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RHEOLOGICAL PROPERTIES OF LOCAL PINEAPPLE FRUIT JAM

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ABSTRACT

The objective of this study is to determine the rheological properties of local pineapple fruit jam at different temperatures of 20, 30, 40, 50 and 60 °C. The experiments were conducted at room temperature using a rheometer as the measuring device. Pineapple fruit jam was chosen because this type of fruit is commonly grown in Malaysia. The jam was prepared at a Brix concentration of 50 %. The rheological properties of the pineapple jam were examined and it was found to exhibit a pseudoplastic behaviour. From the rheological data obtained, it was determined that the Herschel-Bulkey Model was the best fit model and that the Arrehenius equation successfully describes the effect of temperature on the viscosity of pineapple jam.

***Keywords**: Arrhenius Equation, pineapple jam, rheology, viscosity*.

INTRODUCTION

Fruit jam is a type of fruit preserve that can be prepared and stored or canned for a long time. Fruit jam is a middle moisture food which is prepared by boiling the fruit pulp with sugar, acid, pectin and other ingredients that cause the thickness of the jam to be consistent. This means that the jam is firm and can hold the fruit tissues in position. Examples of additional ingredients that can be added during the preparation or boiling of the jam are colouring, preservatives, and also flavouring substances [1, 2].

An influential tool to understand the changes in food structure during processing is to study the rheological parameters [3]. For fruit puree, the rheological properties are affected by the flow performance of the fruit puree which is influenced by the concentration of the dissolved solids, the mode of interaction between the balanced particles, the particle size distribution and shape [4]. In general, fruit and vegetable purees take the form of pseudoplastic fluids [5]. When the fruit purees are heated, there is a significant change in apparent viscosity that is influenced by the velocity and the temperature profile. Thus, knowledge of the influence of temperature and shear rate on the rheological behaviour of fruit purees would be valuable information [5]. Therefore this topic was selected for study.

In addition, studies of the effect of solid concentration by sampling products during evaporation, dilution of purees with de-ionized water, or by addition of glucose were conducted. The study of the fruit purees was also undertaken in order to determine the tendency of fruit puree to easily breakdown when flowing through pipes, especially when the flow pattern changes from laminar to turbulent. Hence, the rheological properties of fruit purees should be considered first before designing a processing system [4]. Santanu and Shivhare (2010) fitted the experimental data of the rheological properties of mango jam which exhibited pseudoplastic flow with yield stress [6]. Thus, the present study is designed to add to that knowledge by determining the rheological properties of local pineapple fruit jam (50 % Brix) at different temperatures from 20 °C to 60 °C.

MATERIALS AND METHODS

Commercial local pineapple jam was purchased and diluted with distilled water until the concentration of the jam was approximately 50 % brix. The rheological properties of the jam sample were determining by using a rheometer (Dynamic Controlled Stress 600 Rheometer, Thermo Electron Corporation, Germany) which was attached to a computer running RheoPlus software. The jam sample (approximately 1 ml) was placed on the rheometer plate. The probe used was a 40 mm cross hatched steel plate (ggz121).

Rheological measurements

For most fruit jams, the shear rate ranges below 450 per second [6, 7]. From the results of the experiment, the best shear rate range of this type of pineapple jam ranged from 14 to 100 per second. This experiment was repeated at temperatures of 20, 30, 40, 50, and 60 °C. The test was set to steady state flow and linear mode. Shear stress versus shear rate data of each jam sample was gathered as a flow curve. The steady-state correlation between the shear rate and the shear stress of food materials is articulated in terms of the Bingham Plastic model:

$$\tau = \tau_0 + \eta\gamma \qquad (1)$$

where τ is the shear stress, τ_0 is the yield stress, γ is the shear rate and η is a consistency index. Other than that, the rheological behaviour of commercial jam can also be expressed in terms of the Herschel-Bulkey model:

$$\tau = \tau_0 + K(\gamma)^n \qquad (2)$$

where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), K is a consistency index (Pa s^n), γ is the shear rate ($s\text{-}^1$) and n is a dimensionless flow behaviour index.

The rheological behaviour of most fruit jam can be normally described by the Power Law Model relationship [9]:

$$\tau = K\gamma^n \qquad (3)$$

where τ is the shear stress (Pa), γ is the shear rate (s^{-1}), K is a consistency index ($Pa.s^n$) and n is the flow behaviour index.

RESULTS AND DISCUSSION

From the result shown in Figure 1, the rheological behaviour of local pineapple fruit jam was found to exhibit a shear thinning (pseudoplastic) behaviour. The figure shows that the shear stress decreased with an increase in temperature at constant rate. Similar observations have also been reported by Santanu and Shivhare (2010) and Alvarez et al. (2006) for mango, apricot, strawberry, peach and raspberry fruit jam [6,7].

