

Mixing Process of Apple Juice Concentrate

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Abstract: The rheological properties of apple concentrate were studied over the range 4-70°C, solid concentration 71 wt% of apple concentrate, and shear rate 9.3-74.4 s⁻¹. Shear rate - shear stress data indicate that apple juice concentrate (71%) behaves as pseudoplastic fluid at (4, 10°C) while the concentrate exhibited Newtonian fluid at temperatures studied (30-70°C). The effect of rheological properties of apple juice concentrate on mixing parameters was investigated. An impeller mixer was connected with ammeter in order to predict the power of the mixer at different impeller to column diameter (D/T). The relation between power number, blend number, pumping number and Reynolds number were calculated at different D/T ratio.

Keywords: Mixing of Non-Newtonian Fluids, Rheology of Fruit Concentrate, Power Consumption

1. Introduction

Apples are amongst the most widely grown and consumed fruit crops. Annual world apple production was estimated to be more than 40 million tons in 1992 and 1993, of which more than 5 million tons were processed to obtain apple juice. At that time, the greatest volume of apple juice was processed into 70 -75°Brix concentrate to reduce volume and weight, which resulted in lower costs for packaging, storage and transportation. Now, apple juice concentrate may be stored and shipped throughout the world as a relatively stable product. Concentration has also solved the problem of seasonal nature of crops and allowed economic utilization of perishable agricultural products [1].

In food industry, knowledge of the physical properties of food is fundamental in analyzing the unit operations. These properties influence the treatment adopted during processing, and they are good indicators of other properties and qualities of food. They benefit the producer, the industry and the consumer [2].

Viscosity and its variation with concentration and temperature are very important for the food industry in general and for fruit derivatives in particular, since it is necessary for the design and the optimization of several processing operations (e.g., pumping, evaporation, membrane filtration etc. [3]. Most fluid foods do not have the simple Newtonian rheological model, hence, their viscosities are independent of shear rate or shear stress and constant with temperature [4]. Therefore complex models are developed to

describe their behavior, [5]. There are many publication on flow properties of juice concentrates and effects of temperature and concentration which most of them are based on viscometry data, [6].

Mixers for the food processing and agricultural industries are reviewed and classified into three categories according to the materials to be mixed. These comprise mixers for Rushton, [1] dispersing and dissolution into liquids, [2] blending of particulate material, and mixing of solids [3] and liquids to form doughs, batters and pastes, [7].

Chemical engineers and food processors often deal with complex fluids in laminar regime which are, usually, highly viscous and shear thinning. It is clear that both vessel and impeller diameters have to be adapted to take these properties into account for distributive as well as dispersive mixing [8 and 9].

Kamienski, [10] examined the influence of vessel diameter to mixer diameter ratio on power consumption. The results were presented in the form of graphical characteristics of power consumption and mathematically in the form of dimensionless equation. Later, the discharge flowrate number was correlated as a function of the paddle dimensions by an experimental investigation set up by Yuji, [11].

There are several important dimensionless numbers that are required to design mixers [12, 13]. All must be determined experimentally for a given impeller configuration. These numbers can be used to quantify the performance characteristics of an impeller. Dimensionless numbers are affected by geometric factors, such as the ratio

of impeller to tank diameter, D/T , and the ratio of clearance from the tank bottom to tank diameter, C/T .

The impeller power number, N_p , is used to predict impeller power, P , directly and torque, t , indirectly:

$$N_p = P / \rho n^3 D^5 \quad (1)$$

Where, N_p is the power number, P is the power of the mixer, Watt, D is the diameter of the impeller, m , n is revolutions per second, and ρ is the density of the concentrate, kg/m^3 .

The impeller blend number, N_B , is used to predict the blend time, θ , in a mixed system. Blend number (N_B) attempts to predict the effect of impeller D/T on the results:

$$N_B = n \theta (D / T)^{2.3} \quad (2)$$

Where, N_B is the blend number, n is revolutions per second, D is the diameter of the impeller, m , T is tank diameter, m , and θ is time in second.

The impeller pumping number, N_Q , is used to predict the impeller pumping rate, q , directly

$$N_Q = q / n D^3 \quad (3)$$

Where, q is volumetric flow rate of fluid leaving the impeller blades, m^3/s , n is revolutions per second of impeller, D is impeller diameter.

