Characterization of time depent behaviour of non fat and full fat stirred yogurt

A. Cancela*, R. Maceiras, E. Álvarez

University of Vigo, Chemical Engineering Department, ETSEI; Rua Maxwell s/n, 36310 Vigo, Spain.

Abstract

The effects of shear rate and temperature on the time dependency of two stirred yoghurt types under constant shear rate were to study in the present work. The analyzed yoghurt were non fat and full fat. The experimental data was measured using a rotational viscometer Viscotester VT550, Searle type, in which the outer cylinder is fixed and the inner cylinder rotates.

Rheological data was obtained at different temperatures (10, 20 and 30 ºC) and three different shear rates (50, 200 and 445 s^{-1}), likewise the time of shearing was fixed to 8000 s. In this work, it was demonstrated that samples exhibit a thixotropic behaviour, which increased with the shear rate and decreased with the temperature. The experimental data were fitted with four rheological models. The best adjustment was obtained with the Weltmann model.

Keywords: stirred yoghurt, time dependent viscosity, thixotropy.

1. Introduction

The knowledge of the rheological and mechanical properties is very important for the design and optimization of processes and equipment in engineering (Odigboh *et al*., 1975; Boger *et al.,* 1974). In addition, viscosity is used for the estimation and calculation of some transport phenomena, which they are necessary for design and process evaluation, process control, and consumer acceptability of a product (Jimenez *et al*., 1987; Saravacos *et al*., 1995). As far as the sensorial evaluation is concerned, viscosity and rheological data provide useful information for to modify and control the process conditions and then to obtain a product with the level of quality desired by the consumer (Shama *et a*l., 1973; Kokini *et al.,* 1985).

Rheological studies contribute to the knowledge of the molecular structure or distribution of the molecular components of foods, as well as to predict the structural changes of the food during its manufacture processes.

The viscosity of most foods depends of factors as such as, composition, temperature, shear rate, shearing time, and their previous thermomechanical history (Tiu *et al.,* 1974). This is due to the fact that many foods are dispersions of colloidal sized particles as solids or immiscible liquids that interact with polymers present in the dispersion (Abu-Jdayil 2003).

The yoghurt is an example of dispersed nature food that presents as fundamental structure a protein network. In the production of yoghurt the addition of cultures of thermophilic bacteria, such as Lactobacillus delbrueckii subsp. bulgaricus and Streptococcus salivarius subsp. thermophilus to the milk produce lactic acid from the lactose, which leads to a progressive lowering of the pH, resulting in changes in the casein. The stirred yoghurt is inoculated and incubated in a fermentation tank. This type of yoghurt is kept in the tank up to obtaining the desired level of pH. Then, the yoghurt gel is broken during the stirring, cooling and packaging stages.

The objective of this work was to characterize behaviour of stirred yogurt. The time-dependent flow behaviour of both stirred yoghurt types has been fitted with four empirical equations, namely, Weltmann, Hahn, First order stress decay and Second order structural kinetic models.

2. Theory

The experimental data, time dependent flow properties, of both stirred yoghurt were modelled using the following equations:

Weltmann model (1943):

$$\sigma = A + B\ Ln\ (t) \tag{1}$$

Hahn et al model (1959)

$$\log\left(\sigma - \sigma_e\right) = P - a\ t \tag{2}$$

First order stress decay model (Figone *et al.,* 1983)

$$\sigma = \sigma_e + \left(\sigma_o - \sigma_e\right)\exp\left(-\ k\ t\right) \tag{3}$$

Second order structure kinetic model (Abu-Jdayil, *et al.,* 2002; 2003)

$$\left[\frac{(\eta-\eta_e)}{(\eta_o-\eta_e)}\right]^{1-n} = (n-1)\,K\,t+1 \tag{4}$$

The eq. (4) is valid only under the constant shear rate conditions, and it was used with a value of n = 2, then the eq. 4 can be expressed as follow:

$$\left[\frac{(\eta-\eta_e)}{(\eta_o-\eta_e)}\right]^{-1} = K\,t+1 \tag{5}$$

Where, σ is the shear stress at shearing time (t), σo is the maximum shear stress, σe is the equilibrium stress, and A, B, P, k and K are constants.

