EFFECT OF TEMPERATURE ON STEADY-STATE FLOW BEHAVIOUR OF SEMISOLID DAIRY DESSERTS

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Introduction

The “natillas”, semisolid dairy dessert of wide consumption in Spain, is composed of milk, starch, hydrocolloids, sugars, colorants and aromas. The particular characteristics of some ingredients, like fat content of milk, type of starch, and/or type and concentration of hydrocolloids, and their crossed interactions, will be reflected in notable differences in their rheological and sensory properties. Little information is available on the differences to be found in commercial samples of this type of dairy desserts [1, 2]. The flow properties of this type of products, e.g. time dependence and pseudoplasticity, are due to the resistance to shear of a biphasic structure defined by the characteristics of the dispersed phase (starch granules) and by the viscosity of the dispersing phase [3, 4]

The objectives of this work are to characterise the steady-state flow behaviour of commercial samples of Spanish “natillas” and to study the effect of the consumption temperatures (5 and 25ºC) on their flow properties.

Experimental

Samples

Seven samples of vanilla dairy desserts (*natillas*) of different brands and characteristics (Fig.1) covering the commercial range, were purchased from the local market (Table 1). The samples were stored at 4±1ºC prior to testing and all measurements were performed within the shelf-life period of each sample.

Table 1. Main composition and price level of commercial vanilla cream dairy desserts samples

Sample	Dairy ingredients [(1)]	Thickeners [(1)]	pH [(2)]	Soluble solids [(2)] (º Brix)	Price[(3)]
1	Semi-skimmed milk	Modified starch Carrageenan Xanthan gum	6.81	24.5	1.4
2	Milk Semi-skimmed milk	Modified starch Carrageenan Guar gum	6.76	23.7	1
3	Milk Cream Semi-skimmed milk powder	Acetylated distarch adipate Gelatine	6.61	28.3	2.3
4	Milk Cream Dairy solids	Modified starch Carrageenan Fatty acid esters	6.60	26.3	2.5
5	Milk Cream	Modified starch Carrageenan Guar gum	6.76	23.5	2.5
6	Milk Cream	Modified starch Carrageenan Guar gum	6.72	24.5	1.7
7	Milk Cream Dairy solids	Modified starch Carrageenan Fatty acid esters	6.75	24.5	1.9

(1) Declared in label.
(2) Average value of two measurements
(3) Lower price considered as reference unit

Rheological measurements

The measurements were carried out in a Haake VT 550 viscometer, using concentric cylinders sensors (MV1 and MV3, with 1.05 and 1.38 radii ratios, respectively), monitored by a Rheowin Job Manager (Haake, 2002). The samples were analysed at two temperatures, 5±1 and 25±1ºC.

Before analysing flow behaviour, the structure responsible for thixotropy was destroyed by shearing for five minutes at 300 s^{-1}, as selected in previous experiments. Sample flow was measured by registering shear stress values at increasing shear rates from 1 to

200 s^{-1} in 60 s. Data obtained were fitted to the Herschel-Bulkley model ($\sigma=\sigma_0+K\dot{\gamma}^{n}$). The yield stress ($\sigma_0$) value, used in the Herschel-Bulkley's model, was previously obtained by fitting the experimental data to the Casson model: $\sigma^{0.5}=\sigma_0^{0.5}+K\dot{\gamma}^{0.5}$ This was taken as the square of the ordinate intercept in the Casson plot . Apparent viscosity values were obtained with the expression: $\eta_{ap}= \sigma_0/\dot{\gamma} + K\dot{\gamma}^{n-1}$.

Statistical analysis

The effect of temperature on the Herschel-Bulkey parameters was analysed by two factors (sample and temperature) ANOVA with interactions. The Fisher test (α=0.05) was used to calculate the minimum significant differences. All calculations were carried out with the Statgraphics Plus 4.1 software.