Finally, Reynolds number, Re , for non-Newtonian fluids measures the ratio of inertial to viscous forces within the mixing environment. The generalized Reynolds number is calculated from the following equation for non-Newtonian fluids [14].

$$Re = \frac{\rho N^{2-n} D^2}{k} \quad (4)$$

Where, ρ is the density of the concentrate, N is revolution per sec, D is the diameter of the impeller, m , K is the consistency index, n is flow behavior index.

All of the dimensionless numbers just discussed are correlated with Re . These correlations depict the trends observed for the applied impeller system for different values of D/T .

2. Material and Methods

2.1. Preparation of Apple Juice Concentrate Samples

Apple concentrate was obtained from fresh apple fruits previously peeled by rasping machine; the fruits were thoroughly washed and transferred for pressing to extract the juice. The pulped juice was collected in special cloth; the pasteurized juice was cooled to 50-55°C and treated with pectinase enzyme and filtered to not less than 85% transparency.

Apple juice was pumped into a five effect evaporator to be concentrated to 71%. The concentrate juice was then pumped to be chilled and cooled from 70 to 10°C. The cooled concentrates were pumped to the heat exchanger for cooling to 4°C and then mixed, then pumped to the filler machine

2.2. Rheological Properties

Apple concentrates of (51, 56, 61, 66, and 71 %) were taken during processing of the concentrate. Flow properties (shear stress, shear rate, and apparent viscosity) of apple concentrate were measured directly with Brookfield Digital Rheometer, Model HA DVIII Ultra (Brookfield Engineering Laboratories INC). The concentrate of apple was placed in small sample adaptor. A thermostatic water bath, was adjusted with the sample. The SC4-21 spindle was selected for the sample measurement. A thermostatic water bath, provided with the viscometer, was used to regulate the sample temperature. The rheological parameters of apple concentrate were studied within the temperature range 30-70°C, and 4, 10°C, shear rate 9.3-93 s^{-1} and different concentrations 51-71%, [15].

2.3. Power Calculation

For calculating the power of the mixer, an impeller was connected with an ammeter to measure the current at different revolutions per minute of the mixer, then use the following equation; [16].

$$P = IV \quad (5)$$

Where P is the power of the mixer, Watt, I is the current, Ampere, and V is the voltage, Volt.

The density of apple concentrate at temperature 4°C, 71% concentration is 1406 kg/m^3 .

3. Results and Discussion

3.1. Rheological Properties of Apple Concentrate

3.1.1. Shear Stress – Shear Rate RELATION

Figures (1, 2) show that apple concentrate exhibited Newtonian behavior fluid at all temperatures (30-70°C) and all concentrations studied. (51, 56, 61, 66, 71%). Also, the relations between shear stress and shear rate were fitted to the following equation:

$$\tau = \mu \gamma \quad (6)$$

Where

τ Shear stress, (Pa)

μ Viscosity, (Pa.s.)

γ Shear rate, (1/s.)

Apple Juice Concentrate at temperatures 4 and 10°C exhibits non-Newtonian pseudoplastic behavior equation (6). This result agrees with the work of (3).

$$\tau = K \gamma^n \quad (7)$$

Where,

τ is the shear stress, (Pa)

γ is the shear rate, (1/s)

K is the consistency index

n is the flow behavior index.

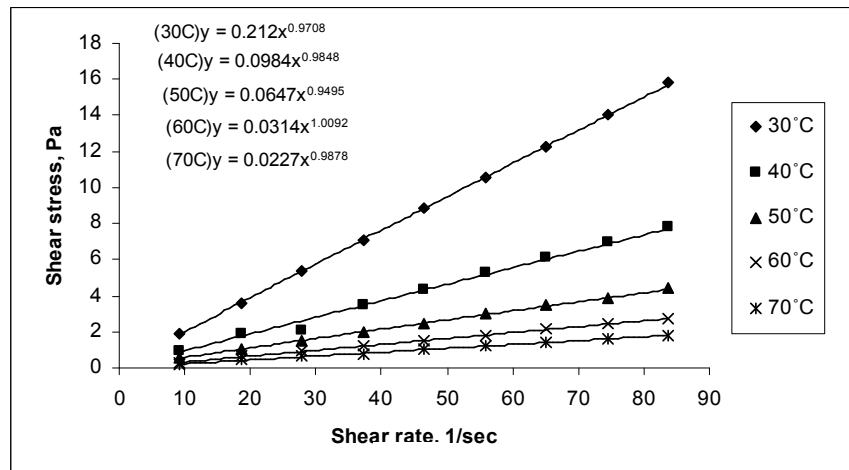


Figure 1. Relation between shear stress and shear rate at different temperatures for 71%T.S.S apple juice concentrate.

