RHEOLOGICAL PROPERTIES OF DATE JUICE CONCENTRATE (DIBS) DURING EVAPORATION PROCESS

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ABSTRACT

Date concentrate was obtained under vacuum using rotary evaporator by heating the date extract (19%) until it reaches (70%). Samples were collected during process until the end of process The rheological properties of Date juice concentrate were studied using Brookfield Rheometer (DV III ultra) at different temperatures (30, 40, 50 and 60°C),concentrations (30, 40, 50 and 60%) and shear rates (9.3– 93 s^{-1}). Shear rate - shear stress data indicated that all samples exhibited non-Newtonian pseudoplastic behavior.Dependence of apparent viscosity on temperature was related through the Arrhenius law. Effect of concentration on apparent viscosity was also studied and fitted well to power law.

Keywords: *Rheological Properties, Date Juice Concentrate, Flow Behavior, Activation Energy*

1. INTRODUCTION

In food industry, knowledge of the physical properties of food is fundamental in analysis, the unit operations present in the food industry. The study of these food properties and their response to process conditions is necessary because they are good indicators of other properties and qualities of food. Viscosity and it's variation with concentration and temperature are very important for the food industry in general and for fruit derivatives in particular, since it's necessary for the design and the optimization of several processing operations (e.g. pumping, evaporation, filtration, ...etc) [1].

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Rheology is the science of deformation and flow behavior of matter. The consistency of a Newtonian fluid like water, milk or clear fruit juice can be characterization by the term viscosity. Viscosity of non-Newtonian fluid however changes with changing rate of shear and hence should be characterized by more than one parameter **[2 and 3]**.

Knowledge of viscosity is of primary importance to the fruit juice industry.Accurate viscosity data over wide temperature, pressure, and concentration regions are needed for a various research and engineering applications in any branch of the food industry. The viscosity of fluid food is an important property which has many applications in food technology such as developing food processes and processing equipment, the control of product, filters and mixers quality evaluation and an understanding of the structure of food and raw agricultural material **[4 and 5]**.

Fluid properties of raw and processed food products affect process design, pipeline transport, and product development as well as final product characteristics and uses. Mathematical models have been used to describe the rheological behavior of different food fluids. Some of the time-independent and time-dependent rheological models can be simple such as Newtonian, Power law and Herschel-Bulkey **[6]**:

$$\tau = \mu \gamma \qquad (1)$$

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

$$\tau = \tau_0 + K \gamma^n \qquad (3)$$

Where, τ is the shear stress Pa; γ; is the shear rate 1/s; μ is the Newtonian viscosity Pa.s; K is the consistency coefficient, n is the flow behavior index, τ_0 is the yield stress Pa and n is the flow behavior index,. The three relationships have been employed over a wide range of shear rates and in a great variety of fluids foods, whereas the last model has been used to fit the rheological behavior of dispersed systems and gums solutions.

The rheological and sensory properties of pekmez (grape molasses/tahin (sesame paste) blends were studied using pekmez concentrations of 2%, 4%, and 6% at 30, 40, 50, 60, 65 and 75°C. the pekmez content and temperature influenced the flow behavior and consistency index values [7].

Altay; and Ak; [8] determined the rheological properties of tahin at temperatures from 20-70°C and shear rates in the range of 0.13-500 1/s . Temporary hysteresis loops were observed in the first cycle of the flow curve. The consistency coefficient exhibited strong temperature dependence for which the activation energy of flow was 21.6 kJ/mol. The flow behavior index of tahin tended to increase whereas the consistency coefficient tended to decrease during storage at room temperature. Tahin oil exhibited Newtonian behavior with a strong dependence of viscosity on temperature. Viscosity of reconstituted tahin suspensions was found to be dependent on particle size only at solid contents above 20%.

