Time-dependent flow properties and thixotropy of *Alyssum homolocarpum* seed gum solutions

Arash Koocheki and Seyed M. A. Razavi
Department of Food Science and Technology, Ferdowsi University of Mashhad (FUM),PO Box: 91775-1163, Mashhad, Iran

The thixotropy and time-dependent rheological behavior of *Alyssum homolocarpum* seed gum solutions, with different gum concentrations (3%, 3.5% and 4%) were studied at different temperatures (5–65°C) using a rotational viscometer. It was found that *Alyssum homolocarpum* seed gum samples exhibited shear thinning and thixotropic behavior for all concentrations and temperatures. The experimental data were fitted with first-order stress decay model with a non-zero stress. At a constant concentration and temperature, the shear stress decreased rapidly with time within the first 100 s of shearing and approached a constant value corresponding to an equilibrium state after approximately 300 s. The extent of thixotropy increased with increasing the gum concentration at constant temperature and decreased with increasing temperature and shear rate at constant concentration. In this work, the decay rate constant generally increased with increasing shear rate, however it did not have any trend with concentration and temperature.

Keywords: Rheology, *Alyssum homolocarpum*, Time-dependency, Thixotropy, First-order stress decay model

1 INTRODUCTION

Alyssum homolocarpum seed is known under the local name of Qodume Shirazi in Iran and it has been used as a traditional medicine for hundreds of years. The seeds are known to produce a large amount of mucilaginous substance when soaked in water [1]. This gum exhibits non-Newtonian, pseudoplastic behavior and it can be used as a thickening agent in food industries [2]. However, there is no information on the time-dependency of *Alyssum homolocarpum* seed gum. Thus the aim of the present work was to characterize the thixotropic behavior of *Alyssum homolocarpum* seed gum and to examine first order stress decay model for describing its time-dependent rheological behavior under the effect of different temperatures, concentrations and shearing conditions.

2 MATERIAL AND METHODS

2.1 Gum extraction

Alyssum homolocarpum seeds were dispersed in preheated deionized water (Milli-Q, Millipore, Bedford, USA) at a water/seed ratio of 60:1, pH:7 and temperature: 55ºC. The slurry was stirred continuously with a mechanical mixing paddle for one hour. The seeds were discarded, and the supernatant was subjected to ethanol precipitation (97% ethanol/mixture ratio of 3:1). Later, the precipitate was recovered using a sieve to allow the drainage of excess solvent and it was dispersed in deionized water. The dispersion stored overnight at 4ºC with continuous stirring. Ultimately, the dispersion was dried in a conventional oven (overnight at 45ºC), milled and sieved using a mesh 18 sifter [1].

2.2 Sample preparation

Gum solutions were prepared at concentrations of 3%, 3.5% and 4% (w/w) by dispersing the required amount of gum in deionized water (Milli-Q, Millipore, Bedford, USA), under slow stirring at room temperature, and stored for 18 h at 4ºC for their complete hydration prior to any assessment.

2.3 Rheological measurement

Measurements were carried out using a rotational viscometer (Bohlin Model Visco 88, Bohlin Instruments, UK) equipped with a heating circulator (Julabo, Model F12-MC, Julabo Labortechnik, Germany). For characterizing the thixotropic behavior, the gum solutions were subjected to a shearing period at constant values of shear rate, to ensure that the material reached a completely destructed structure at which the rheological behavior is no longer dependent on shearing time. Different concentration of *Alyssum homolocarpum* seed gum solutions (3%, 3.5% and 4%) were sheared at constant shear rates, namely 14, 25 and 50 s^{-1} and different temperatures (5, 25,45 and 65°C). First order stress decay model was used to describe the time-dependent flow properties of *Alyssum homolocarpum* seed gum solution samples as follows:

$$\tau - \tau_{eq} = (\tau_0 - \tau_{eq})e^{-kt}$$

Where, τ_0 is the initial shear stress value, τ_{eq} is the equilibrium stress value and *k* is the breakdown rate constant.

3 RESULTS AND DISCUSSION

First order stress decay model, being the case and for the sake of inspecting the presence of a non-

zero equilibrium shear stress value, at a relatively infinite time, the measurements were extended up to 500s of shearing time. Fig 1 shows the experimental data of shear stress versus shearing time of *A. homolocarpum* seed gum solution, evaluated at different shear rates. It seems that this model (solid line) fits well the relationship between the shear stress and shearing time data for all samples.

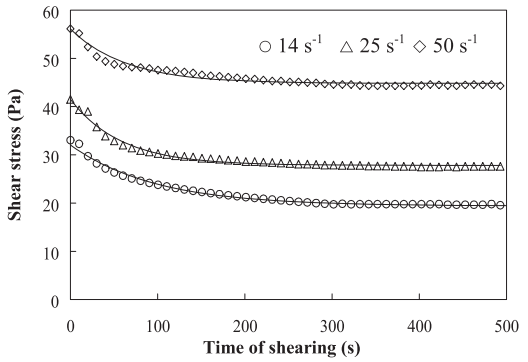

Figure 1. Shear stress data at different shear rates (gum concentration: 3%, temperature: 25°C) as a function of shearing time. Experimental values and fits to the first-order stress decay model.

