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Rheological Properties of Date Syrup/Sesame Paste Blend

Mohammad B. Habibi-Najafi and Z. Alaei

Department of Food Science and Technology, Faculty of Agriculture,
Ferdowsi university of Mashhad, P.O. Box 91775-1163, Mashhad, Iran

Abstract: The viscosity of raw materials is one of the most important parameters required in the design of technological processes in food industries. In order to be able to increase date consumption and also produce value-added products from poor quality dates, the development of a date syrup/sesame paste blends as a novel product was studied. Due to lack of knowledge on the flow behavior of this product, it is necessary to have deep information on rheological properties of such blends. A standardization of such products is mainly possible by knowing the rheological properties. In this study, date syrup with different solid content (60 and 65°Bx) was mixed with sesame paste at different ratio (45, 50, 55%) and the viscosity to each blend was measured at different temperature (25, 35, 45, 55°C). Data obtained from apparent viscosity (η_a) and rotational speed were used to describe the flow behavior by the power law model both in the forward (increasing shear rate) and backward (decreasing shear rate)-measurement. The consistency index (k) for all samples was >1 and ranged from 4.11-8.2 (Pa.s^n) and flow behavior index (n) was <1 and ranged from 0.34-0.7. Therefore, it is concluded that all samples exhibit pseudoplastic behavior at experimental temperatures. The effect of temperature on viscosity can be described by means of an Arrhenius type equation. E_a value ranged from 22366.32-29478.95 J/mol as blends. The effect of steady shearing on the flow properties of blends is concerned, first-order stress decay model was used to predict the flow behavior. It was found that blends exhibit a thixotropic behavior.

Key words: Date syrup · sesame paste · viscosity · rheology · sensory evaluation

INTRODUCTION

Sesame paste is a commodity produced from milled seeds of sesame (*Sesamum indicum* L.), which are dehulled and roasted without adding or removing any of its constituents. This product is popular in Iran and other Middle East and Eastern Asian countries and is known by various names such as Ardeh (in Iran) and Tahineh (in Arabic countries). It is being used in preparation of some local dishes such as hummus bi tahina, Bakdoonsiyeh and halwa. It has remarkable oil stability and resistant to oxidative deterioration at ambient temperature due to presence of some natural antioxidants such as Sesaminol, sesamin and tocopherol. Sesame paste has flavor similar to that of roasted peanut and contains about 60% oil which is more fluidity than peanut butter. It has high nutritive value which comes from about 25% protein, 8% carbohydrates, 4.5 mg/100 g niacin, 1.08 mg/100 g thiamin and some minerals such as calcium, phosphorous and iron [1, 2]. On the other hand, date syrup is a product obtained from matured dates (tamar) and being used as such or in the preparation of some traditional and industrial foods such as ice cream, confectionery, beverages, alcohol, vinegar etc [3].

Date fruit (*Phoenix dactylifera*) is also a highly nutritious food and rich in calories due to high vitamin and mineral content.

It is exceptionally rich in potassium and extremely low in sodium.

Sesame paste/date syrup blend is a promising nutritious and healthy product due to high protein and fiber content of sesame paste and high minerals and vitamins of date syrup. This blend is an emulsion of oil in water and as with all emulsions, testing the emulsion stability and rheological properties of this blend considered an essential step to evaluate the flow behavior and consumer acceptance of the blend.

The objective of this study was to investigate the effect of temperature, date syrup ratio and concentration on flow behavior and emulsion stability of the blends.

Corresponding Author: Dr. Mohammad B. Habibi-Najafi, Department of Food Science and Technology, Faculty of Agriculture, Ferdowsi University of Mashhad, P.O. Box 91775-1163, Mashhad, Iran

MATERIALS AND METHODS

Sesame paste was obtained locally (Simorgh Tahini Halva Co. Mashhad, Iran). Concentrated date syrup with °Bx 72 was produced in the pilot plant, Department of Food Science and Technology, Ferdowsi University of Mashhad, Iran.

