concentration of cress seed gum into skim milk (0.05, 0.07, 0.1 and 0.15) as stabilizer. Control sample was made from skim milk without hydrocolloid. After blending, each mix was pasteurized at 85˚C for 30 minutes, then cooled to 42˚C and inoculated with 0.1% yogurt starter, dispensed into plastic containers and incubated at 42˚C for approximately 4 - 4.5 hours; until the pH reached 4.6. Then cooled to 4˚C and kept at refrigerator.

2.5. Rheological Analysis

The rheological parameters were determined using rotational viscometers (model RV, DV-III ULTRA, BROOKFIELD). The temperature of the system was set and maintained at ambient temperature (25˚C) for the flow curve. The flow curves of the low fat yogurts were determined using shear rate ranging from 0 to 85 s^{-1}. The rheological properties were fitted to three models including: the Power law, Herschel-Bulkley and Casson models.

The equations for these models are:

Power law model: $\sigma = K(\dot{\gamma})^n$

Herschel-Bulkley model: $\sigma = \sigma_\circ + K(\dot{\gamma})^n$

Casson model: $\sigma^{1/2} = \sigma_\circ^{1/2} + K(\dot{\gamma})^{1/2}$

Where σ is the shear stress (Pa), $\sigma_\circ$ is the yield stress, $\dot{\gamma}$ is the shear rate (s^{-1}), K is the consistency index (Pa. s^n) and n is the flow behavior index (dimensionless).

2.6. Statistical Analysis

The experiments were performed in two duplicates. Analysis of variance (ANOVA) was performed using the Duncan's multiple-range test to compare treatment means. Significance was defined at $p < 0.05$.

3. RESULTS AND DISCUSSIONS

The flow curves for samples containing cress seed gum with different concentrations at 25˚C are depicted in **Figure 1**. A shear-thinning behavior was observed for all concentrations (**Figure 2**) and becomes more prominent as the concentration is increased shown by a decrease in values of the flow behavior index (data for power law model, **Table 1**). For all samples, an increase in concentration was accompanied by an increase in pseudoplasticity,

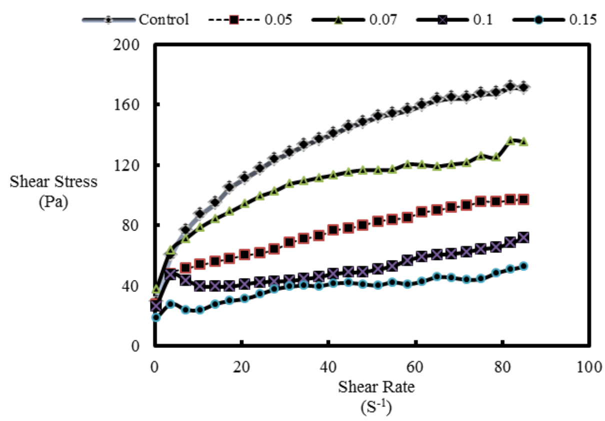

Figure 1. Flow curves of yogurt samples containing cress seed gum.

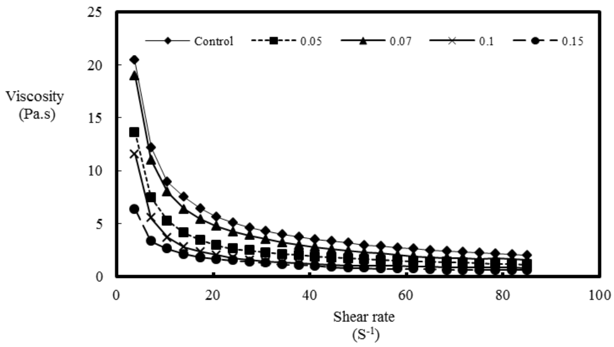

Figure 2. Viscosity curves for different yogurt samples.

Table 1. Calculated flow model parameters for yogurt samples with different concentrations (25˚C).

Model Sample	Power law			Herschel-Bulkley				Casson		
	R^2	*K*	*n*	R^2	σ_0	*K*	*n*	R^2	σ_0	*K*
Control	0.99	41.39	0.32	0.99	20.54	29.01	0.37	0.95	50.30	0.70
0.05%	0.97	27.20	0.28	0.99	27.19	7.33	0.51	0.98	32.04	0.46
0.07%	0.98	46.63	0.23	0.97	14.63	34.62	0.27	0.92	53.66	0.47
0.1%	0.73	24.49	0.20	0.98	34.66	0.10	1.31	0.84	26.23	0.31
0.15%	0.91	16.18	0.24	0.93	16.56	3.43	0.51	0.93	18.60	0.29

shown by a decrease in values of the flow behavior index (**Table 1**). This suggested that the deviation from the Newtonian behavior (n = 1) increased with increasing the solids concentration of hydrocolloid.

In addition the consistency coefficient generally showed an increment with the concentration of cress seed solutions (0.07% concentration) (**Table 1**). This behavior is generally explained to arise from disentanglement of the polymer network and the partial chain orientation or alignment of micro-structure in the direction of the shear flow, thus, reducing the local drag [21]. The viscosity of solutions decreased with increasing shear rate (**Figure 2**). With further shear rate increasing the intermolecular interactions (particularly the entanglements) may be declined due to a micro structural anisotropy resulting from the shear deformation and consequently the shear stress is further decreased [22].

A pronounced shear-thinning behavior of samples may be interpreted by its rather rigid chain conformation that gives rise to a highly entangled macromolecular solution [16] and the presence of gel-like structure which is chiefly related to the tendency of molecular association, demonstrated by the high-hydro gel content of the extract (76%) and its high M/G ratio (8/2) [18].

All models used in this study were directly applied to the experimentally measured shear stress-shear rate data define flow behavior. Although all these mentioned models with yield stress indicate high R^2, from the point of being in better agreement with the experimental data and consistency with theories, Herschel-Bulkley model do the best (**Table 1**). Such behavior was obtained other concentrations. The parameters obtained for the different models are summarized in **Table 1**. The results showed that n values were less than unity conforming that these products are pseudo-plastic materials at all concentrations studied. The coefficients of determination (R^2) obtained were high, indicating that all model were adequately suitable for describing the flow behavior of samples.

The value of consistency coefficient (K), flow behavior index (n), and yield stress ($\sigma_\circ$) ranged from 0.1 to 29.01 Pa. s^n, 0.3 to 1 and 14.63 to 34.66 Pa, respectively. The existence of $\sigma_\circ$ indicates that there is a cross-linked or other interactive in a material which must be broken down before flow can occur at an appreciable rate [23,24].

Results show that samples containing hydrocolloids have a higher viscosity, because hydrocolloid can bond water in samples and consequently increase the viscosity, but this increment in up to 0.1% gum concentration which shows some possible variations in protein-protein interactions in three dimensional protein networks in samples. The data's of water loss confirm these results (data are not presented here).

4. CONCLUSION

Cress seed gum exhibited a positive relationship with yogurt quality parameters. All samples showed a shear thinning profile. Herschel-Bulkley model found to be the best model to describe the rheological behavior. Yogurts showed to have a yield stress which indicates a cross linked structure in samples. Addition of cress seed gum due to its high pharmaceutical properties and simple extraction and availability in the yogurt mixes could be plausible measure to improve yogurt gel quality.

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