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Effect of pasteurization on rheological properties of white carrot juice

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Abstract

The rheological behaviour of untreated and pasteurized white carrot juice was modelled to investigate the influence of temperature on viscosity and its fluid type. The research was conducted using a rotational viscometer at shear rates ranging from 1 to 100 s^{-1} and temperatures between 10 and 60°C. The rheological behaviour of untreated white carrot juice was well described by the Newtonian model while the pasteurized juice showed a pseudoplastic behaviour and was satisfactorily fitted to Ostwald-de Waele model. The Arrhenius equation adequately described the effect of temperature on the viscosity. The activation energies were depended on kind of fluid and were 15.41 and 5.90 kJ/mol for untreated and pasteurized white carrot juice, respectively.

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Keywords: white carrot juice; thermal treatment; rheological properties.

1. Introduction

Sustainable agriculture is the production of food, plant or animal products by methods that are profitable, environmentally friendly and good for human communities. This definition includes also production of food on the basic of natural ingredients and effective energy-saving management.

Food industry has been looking for suitable, natural raw materials for manufacturing products with designed

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colour for a long time. One of the raw materials which can fulfil these requirements is white carrot. It is little known and widespread vegetable but contains almost all nutrients of traditional, orange carrot apart from carotenoids Wronowska and Zadernowski 2012). White colour of the carrot products gives possibility to mix them with other vegetables and fruit juices. Addition of juice from white carrot doesn't change the colour but influences on rheological properties of obtained mixture.

The knowledge of the rheological behaviour is necessary for processing of fruit and vegetable products. The rheological properties of juices have several application in developing food process, equipment, quality evaluation and structural understanding of food and raw material (Manjunatha, Raju 2013). They are required to determine the power requirements for unit operation such as: pumping, sizing of pipes, pasteurization, filling, mixing and evaporation (Barbosa-Canovas et al. 1996, Rao 1999). They are also important in the calculation of heat, mass and momentum transfer phenomena (Telis-Romero et al. 1999). Vegetable and fruit juices were subjected to different temperatures and concentration levels during processing, storage and transportation, where the rheological properties can be changed dramatically (Kobus et al. 2014).

Nomenclature

σ	shear stress (Pa),
γ	shear rate (s^{-1}),
μ	viscosity (Pa·s),
n	flow behaviour index,
K	consistency coefficient ($Pa \cdot s^n$),
K_0	frequency factor ($Pa \cdot s^n$),
E_a	activation energy of flow ($kJ \cdot mol^{-1}$),
R	universal gas constant ($kJ \cdot mol^{-1} \cdot K^{-1}$),
T	absolute temperature (K),

2. Objective, data and methodology

The aim of the paper was to determine the influence of pasteurization on the rheological properties of juice from white carrot variety *White Satin F1*. The juice was obtained with the help of laboratory press. Pasteurization was conducted at 90°C for 20 minutes. Rheological properties were measured using Brookfield viscometer (Brookfield Engineering Laboratories: model LVDV-II + PRO). A sample of 16 ml of carrot juice was used in ULA-baker for all experiments. The concentration of carrot juice was 10°Bx. The temperature of sample was changed from 10 to 60°C and kept at constant value using water bath (Brookfield TC-502P). The computer software (Rheolac 3.1) was applied to control viscometer and data acquisition. All experiments were carried out in three replications. The rheological data obtained for white carrot juice were fitted to Newton model:

$$\sigma = \mu\gamma \tag{1}$$

and Ostwald-de-Waele model:

$$\sigma = K\gamma^n \tag{2}$$

The influence of temperature on consistency coefficient was evaluated from Arrhenius relationship (Quek et al., 2013):

$$K = K_0 e^{\frac{E_0}{RT}} \tag{3}$$

3. Results

The rheograms in Fig 1 show plot of shear stress and viscosity versus shear rate of untreated white carrot juice. Shape of flow and viscosity curves indicates that this juice exhibited Newtonian behaviour.