Preparation of sesame paste/date syrup blends: Blends were prepared by adding date syrup with concentration of 60 and 65 °Bx in a ratio of 45, 50 and 55% (w/w) to sesame paste while mixing evenly with a spatula. The concentration of date syrup and its level in sesame paste were selected based on emulsion stability of blends and acceptable range for a consumer.

Emulsion stability: The blends samples were transferred to microtubes (2 mL) and heated at 80°C for 30 min in a water bath, then cooled down under running tap water and weighted before centrifugation. Blends were centrifuged at 4000 X g for 10 min and the separated oil was removed with samplers and the percent of oil (w/w) released from the total oil in the emulsion was expressed as emulsion stability [4].

Rheological properties: Brookfield rotational viscometer (Model DVD VII, Brookfield Engineering Laboratories, Stougton, NA, USA) equipped with spindle 7 was used. Enough samples in a 600 mL beaker were used to immerse the groove on the spindle with guard leg. The flow behavior of six different blends was determined at 25, 35, 45 and 55°C as forward measurement (speed increasing) and also as backward measurement (speed decreasing). Temperature was maintained using thermostatically controlled water bath. Shear rate and shear stress were calculated using the apparent viscosity (η_a) and speed (rpm) in the following equations:

$$\text{Shear rate} = 0.209 \text{ X N} \quad (1)$$

$$\tau = \eta\gamma \quad (2)$$

Where; N is rotational speed (rpm), τ is shear stress (Pa), ηa is the apparent viscosity (Pa. s) and γ is the shear rate (1/s). The power law model described flow behavior:

$$\tau = k\,(\gamma)^{n} \quad (3)$$

k is the consistency coefficient (Pa. s^n) and n is flow behavior index (dimensionless).

Statistical analysis: All experiments were carried out in triplicates unless otherwise specified. Data were evaluated by analysis of variance (ANOVA). The mean comparison was made with Duncan's multiple range test at $p<0.05$ level using Mstat software version 4.01.

RESULTS AND DISCUSSION

Flow behavior of blends: The flow curves of 2 blend samples prepared with 60 and 65 °Bx syrup in a ratio of 50% (w/w) at 35 and 55°C in both forward and backward measurement are shown in Fig. 1 and 2 as a typical example of all experimental blends. The presence of hysteresis loops in Fig. 1 is an indication of the shearing effect on the molecular structure of blend, such that the apparent viscosity has decreased. In other words, shear induced an irreversible and permanent damage affecting the molecular structure of food biopolymers, namely fats. The flow behavior index (n) and consistency coefficient (k) values obtained by fitting the rotational speed versus apparent viscosity data to a power law model (Eq. 3) both in forward and backward directions. The above mentioned parameters for all blends at different temperature are presented in Table 1. The results show that the shear stress-shear rate relationship is non-linear, indicating that sesame paste/date syrup blends behave as non-Newtonian fluids. Moreover, the fact that n is less than unity indicates that the experimental blends are pseudoplastic foodstuff. This behavior is expressed as the shearing of fats causes disruption of the three-dimensional structure through the breaking of primary and secondary bond [5]. However, the increase in date syrup ratio resulted in increasing the flow behavior index toward one. In other words, the blends are getting closer to Newtonian behavior. This might be as a result of the increase in pectic compounds in such blends. Pectin was reported to behaves as Newtonian fluid [6]. Consistency coefficients decreased when date syrup ratio increased in the blends at constant temperature and °Bx. The same trend was observed by other workers [7, 8]. The decrease in viscosity as the sugar increased has been related to the physicochemical role of sugar in relation to water [9]. On the other hand, as the date syrup °Bx increased from 60 to 65 at constant temperature and date syrup ratio in the blends, the consistency coefficient increased which might due to the increase in solid content [10, 11]. The consistency coefficient for all blends decreased as the temperature increased. No such trend was observed in relation to flow index and temperature. This finding is in agreement with that of Abu-Jdayil *et al*. [1] and Maskan