Table 1 shows the parameters of the first-order stress decay with a non-zero equilibrium stress value, for a shearing period of 500s, evaluated at different conditions studied. A good agreement (R^2>0.96 and lowest RMSE) was found between the model fitted results and experimental shear stress data for all samples (Table 1). The equilibrium stress and initial stress values decreased with both increasing temperature and decreasing concentration. Besides, they increased with increasing shear rate which was similar to Balangu seed gum [3]. The decay rate constant, *k*, is an indication of how fast the gum solution, under the action of shearing, reaches the equilibrium stress value beyond which, the apparent viscosity remains constant. In this research work, the decay rate constant generally increased with increasing shear rate (except for 4% gum solution); however it did not have any trend with concentration and temperature (Table 1). Though the goodness of fit as assessed by the coefficient of determination (R^2) values were high (0.96-0.99), the RMSE values offer a better picture, thereby showing that R^2 values may not be a true indicator of the extent of fit, particularly when a large number of data points are analysed. Examination of the suitability of the time-dependent rheological model indicated that this model was suitable for characterizing the time-dependent rheological behavior of the *A. homolocarpum* seed gum.

4 CONCLUSIONS

The *A. homolocarpum* seed gum concentration had a considerable effect on the degree of the thixotropic behavior. On the other hand, the solution became a somewhat less thixotropy at higher temperatures. The results on the suitability of a rheological model may be used for scaling up purposes.

Table 1. The parameters of first-order stress decay model of *A. homolocarpum* seed gum solutions.

C (g/ml)	T (°C)	γ (s^{-1})	τ_0 (Pa)	τ_{eq} (Pa)	$k\times10^{-3}$ (s^{-1})	R^2	RMSE
3%	5	14	51.88	36.55	8.6	0.98	1.32
		25	61.10	46.51	11	0.99	0.82
		50	73.59	57.56	25	0.99	0.80
	25	14	32.06	19.39	10	0.99	1.93
		25	41.52	27.82	17	0.99	1.74
		50	56.13	44.82	16	0.96	1.17
	45	14	27.61	17.41	14	0.99	0.77
		25	31.16	22.29	22	0.99	0.55
		50	39.55	30.84	29	0.99	0.62
	65	14	17.10	12.62	16	0.98	1.05
		25	24.35	18.35	18	0.99	0.98
		50	30.52	24.85	20	0.99	0.75
3.5%	5	14	58.34	38.03	11	0.98	2.44
		25	74.25	58.42	12	0.99	0.52
		50	86.04	71.92	24	0.99	0.72
	25	14	57.76	37.84	8.5	0.99	1.31
		25	63.02	46.32	11	0.98	1.36
		50	90.54	68.78	30	0.97	1.40
	45	14	48.69	31.65	10	0.99	0.74
		25	53.55	37.18	11	0.99	0.56
		50	64.25	51.66	26	0.99	0.26
	65	14	44.75	28.25	7.5	0.98	1.10
		25	49.35	32.55	15	0.99	0.87
		50	58.15	45.35	27	0.99	0.64
4%	5	14	111.16	77.14	7.1	0.99	0.80
		25	126	95.69	14	0.99	0.94
		50	142	127.90	10	0.99	0.73
	25	14	80.77	53.15	6.9	0.98	1.02
		25	92.02	71.43	2.4	0.98	0.70
		50	128	115.17	9.9	0.99	0.44
	45	14	57.37	36.22	90	0.99	0.98
		25	72.91	44.48	16	0.98	1.53
		50	80.03	63.39	49	0.96	1.66
	65	14	53.25	32.15	11	0.97	1.87
		25	65.52	39.57	39	0.98	1.45
		50	72.15	48.19	48	0.98	1.15

REFERENCES

[1] Koocheki A, Mortazavi SA, Shahidi F, Razavi SMA, Kadkhodaee R, Milani J: Optimization of mucilage extraction from Qodume shirazi seed (*Alyssum homolocarpum*) using response surface methodology. J. Food Process Engineering (2008) doi: 10.1111/j.1745-4530.2008.00312.x

[2] Koocheki A, Mortazavi SA, Shahidi F, Razavi SMA, Taherian AR: Rheological properties of mucilage extracted from *Alyssum homolocarpum* seed as a new source of thickening agent. J. Food Engineering (2009) 91, 490-496.

[3] Razavi SMA, Karazhiyan: Flow properties and thixotropy of selected hydrocolloids: Experimental and modeling studies. Food Hydrocolloids (2009) 23, 908-912.