Sorour and assous [9] studied the Date juice of Siwi dates variety at tamr stage (simi-dry) was obtained with three different methods of extraction. In the first method, date was extracted with water at 25°Cfor 2.0 min (T1), the second method, date residue of extraction (T1) was subjected to second extraction at 75°C for 15 min. (T2) and the last method,date was extracted at 75°C for 15 min. (T3)at ratio3:1of water/date (wt/wt). Mixing of date with water was investigated using paddle impeller. The flow behavior of date juices were studied at 25°C, for treatment (T1) and 75°C for treatments (T2 and T3). The speed of spindle used is 20-200 rpm. Shear stress-Shear rate data indicate that the juice behaves as non-Newtonian pesudoplastic fluid. An impeller mixer was connected with Ammeter in order to predict the power of the mixer. Prediction of the power number, blend number and pumping number as a function of Reynolds number were plotted and this enables an economic scale –up for non-Newtonian fluid. Excellent quality of date juice and minimal time were recorded for T2 and T3. Also, it is recommended to apply the 45-91 rpm for the mixer scale-up value.

The main objectives of this work are to study the rheological properties of Date juice during evaporation process and evaluate the effect of temperature on apparent viscosity of date juice concentrate.

2. MATERIALS AND METHODS

2.1.Material

Samples of Siwi dates were obtained from Siwi Oasis, El-Wadi El-Gidid Govenorate, Egypt.

2.2. Methods

2.2.1. Processing Methods

Extract from siwi dates variety at tamr stage (semi-dry) was obtained by: Preparing a mixture of water-date at a ratio 3:1 (w/w).Extraction by mixing with paddle impeller at 20-200 RPM with heating till TSS reached the maximal level, Fig (1) as it was previously described by [10].

Date extract was filtered using white cloth then concentrated by evaporator under vacuum (100 mmHg) until the total soluble solids exceeded 69% as previously described by [11].

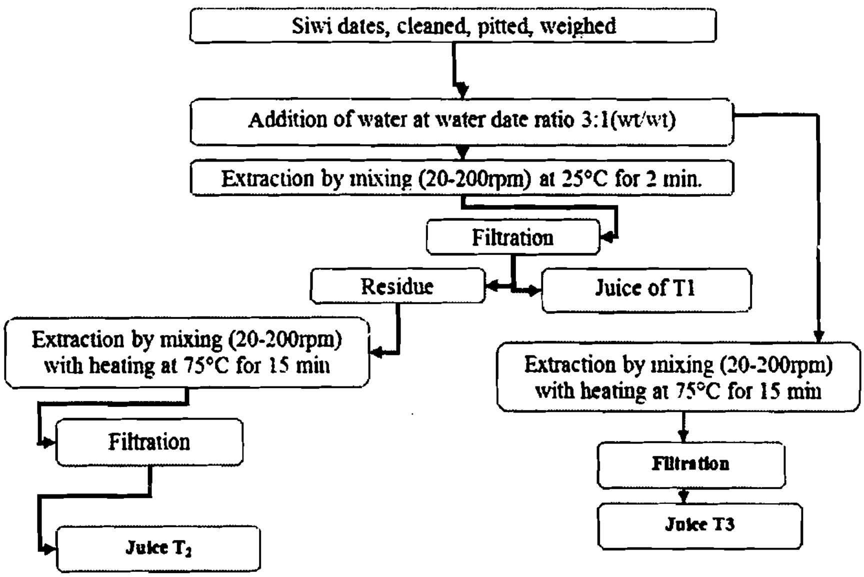

Fig. (1): Flow sheet diagram for production of date juices.

2.2.2. Chemical Analysis of Siwi Date at Tamr Stage Date Extract, Date Juice Concentrate

Total soluble solids (Tss, PH value, moisture content, total acidity, fiber ash, reducing, non-reducing sugars and hydroxyl fural content) were determined according to [12].

Pectin content was determined as described by [13].
Browning was measured (absorbance at 420nm) as mentioned in [14].

Table 1. Physical and chemical analysis of Siwi date, date extract and concentrate.