Table 1: Rheological parameters of date syrup/sesame paste blends calculated from power law model (Eq. 3)

% of date syrup in sesame paste			Forward measurements			Backward measurements		
°Bx	% Syrup	Temperature	K (Pa.s^n)	n	R^2	K (Pa.s^n)	n	R^2
60	45	25	306.415	0.38	0.998	290.000	0.43	0.996
		35	160.578	0.34	0.999	134.734	0.43	0.998
		45	129.445	0.48	0.996	125.724	0.49	0.999
		55	125.990	0.45	0.999	113.719	0.47	0.999
	50	25	108.000	0.49	0.998	95.420	0.57	0.999
		35	64.540	0.47	0.997	60.310	0.53	0.998
		45	49.120	0.44	0.997	41.700	0.55	0.999
		55	44.000	0.42	0.999	40.670	0.51	0.998
	55	25	26.360	0.65	0.999	23.550	0.69	0.999
		35	17.950	0.66	0.999	16.500	0.69	0.999
		45	11.470	0.66	0.997	10.600	0.69	0.999
		55	9.350	0.66	0.998	8.200	0.69	0.999
65	45	25	411.000	0.38	0.997	301.200	0.42	0.997
		35	273.400	0.42	0.999	246.796	0.45	0.998
		45	217.031	0.35	0.996	172.252	0.43	0.997
		55	171.729	0.36	0.998	130.650	0.49	0.999
	50	25	147.885	0.52	0.999	95.450	0.48	0.998
		35	78.900	0.53	0.999	64.900	0.49	0.999
		45	78.730	0.47	0.999	57.307	0.59	0.996
		55	59.490	0.43	0.998	39.780	0.59	0.999
	55	25	57.900	0.57	0.999	39.240	0.66	0.998
		35	34.350	0.57	0.998	24.478	0.69	0.997
		45	31.100	0.55	0.999	22.110	0.66	0.997
		55	21.280	0.60	0.999	14.400	0.70	0.999

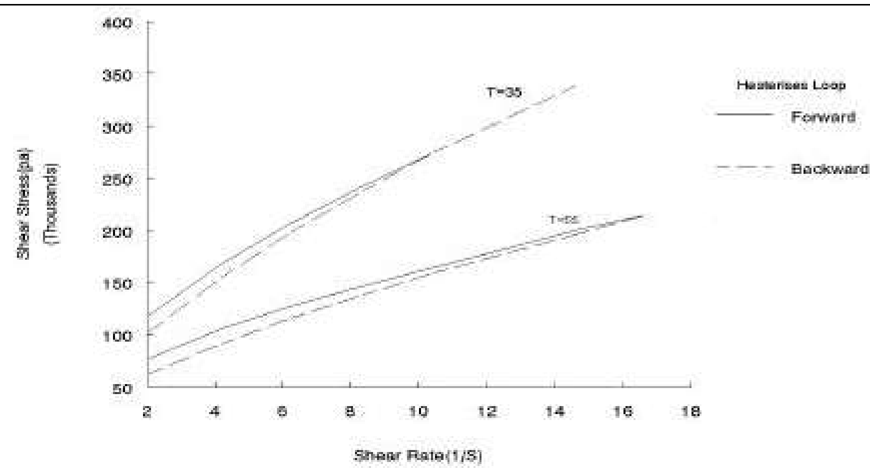

Fig. 1: Hysterises loop of the flow curves of Sesame paste/Date Syrup blend with 50% Syrup (65°Bx)