3. Experimental

3.1. Yoguhurt composition and nutritional analysis

Commercial stirred yogurts were used. The samples of non fat and full fat stirred yoghurt were obtained directly from a local dairy. Total solid contents (%) of each sample were: non fat, 12.3% and full fat, 14.6%. The composition of samples are:

Non Fat Stirred Yoghurt (NFSY): skimmed milk, skimmed milk powder, fructose (2.4%), milk proteins, sweeteners (aspartame), lactic ferments and vitamins (B1, B5, B6, B9 y D)

Full Fat Stirred Yogurt (FFSY): milk, sugar (7.5%), milk cream, milk proteins, skimmed milk powder and lactic ferments.

The nutritional content of both samples is shown in the table 1.

Nutritional values by 100 gr	NFSY	FFSY
Energy (Kcal)	48	108
Proteins (g)	5.2	4.1
Carbonhydrates (g)	7.7	11.3
Fat (g)	0.1	4.7
Vitamin B1 (mg)	0.21	-
Vitamin B5 (mg)	0.9	-
Vitamin B6 (mg)	0.3	-
Vitamin B9 (μg)	30	-
Vitamin B12 (μg)	0.22	-
Vitamin D (μg)	0.75	-
Calcio (mg)	186	133
ºBrix to 20ºC	12.38	14.68

3.2. Measurements of the Time-dependent Rheological Properties

Both stirred yoghurt samples were characterized for their rheological properties using steady shear measurements, which were carried out using rotational viscometer (Haake VT550/MV3, Searle type system). This viscometer is equipped with two coaxial cylinders, thereby that it has an inner cylinder rotating in a fixed outer cylinder. The gap width between two cylinders was 1.45 mm. Radius and length of the rotating cylinder were 10.1 mm and 61.4 mm, respectively. Thermostatic bath was used to control the working temperature with a precision of ± 0.1°C. This apparatus measures the shear rate and the apparent viscosity of a fluid at a certain temperature.

The apparent viscosity, η, is defined as the ratio of shear stress, τ, to that of shear rate, γ, ($\eta = \tau / \gamma$). The SV1 sensor system was used since this allows to measure high viscosity liquids and pastes, it is working in the low medium shear rate range. The amount of sample to be used must be adjusted in order for the top surface or the inner cylinder to be just covered. The temperature of this system was kept constant by means of a thermal liquid circulator.

Shear stress was analyzed as function of shearing time. Each test required around of 120 ml of yoghurt. Each measure of constant shear rate was evaluated at 10, 20 and 30°C and a fresh container of yoghurt was used for each experiment. To minimise damage to the yoghurt structure prior of shearing, samples were carefully poured into the cup. Samples were allowed to stand for 10 min prior of shearing.

In this study, in order to determine the time dependent behaviour of stirred yoghurt, the samples were sheared at constant shear rates, namely at 50, 200 and 445 s^{-1}, and the shear stress was measured as a function of shearing time during 8000 s, at fixed temperature. The experiments were made with an uncertainly of ± 0.001. In order to investigate the reproducibility of the results, three replicates were made for most of the experiments and the reproducibility was ± 5% on average

4. Results and Discussion

Figs. 1 and 2 show the temperature effect on the apparent viscosity of FFSY and NFSY samples, which were evaluated at three conditions of fixed shear rate. Based on apparent viscosity – shearing time curves was observed that the samples exhibited a general trend, in which the apparent viscosity values decreased with shearing time at constant shear rate and temperature, this behaviour is an indicative of the thixotropic character of the yoghurt samples.