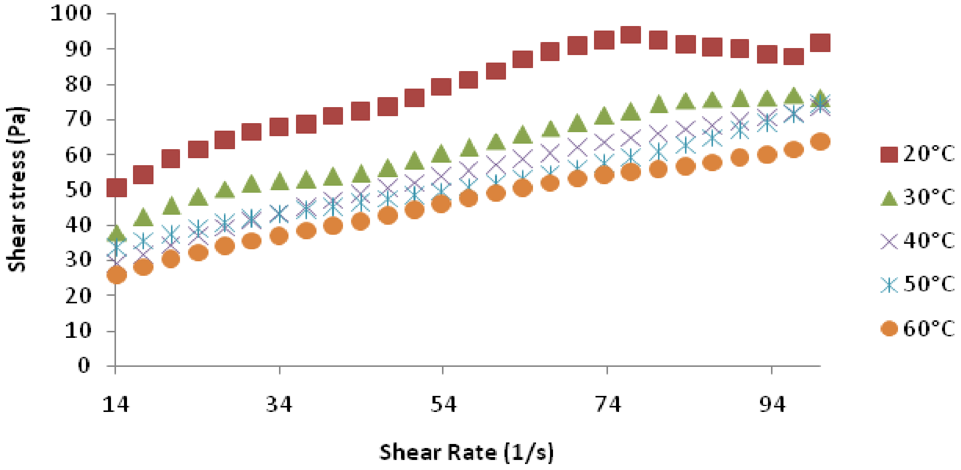

Fig. 1: Rheogram of pineapple jam at 50 °Brix concentration at 20°C, 30°C, 40°C, 50°C and 60°C

The experimental result of shear stress (τ_0) and shear rate (η) indicates that it can be fitted by the Bingham model (R^2= 0.99), the Herschel-Bulkey model (R^2= 0.998) and the Power Law model (R^2= 0.953) at a temperature of 60 °C (equations 1, 2, and 3). From the experimental data, the Herschel-Bulkey model is the best fitting model for pineapple fruit jam. This is due to the good regression which varies from 0.90 to 0.99 (Table 1). A similar result was obtained by Santanu and Shivhare (2010) and Marjan and Johari (2010) which strongly indicates that the Herschel-Bulkey model is the best fitting model for fruit jam [8].

Table 1: Rheological parameters of the Bingham, Herschel-Bulkey and Power Law model of Local Pineapple Fruit Jam at Brix 50%

Temp (°C)	Bingham model			Herschel-Bulkey model			Power Law model		
	τ_0 (Pa)	η (Pa.s)	R^2	K (Pa.s^n)	n	R^2	K (Pa.s^n)	n	R^2
20	51.16	0.48	0.88	1.24	0.84	0.90	33.26	0.22	0.88
30	36.23	0.48	0.97	5.92	0.51	0.99	17.66	0.32	0.99
40	25.50	0.50	0.99	1.49	0.80	0.99	14.19	0.34	0.95
50	27.54	0.43	0.98	1.43	0.75	0.99	19.01	0.26	0.90
60	22.34	0.42	0.99	1.62	0.74	0.99	12.56	0.34	0.95

Effect of Temperature

Reliance of the flow performance of fluid foods on temperature can be described by the Arrhenius relationship [9, 10]:-

$$K = A_K \exp (E_K / RT) \qquad (4)$$

where, A_K is the frequency factor (Pa s^n), E_K represents the activation energy (kJ/mol), R is the gas law constant (R = 8.314 J/mol K), and T is the absolute temperature (K).

Figure 2 shows the Arrhenius model for consistency index, K of 50% Brix of jam. The frequency factor, A_K is 0.05 Pa.s. The log (K) was found to increase with increasing of 1/T. A similar result was recorded by Santanu and Shivhare (2010) who showed the same graph trend for mango jam at Brix 50% [6].

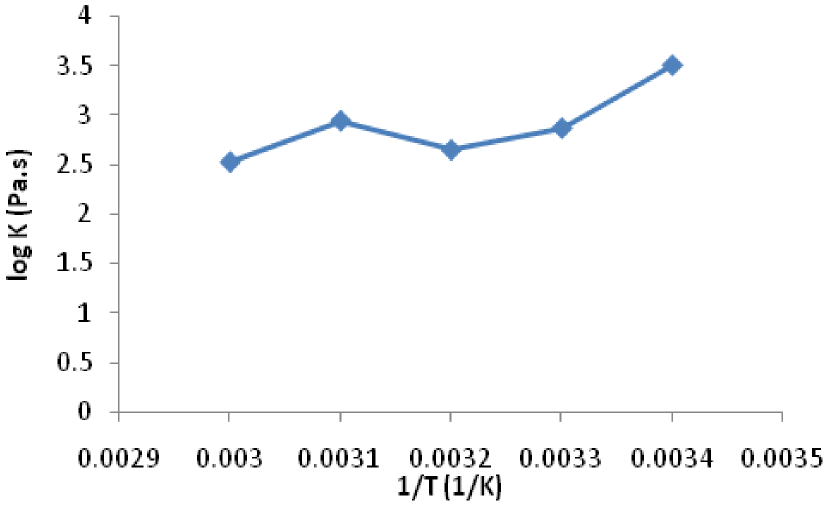

Fig. 2: Applicability of the Arrhenius model to the consistency index, K for pineapple jam at different temperature at °Brix 50.

In this study, the activation energy, E_k of local pineapple jam was determined as 15.58kJ/mol. The value of the activation energy, E_k, obtained in the experiment is close to the value for blueberry puree which is around 11.3 to 17 kJ/mol [4]. The value of the activation energy of jam is higher because of the fact that jam is a physical gel which gives more resistance to deformation [6].

CONCLUSION

The results show that local pineapple jam behaves as a pseudoplastic fluid exhibiting yield stress. The Herschel-Bulkey model effectively describes the steady-state rheological behavior of local pineapple jam. The Arrhenius equation was successfully describes the effect of temperature on the viscosity of the pine jam.

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