Characteristics	**Siwi dates**	**Siwi date extract**	**Date concentrate dibs**
Moisture content, %	17.85	80.41	29.58
TSS, %	76.2	19	70
pH value	5.81	5.42	4.55
Browning absorbance at (420 nm)	0.201	0.268	0.848
Total sugars, %	85.12	91.54	90.11
Reducing sugars,%	79.21	86.51	86.34
Non-Reducing sugars, %	5.89	5.03	3.77
Acidity as malic acid	0.32	0.408	0.302
Pectin, %	2.27	2.56	2.23
Total phenol, %	0.65	0.714	0.603
Hydroxymethylfurfural, mg/100gm	2.99	5.81	7.37

*on dry weight basis

2.2.3.Rheological Properties

Flow properties (shear rate, shear stress and apparent viscosity) of date juice and its concentrate were measured directly with Brookfield Digital Rheometer, model HA-DVIII ultra (Brookfield Engineering Laboratories INC). The concentrate was placed in a small sample adapter, SC4-21 spindle was selected for the sample measurement. A thermostatic water bath provided with the instrument was used to regulate the sample temperature. The rheological parameters for date juice concentrate were studied at different temperatures (30, 40, 50 and 60°C), shear rates 9.3-232.5 s^{-1} and different concentrations (30, 40, 50 and 60%).

3. RESULTS AND DISCUSSION

3.1.Rheological Properties of Date Concentrate

The process of concentrating juices are not so easy for processors as they are faced many problems relating to the rheological properties of the

structure of concentrate, as a result of thickening of the solid content and viscosity created.
The obtained results are illustrated in the following visions:

3.1.1.Shear Stress - Shear Rate Relation

Table 2. Relation between k and n with temperature.

Conc., %	Temperature, °C	k	n
30%	30	0.044	0.661
	40	0.015	0.861
	50	0.064	0.586
	60	0.068	0.451
40%	30	0.057	0.718
	40	0.015	1.045
	50	0.108	0.502
	60	0.018	0.838
50%	30	0.051	0.928
	40	0.072	0.786
	50	0.128	0.619
	60	0.023	0.939
60%	30	2.253	0.738
	40	1.242	0.75
	50	1.168	0.756
	60	0.637	0.752

Shear rate –Shear stress data of date juice concentrate (60%) were obtained in the range of shear rates 9.3 – 93.00 s^{-1} and temperatures (30-60°C). the results observed that all samples behaved as Non-newtonian pseudoplastic fluids and power law model equation (4) was fitted to experimental data. The same trend was observed at 45, 55% total soluble solids of date concentrate.

$$\tau = K\,\gamma^{n} \qquad (4)$$

Where, τ is the shear stress, Pa; k is the consistency index; γ is the shear rate, 1/s; and n is the flow behavior index.

3.1.3. Effect of Concentration on Viscosity

The effect of concentration on the apparent viscosity of date juice concentration at shear rate between 9.3 – 93.00 s^{-1} were investigated over a temperature rang 30-60oc, as shown in Fig (4). The results show that the change in viscosity with concentration follows the power law relationship as concentration of the extract increases the apparent viscosity increases all samples exhibited the same trend equation (6), which was mentioned by work of [15] on peach dietary fibre suspension, the authors described the variation of viscosity with concentration of peach dietary fibre.

$$\mu = AC^{\alpha} \qquad (6)$$

μ is the viscosity, pa.s;

C is the concentration, wt%; and

A, α are empirical constant related to shear rate and temperature.

The values of flow behavior index (n) and consistency index (k) at different temperatures and concentrations are shown in Table(2).

The results show that the values of consistency index (k) and flow behavior index show a good trend with temperature at each level of concentration.

3.1.2.Effect of Shear Rate on Apparent Viscosity

Values of viscosity for date juice concentrate were plotted against shear rate (γ) at different solid concentrations (30, 40, 50 and 60% wt) and different temperatures (30, 40, 50, 60C) as shown in fig. (3).

It was observed that apparent viscosity (μ) decreases with increasing shear rate, the results were fitted well to the following equation

$$\mu = K\,\gamma^{n} \qquad (5)$$

Where $\mu$is the apparent viscosity, Pa.s;

γ is the shear rate, 1/s;

K is the plastic viscosity; and

N is the flow behavior index.