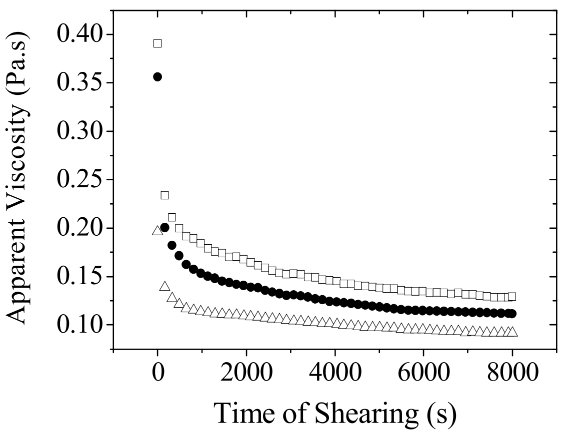

Figure. 1. Viscosity of FFSY as a function of shearing time at.445 s^{-1}. (□) 10 °C, (●) 20 °C, (△)30 °C

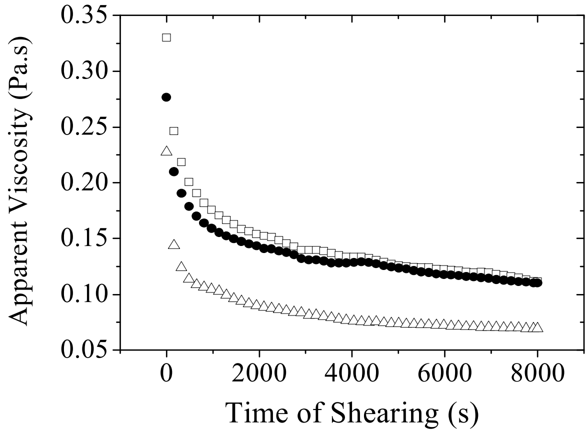

Figure 2. Viscosity of NFSY as a function of shearing time at 445 s^{-1}. (□) 10 °C, (●) 20°C, (△)30 °C

The results indicated that there was a higher dependency in the initial stages of the process. The dependency of viscosity decreased as a function of shearing time, and it reached the equilibrium state around 30 min. O'Donnel *et al.*, 2002, and Ramaswamy *et al.*, 1992, have reported similar trends for stirred yoghurt.

The apparent viscosity as function of shearing time at 50 s^{-1} of the FFSY sample is greater than the apparent viscosity of NFSY sample (Fig. 3), whereas the apparent viscosity values of both samples were very nearby, when shearing rate is 445 s^{-1} (Fig. 4).

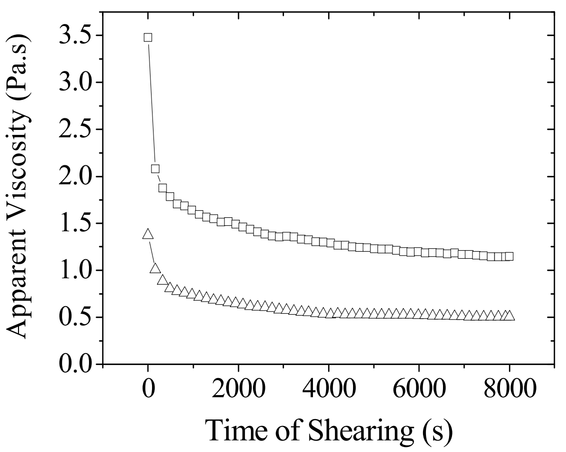

Figure 3. Time dependence curves for analyzed samples at a constant shear rate of 50 s-1 and 10 °C. (□) FFSY, (△) NFSY