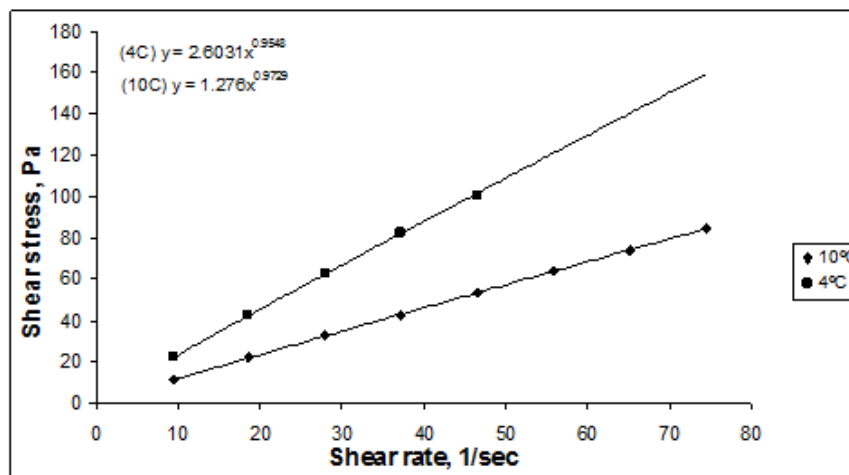


Figure 2. Relation between shear stress and shear rate at different temperatures for 71% T.S.S. apple juice concentrate.

3.1.2. Shear Rate – Viscosity Relation

Figures (3, 4) show that viscosity of apple juice concentrate at 51-71% remains at constant at all temperatures studies except and 10°C viscosity decreases with increasing shear rate as shown in Figure (3). These results agree with the work of [17].

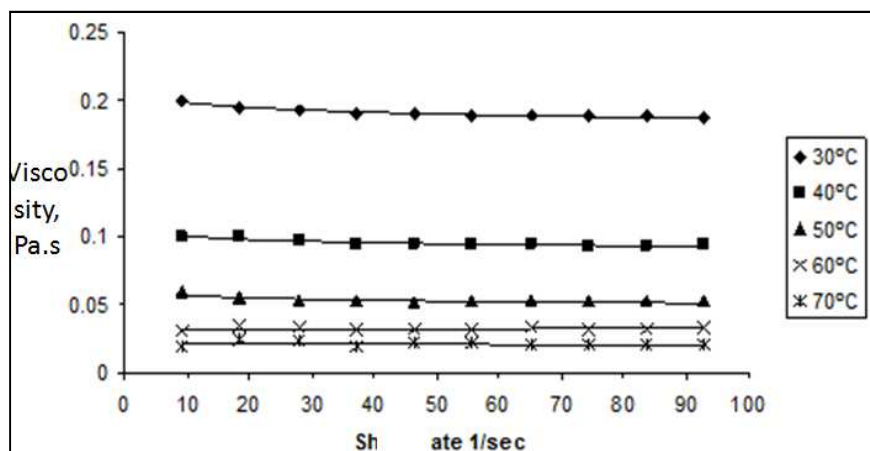


Figure 3. Effect of shear rate on viscosity at different temperatures for 71% T.S.S. solid concentration apple juice concentrate.