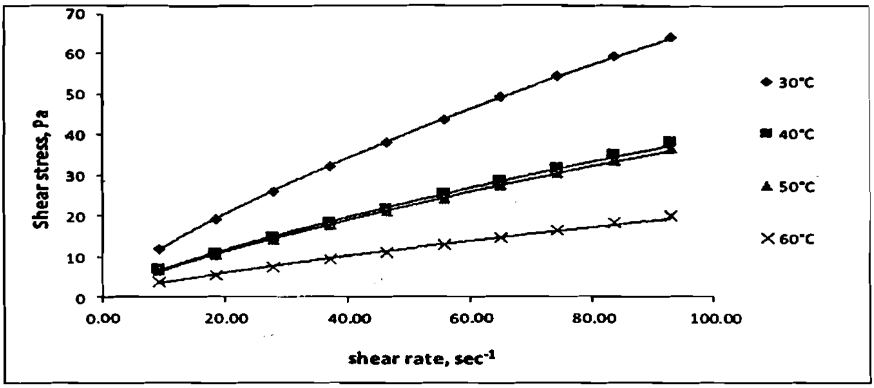

Fig. (2): Relation between Shear rate and shear stress at different temperatures and 60 wt% of date juice puree.

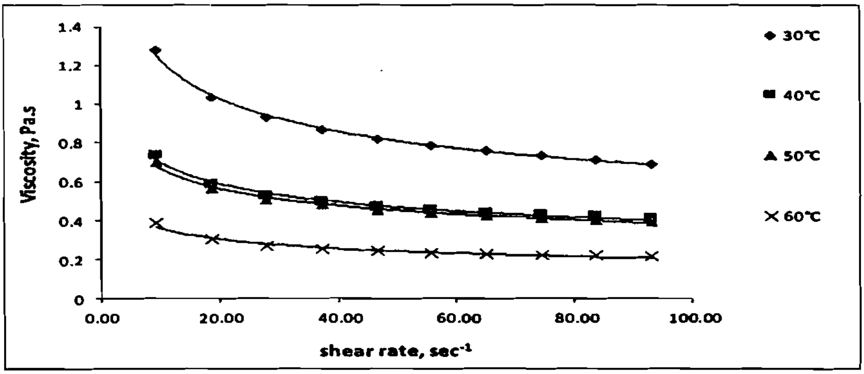

Fig.(3): Effect of shear rate on viscosity at 60% soli concentration of Date juice concentrate and different temperatures.

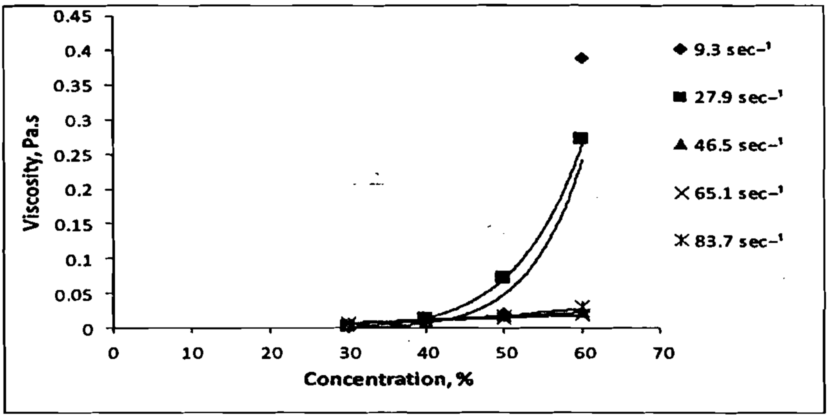

Fig.(4): Effect of concentration on viscosity at different shear rates, at 60°C.

3.1.4. Effect of Temperature on the Apparent Viscosity of Date Juice Concentrate

Figs (5 through 7) show the variation of apparent viscosity with temperature (30, 40, 50 and 60°C) at different shear rates 9.3 – 93.00 s^{-1} and different concentration (30, 40, 50, 60%).