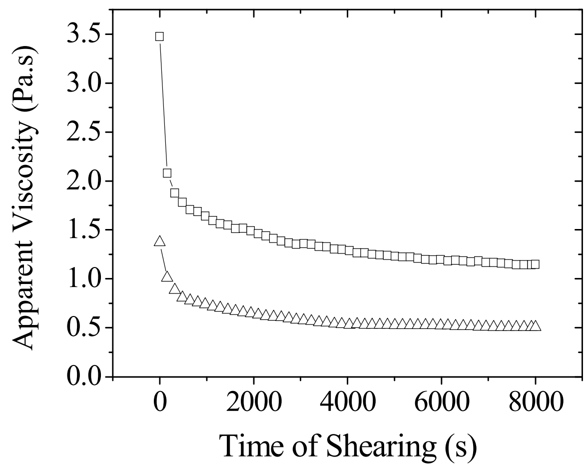

Figure 4. Time dependence curves for analyzed samples at a constant shear rate of 445 s-1 and 10 °C. (□) FFSY, (△) NFSY

The time dependence of viscosity was quantified by means of an assessment of empirical parameters, which were obtained from the adjustment of the experimental data to the different models used in this study.

Figure 5 shows typical time dependent curves of stirred yoghurt, which are shown the different models used to evaluate the time dependent behaviour of FFSY and NFSY samples. In this Figure can be seen that the Weltmann model for both analyzed samples fitted the time dependency data better than Hahn, first order stress decay and second order structural kinetic models.

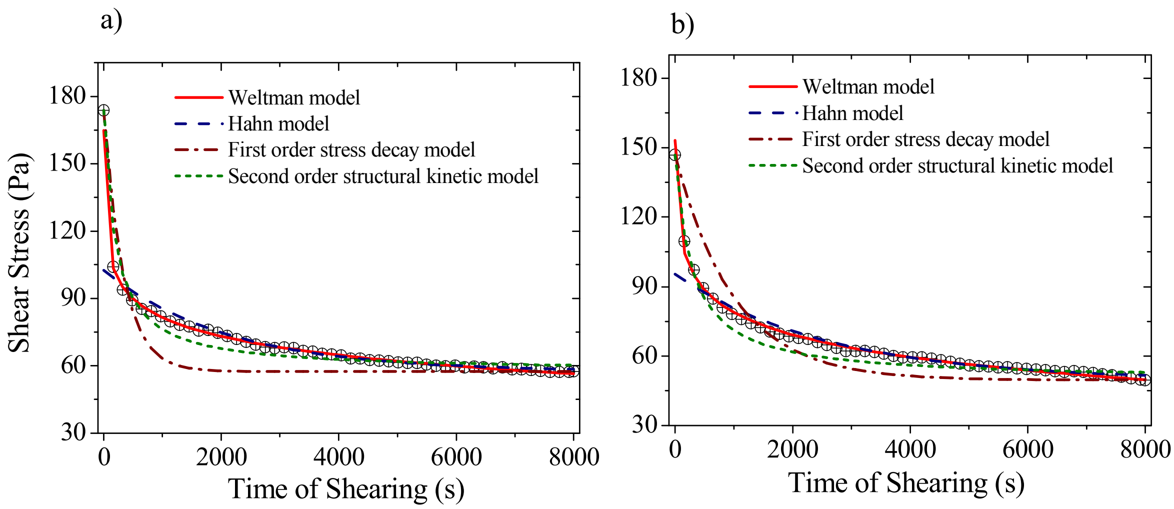

Figure 5. Testing of models used for to fit the experimental data of a) FFSY and b) NFSY samples at 10°C y 445 s-1:

5. Conclusions

In this work, the rheological behaviour of samples of stirred yoghurt was studied. These samples of yoghurt (FFSY and NFSY) exhibit a thixotropic behaviour that increased with the shear rate and decreased with the temperature. Additionally, in this work was found that the dependency the time with viscosity decreased rapidly, it is reached an equilibrium time after of 25 min approximately.

Experimental values were fitted to four models, of which the Weltmann model fitted better the experimental data under conditions of shear rate and temperature established in this study.

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