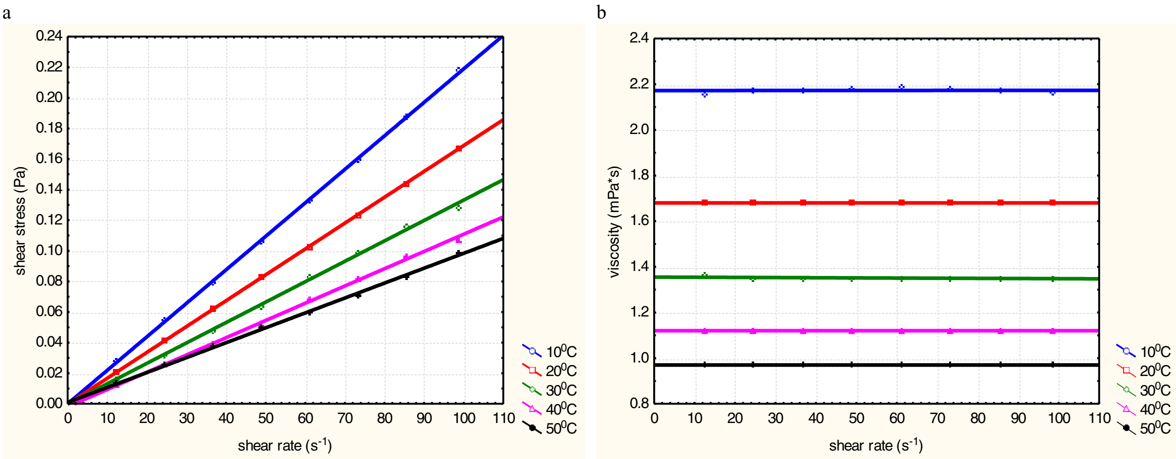

Fig. 1. (a) flow curves of raw carrot juice (10ºBx) at different temperatures; (b) viscosity curves of raw carrot juice (10ºBx) at different temperatures

In Fig 2 were shown flow and viscosity curves of pasteurized carrot juice. In this case rheograms of viscosity versus shear rate show concave curves downward that indicates on non-Newtonian, shear –thinning behaviour.

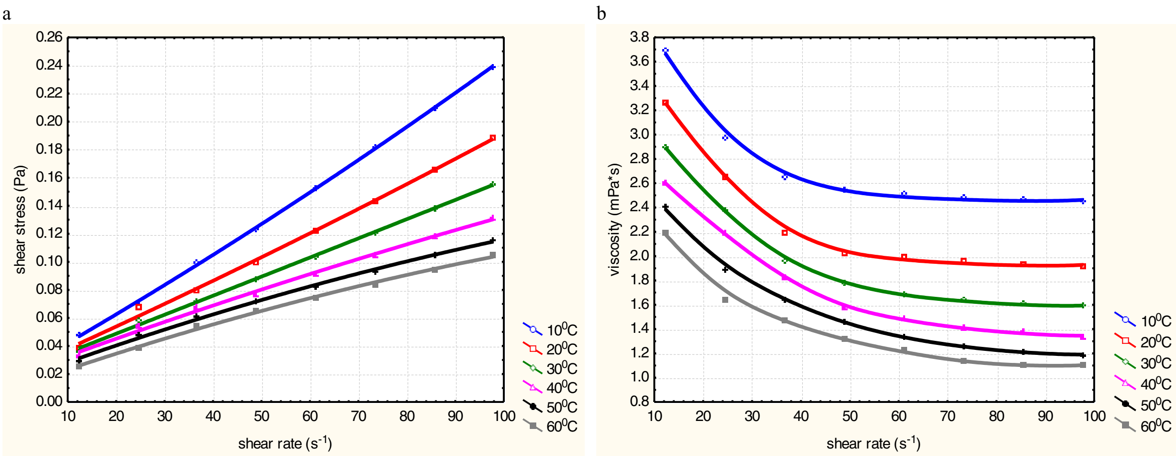

Fig. 2. (a) Flow curves of pasteurized carrot juice (10ºBx) at different temperatures; (b) viscosity curves of pasteurized carrot juice (10ºBx) at different temperatures

Because the pasteurized white carrot juice exhibited non-Newtonian behaviour Ostwald-de-Waele model was applied to calculate its rheological properties. The values of consistency coefficient and flow behaviour index for pasteurized white carrot juice were presented in Table 1. All the values of flow behaviour index are below 1 supporting the pseudoplastic behaviour of pasteurized juice.

Table 1. Rheological properties of Ostwald-de-Waele model for pasteurized white carrot juice

Temperature (^0C)	Consistency coefficient ($Pa \cdot s^n$)	Flow behaviour index (-)
10	0.00624	0.787
20	0.00584	0.743
30	0.00550	0.700
40	0.00520	0.662
50	0.00485	0.657
60	0.00414	0.685

The Arrhenius equation was used to describe the effect of temperature on the consistency coefficient both juice. From this relationship the frequency factor and the activation energy were obtained. The results were shown in Table 2.

Table 2. Rheological parameters for untreated and pasteurized white carrot juice

Kind of juice	Frequency factor ($Pa \cdot s^n$)	Activation energy ($kJ \cdot mol^{-1}$)
Untreated	$2.91 \cdot 10^{-6}$	15.41
Pasteurized	$5.21 \cdot 10^{-4}$	5.90

The activation energy for untreated juice was significant higher that for pasteurized juice. The greater the activation energy for untreated white carrot juice provides that there is higher effect of temperature on viscosity than in the case of pasteurized juice.

4. Summary and conclusion

The rheological behaviour of untreated carrot juice was satisfactorily described by the Newtonian model, while the pasteurized juice showed a pseudoplastic behaviour. To compare different in behaviour fluid the consistency coefficient and the energy activation was calculated. The higher consistency coefficient values were obtained for pasteurised carrot juice while the energy activation was higher for untreated juice. The pasteurization process can change not only the viscosity but also the rheological properties of white carrot juice.

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