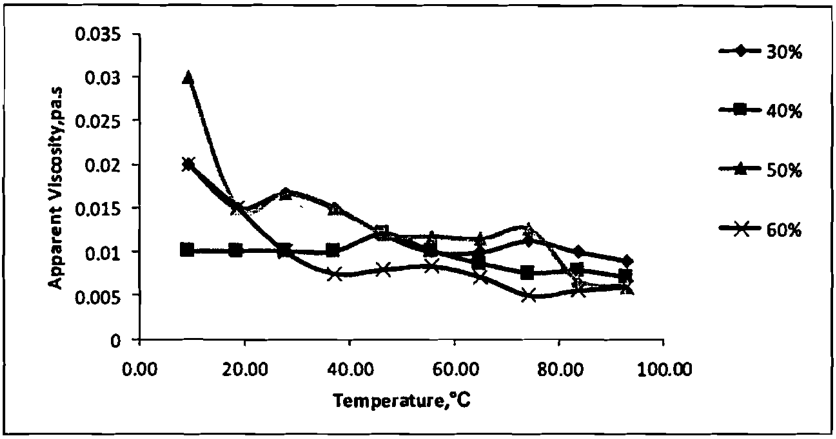

Fig.(5): Relation between viscosity and temperature at different solid concentrations of date juice concentrate.

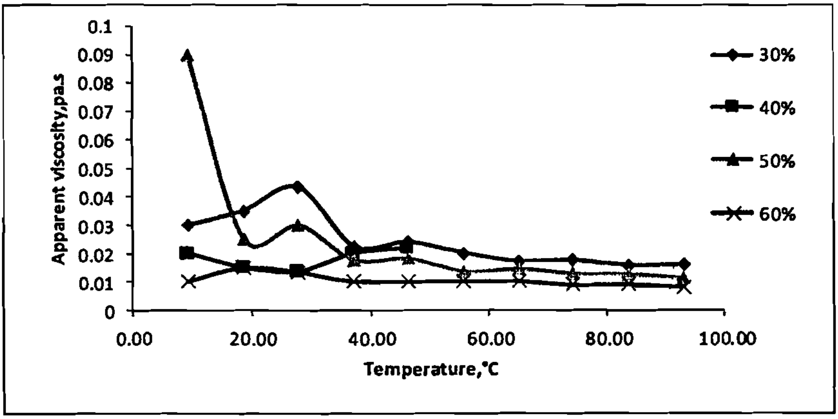

Fig.(6): Relation between viscosity and temperature at different solid concentrations of date juice concentrate

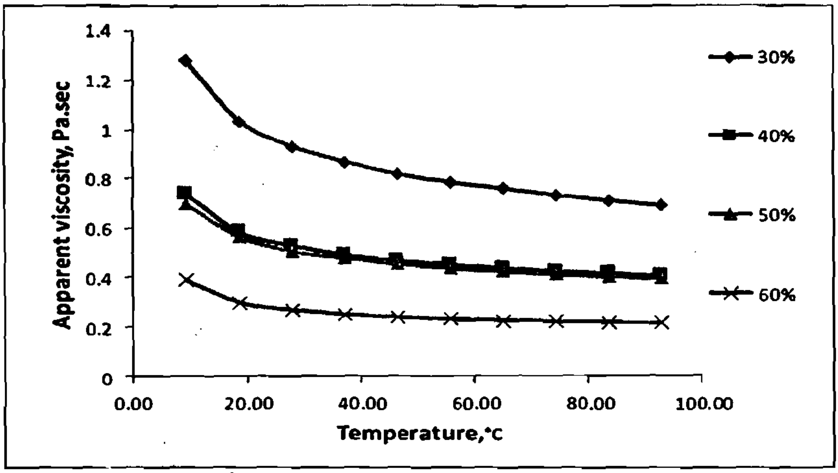

Fig.(7):Relation between viscosity and temperature at 60% solid concentration of date juice concentrate and different shear rates.

The result show that viscosity decreases with increasing temperature at all shear rates studied. The fluctuations in viscosity over a certain range of temperature may be explained due to local agglomeration of dispersed particles around the spindle which may lead to a fictitious increase in viscosity.