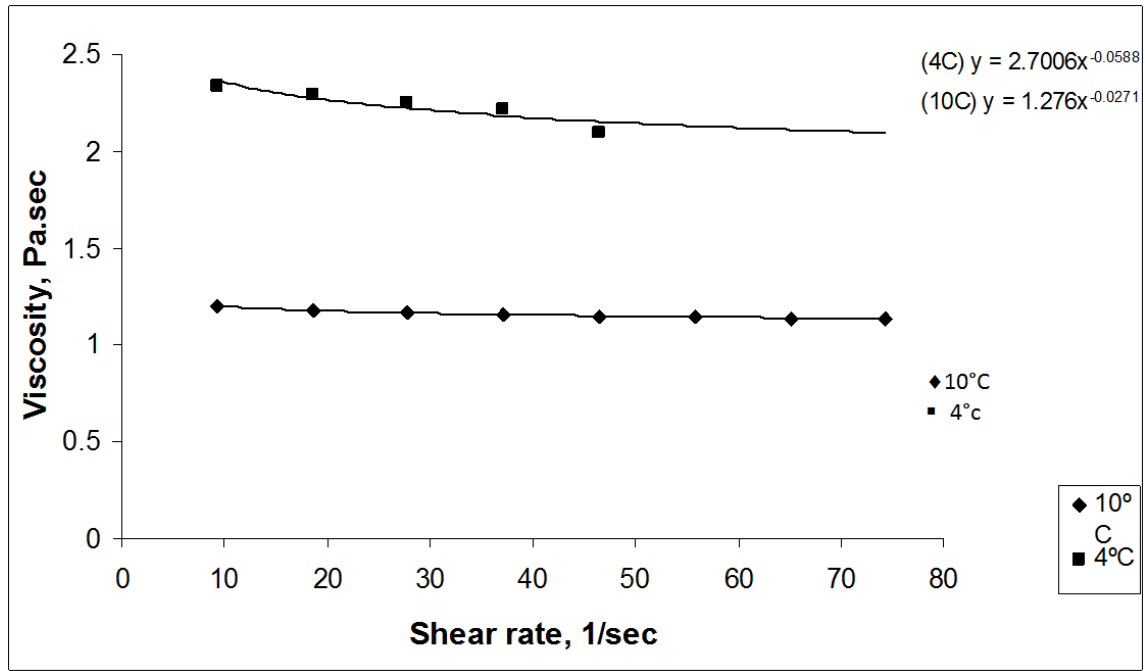


Figure 4. Effect of shear rate on viscosity at 4, 10°C for 71% T.S.S. apple juice concentrate.

3.2. Effect of Impeller to Tank Diameter Ratio on Dimensionless Groups

3.2.1. Power Number – Reynolds Number Plot

The Power number is analogous to a friction factor. It is proportional to the ratio of the drag force acting on a unit area of the impeller and inertial stress, the inertial stress is related to the flow of momentum associated with the bulk motion of the fluid, [18].

The relation between Reynolds number and power number was fairly fitted to the following equation (8), [19].

$$\log NP = \log A + B \log Re \quad (8)$$

Where, P_0 is the power number, Re is Reynolds number, A and B are constants.

Figure (5), shows the relation between power number and Reynolds number at different impeller to column diameter

(D/T) ratios at temperature 4°C.

3.2.2. Blend Number – Reynolds Number Plot

Figure (6) shows that as D/T increases, for the same blend number (i.e., same time of mixing), Reynolds number decreases with the increase of Reynolds number (i.e., revolutions per second decreases) which is logically accepted.

3.2.3. Pumping Number – Reynolds Number Plot

Figure (7) shows it is clear that the increase in D/T ratio causes decrease in pumping number at the same Reynolds number. This may be explained due to the fact that constant volumetric flow rate of fluid leaving impeller, q , requires the decrease of pumping number with increase in impeller diameter. (Eq. 3).

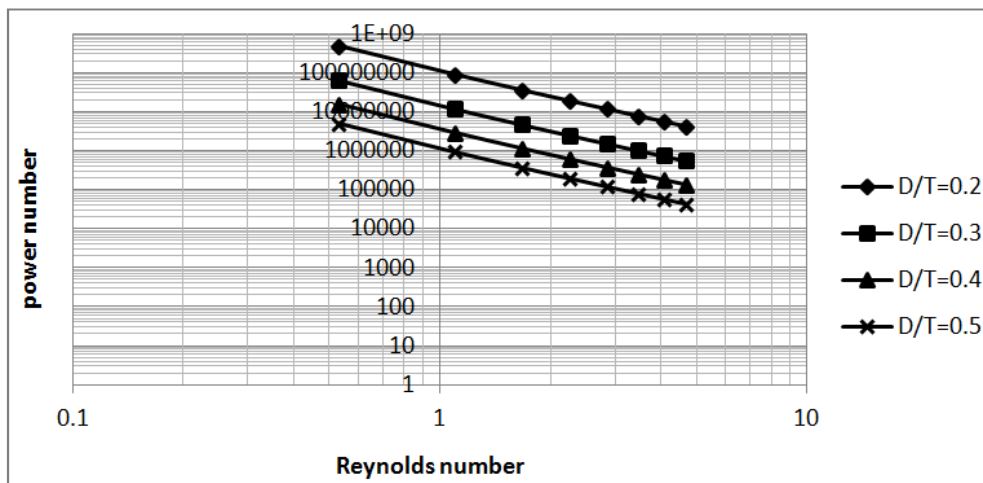


Figure 5. Relation between N_p and Re of Apple concentrate at 4°C and different D/T.