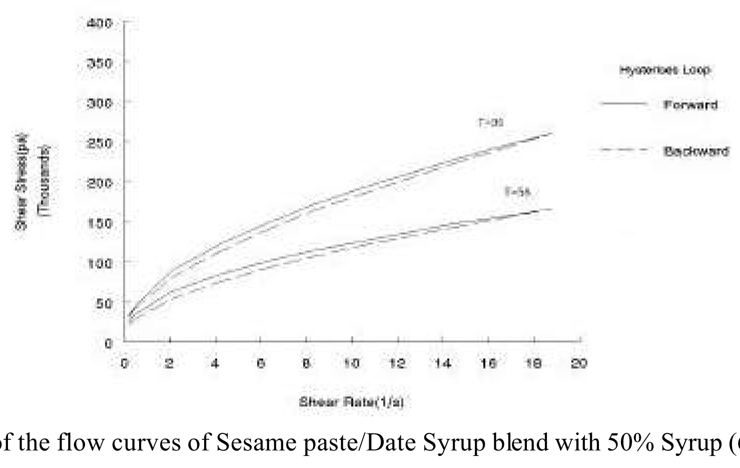

Fig. 2: Hysterises loop of the flow curves of Sesame paste/Date Syrup blend with 50% Syrup (60°Bx)

Table 2: Estimated parameters of the Arrhenius type equation for all experimented sesame paste/date syrup blends

	Upward curve			Downward curve		
Sample	R_2	$K_0(Pa.s^n)$	Ea (J/mol)	R_2	$K_0(Pa.s^n)$	Ea (J/mol)
45% Syrup						
60ºBx	23750.60	0.018168	0.83	23750.60	0.016748	0.77
65ºBx	23251.35	0.033263	0.99	23251.35	0.026431	0.98
50% Syrup						
60ºB	24330.09	0.005381	0.93	24330.09	0.004809	0.92
65ºB	22366.32	0.015783	0.85	22366.32	0.011267	0.97
55% Syrup						
60ºB	29478.95	0.000177	0.99	29478.95	0.000159	0.99
65ºB	25296.18	0.002018	0.95	25296.18	0.001400	0.95

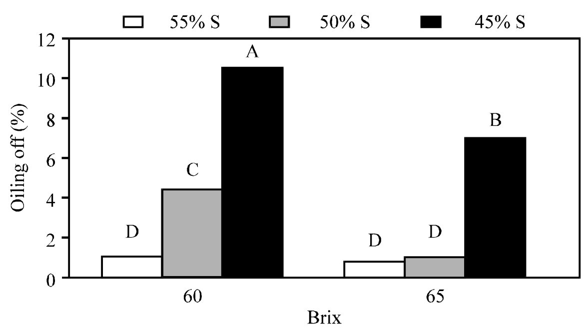

Fig. 3: The means comparison for emulsion stability of all experimented sesame paste/ date syrup blends

and Gogus [4]. The effect of temperature on k for the forward and backward measurements is obtained by applying Arrhenius type equation

$$L_n k = L_n k_0 + E_a / RT \qquad (4)$$

Rheological parameters for all blends are shown in Table 2. Activation energy E_a decreased when the date syrup concentration at constant ratio increased in the blends, which is in agreement with the finding of Maskan and Gogus [4].

Time-dependent flow properties: The relationship between shear stress/shear rate for both forward and backward directions for all blends as shown in Fig. 1 and 2 is thixoptropic. The difference in consistency coefficient of the experimental blends in forward and backward measurement is an indication of time-dependent behavior of blends (Table 1). Generally, when a material is sheared at a constant shear rate, the viscosity of a thixotropic material will decrease over a period of time, implying a progressive breakdown of structure. In order to study the thixotropic behavior of blends, constant shear rate (1/s) was applied for 10 min as suggested by other workers [1].

Emulsion stability: The emulsion stability of the blends is illustrated in Fig. 3. The means comparison with Duncan's multiple range test at $p<0.05$ indicated that emulsion stability of blends prepared with 55% of °Bx 60 date syrup, 50 and 55% of °Bx 65 date syrup exhibit higher stability. Figure 3 shows also that the increase in the date syrup concentration from 60 to 65% at constant date syrup ratio, resulted in decreased the oiling off. This trend was also vice versa (increase in date syrup ratio at constant °Bx). The increasing amount of sugar was shown to increase the stability of emulsions [4, 12] and results obtained from this study agree with that finding.

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