Figs (5 through 7) show that as temperature increases, viscosity will decreases except for concentration (30, 40, 50, 60%) as there were some fluctuations in the temperature range of 30 and 60°C, it may be due to the effect of temperature on the structure of date juice concentrates as it contains pectin as previously discussed by [15].

The variation in apparent viscosity with temperature can be described by an Arrhenius-type equation (7):

$$\mu = \mu a \exp(Ea / RT) \qquad (7)$$

Where μ is the apparent viscosity, Pa.s; μa is the constant; Ea is the activation energy of flow; (kj/mol), R is the gas constant (8.314 kj/mol.K); and T is the absolute temperature in (K).

To obtained the estimates of the parameters of the Arrhenius relationship, the logarithm of the viscosity was plotted against 1/T.

$$Ln\ \mu = ln\ \mu a + (Ea/RT)$$

Table (3) show the effect of temperature on apparent viscosity of date juice concentrate according to the Arrhenius equation and the best fit lines are drawn at 60% solid concentration of date juice concentrate, the same trend was observed at concentration 30, 40, 50, and 60% and all shear rates studied.

Table (3): Activation energy at different shear rates and concentration, KJ/mol.

γ	30%	40%	50%	60%
Sec-1	Ea	Ea	Ea	Ea
9.30	16420.15	30620.46	20261.22	30337.79
18.60	14233.57	7786.89	22846.87	31410.29
27.90	14349.96	192.97	21666.28	31451.86
37.20	19695.87	23570.19	25025.14	33829.67
46.50	11065.93	25648.69	22630.71	33646.76
55.80	3122.74	18930.98	20942.97	31002.91
65.10	9286.74	15896.37	19637.67	30753.49
74.40	22057.04	18457.08	20294.47	30229.70
83.70	16112.53	14882.06	19562.84	29897.14
93.00	10941.22	18756.38	18706.5	29498.07

4. CONCLUSION

The rheological properties of date juice were studied using a Brookfield viscometer at various temperature 30, 40, 50, 60°C at different concentrations, 30, 40, 50, 60% by wt; shear rates 9.3–93.00 s^{-1}

The result show that the all samples exhibited non-Newtonian pseudoplastic behavior. The result show that viscosity decreases with increasing temperature at all shear rates studied.

It is recommended to study the optimization of dibs production line as an application for food industry , due to that there are no many factories that produce dibs in Egypt.

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الملخص العربي

الخواص الريولوجية لمركز عصير البلح (دبس) أثناء عملية التبخير

أمنية السيد سلامة[3] ، منال عبد الرحمن سرور[2]، مبارك محمد مصطفى[1]، محمود أحمد النونو[1]

تم تصنيع مركز مستخلص البلح بإستخدام المبخر الدوار تحت تفريغ ويتم ذلك بتسخين مستخلص البلح (١٩%) الى ان يصبح التركيز (٦٠%). تم تجميع العينات أثناء عملية التركيز، ودراسة الخواص الريولوجية لمركز مستخلص البلح بإستخدام جهاز اللزوجة Brookfield Rheometer (DV III ultra) ودراسة العلاقة بين اجهاد القص ومعدل الانفعال عند درجات حرارة مختلفة (٣٠، ٤٠، ٥٠ ، ٦٠°م) و تركيزات مختلفة (٣٠، ٤٠ ، ٥٠، ٦٠ %) بهدف الحصول على علاقات يمكن من خلالها التنبؤ بفقد الضغط الناتج عن تدفق هذه المركزات فى مساراتها اثناء التصنيع ثم ايجاد قطر الأنابيب الأمثل فى خط التصنيع .

وقد تم دراسة تأثير العوامل الآتية :

اجهاد القص لمركز البلح ، ومعدل الانفعال ، وتركيز مستخلص البلح ، ورجات الحرارة ومن ثم استنتاج تأثير كل من هذه العوامل على اللزوجة الظاهرية للمركزات.

ثم استنتاج أن هذه المركزات تتبع العلاقة العامة التالية بين معدل الانفعال واجهادة القص Pseudoplastic Fluid

$$\tau = K \gamma n$$

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