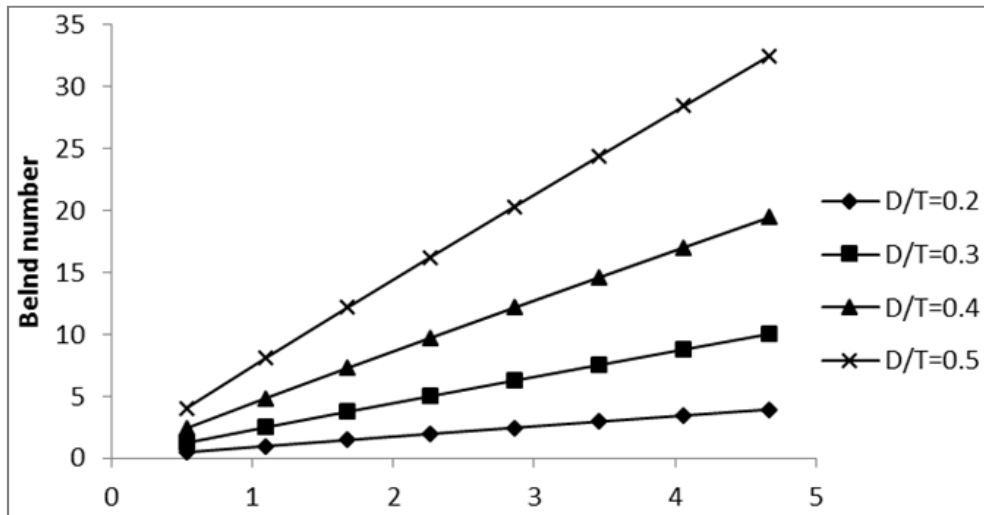


Figure 6. Blend number (N_B) as function of Re at different D/T ratios.

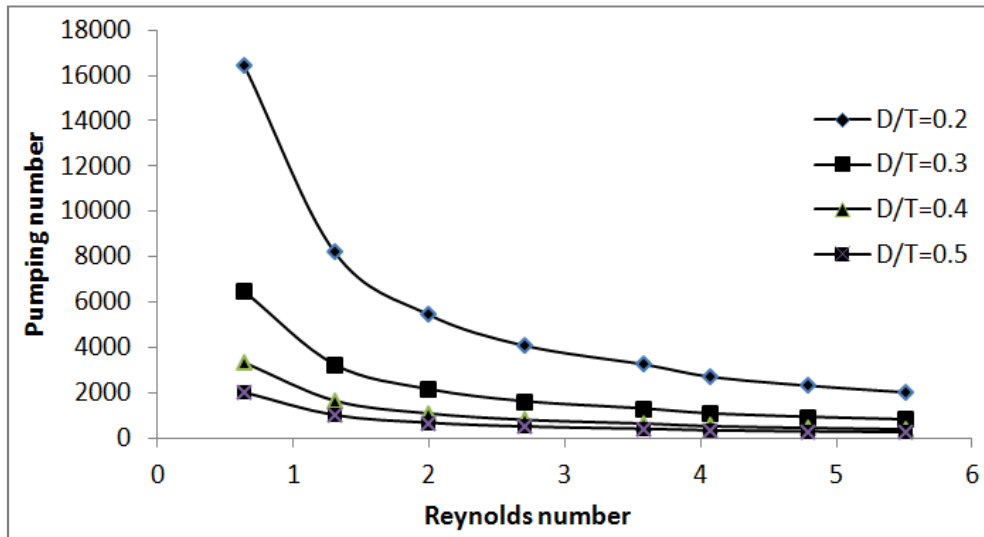


Figure 7. Pumping number (N_Q) as function of Re at different D/T ratios.

4. Conclusion

Apple concentrate behaves as Newtonian fluid at temperatures (30, 40, 50, 60 and 70°C) and solid concentration 71% wt while at 4, 10 behaves as Non-Newtonian pseudoplastic fluids. An impeller mixer was used to predict the power number, blend number and pumping number as function of Reynolds number at different impeller to tank diameter ratios at 4°C and 71% concentration. The effect of D/T on N_p , N_B and N_Q was explainable.

Notation

A and B are constants in equation (8), dimensionless
 D: impeller diameter, m.
 I: current intensity, Ampere.
 θ : is time in second
 k: consistency index, Pa.s
 n: revolutions per second

N_p : power number
 N_B : blend number
 P: power of the mixer, Watt
 P_M : motor power, hp
 q: volumetric flow rate of fluid leaving the impeller blades, m^3
 Re : Reynolds number
 T: tank diameter, m
 V: voltage, Volt
 γ : shear rate, s^{-1}
 M: viscosity, Pa.s
 P: density, kg/m^3
 τ : shear stress, Pa

References

- [1] Rao M. A., Concentration of apple juice. In D. L. Downing, Processed Apple Products. New York: Van Nostrand Reinhold, 1989, 137-168.

- [2] Ramos A. M. and Ibarz A., Density of juice and fruit puree as a function of soluble solids content and temperature. *J. Food Eng.*, 35(17), 1998, 57–63.
- [3] Ibarz, A., Gonzalez C., Esplugas S. and Vicente M., Rheology of clarified fruit juices. I: peach juices. *J. Food Eng.*, 15(18), 1992, 49–61.
- [4] Keshani S., Chuah AL., and. Russly A. R, Effect of temperature and concentration on rheological properties pomelo juice concentration. *International Food Research Journal* 19, 2012, 553-562.
- [5] Alvarez E., Cancela MA and Maceiras R., Effect of temperature on rheological properties of different jams. *International Journal of Food Properties* 9, 2006, 135-146.
- [6] Ahmed, J., Ramaswamy H.S and Sashidhar K., Rheological characteristics of tamarind (*Tamarindusindical* L) juice concentrate *food Sci Technol- LEB* 40, 2007, 225-231.
- [7] Niranjana K, Smith D.L.O., Rielly C.D, Lindley J. A, and Phillips V.R., Mixing processes for Agricultural and Food materials: Part 5, Review of Mixer Type J. of *Agricultural Engineering Research*, 59, 1994, 145-161.
- [8] Thakur R.K., Vial Ch., Djelveh G. and M. Labbafi, Mixing of complex fluids with flat bladed impellers: effect of impeller geometry and highly shear thinning behavior. *Chemical Engineering and Processing*, 43, 2004, 1211-1222.
- [9] Chenxu Yu. and Gunasekaran S., Performance evaluation of different model mixers by numerical simulation, *Journal of Food Engineering*, 71. 2005, 295-303.
- [10] Kamienski J., Mixing power of turbine mixers with divided angled blades. *Industria Chemical Processes*, 7 (3), 1986, 417-431.
- [11] Yuji S. and Hiromoto U., Effects of paddle dimensions and baffle conditions on the interrelations among discharge flowrate, mixing power and mixing time in mixing vessels. *Journal of Chemical Engineering of Japan*, 20 (4), 1987, 399-404.
- [12] Wilkens R. J., Henry C., and. Gates L. E, *Chemical Engineering Progress*, 2003, 44-52.
- [13] Geankoplis, C.J. (1983). *Transport Processes and Unit Operations* Allyn and Bacon, Inc., 2nd Ed.
- [14] Xueming Z., Zondong H., Nienow A.W. and Kent C.A., Rheological characteristics, power consumption, mass and heat transfer during xanthan gum fermentation. *Chinese Journal of Chemical Engineering*, 2(4), 1994, 198-210.
- [15] Brookfield manual, Brookfield Manual No. M/98-211-B0104, Operating Instruction, Brookfield Engineering Laboratories, Inc. Middleboro, MA, USA, 1998.
- [16] Sorour M.A., Prediction of power number in mixing of apricot jam puree. *Journal of Engineering and Applied Science*, 53(1) 2006, 133-140.
- [17] Sean X. L., Dong, D. X. Zheng D. C. and B. Pratish, Shear rate dependent thermal conductivity measurement of two fruit juice concentrates. *J. Food Eng.*, 57(17), 2003, 217-244.
- [18] Rushton J.N., Costich E.W. and H. Everett, Unit operation, *Chem. Eng. Prog.*, 1950, 46-395.
- [19] Maingonnat J.F., Muller L. and Leuliet J.C., Modelling the build-up of a thixotropic fluid under viscosimetric and mixing conditions, *J. of Food Eng.*, 71, 2005, 265-272.