Results

On registering shear stress variation with shear rate, all samples showed non-Newtonian shear-thinning behaviour with an apparent initial resistance to flow. Experimental data fitted well to the Herschel-Bulkley model (Fig. 3) with R^2 values ranging between 0.993 and 0.998 for measurements at 5ºC and between 0.990 and 0.999 for those at 25ºC. The yield stress values, obtained for all samples at both temperatures, were important - higher than 7.77 Pa at 5ºC and higher than 5.76 Pa at 25ºC- indicating plastic behaviour.

Since the parameter K values depend on n values, apparent viscosity at 1 s^{-1} (η_1) values were used in the analysis of variance performed to study the effects of sample and temperature on flow properties. ANOVA results showed that sample-temperature interactions were significant for σ_0 (F_{int} = 5.40, p=0.005) and for (F_{int} = 6.63, p=0.002). Both the yield stress and the apparent viscosity values were lower at 25ºC, this difference being significant for all samples but for sample 1. The effect of temperature on flow index was significant but of low entity (Fig. 4). Differences among samples for the flow parameters were always higher at 5ºC. At this temperature, sample 1 exhibited lower initial resistance to flow, lower consistency and lower pseudoplasticity than the rest of samples.

Similar results to those obtained here for "natillas" have been reported for starch pastes by other authors. Recently, Nayouf et al [5] studied the rheological properties of crosslinked waxy corn starch and concluded that, except for the lower concentration

(2% starch) pastes, experimental data fitted well to the Herschel-Bulkley's model. Acquarone et al [6] also used this model to characterise the flow of waxy corn starch dispersions with added sucrose.

Conclusions

Though quantitatively different, all samples of "natillas", after eliminating thixotropy by shearing, showed shear-thinning properties with measurable initial resistance to flow, e.g., a plastic behaviour that fitted well to the Herschel-Bulkley model. Although the extent of the differences varied among samples, in general, time dependence, plasticity and consistency were lower and pseudoplasticity was slightly higher at the higher temperature (25 vs. 5ºC)

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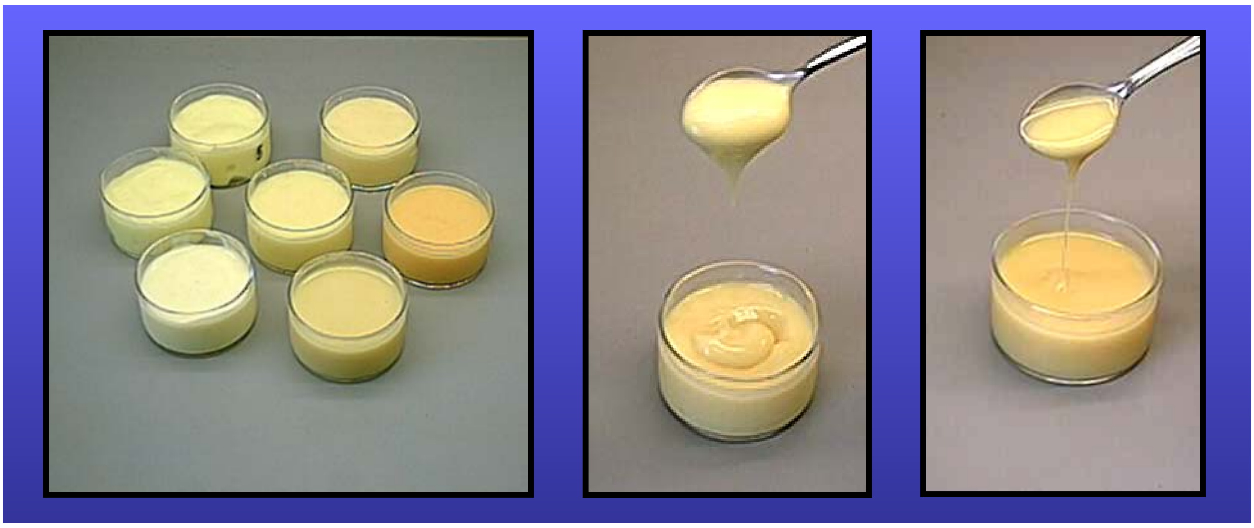

Figure 1. Samples of vanilla dairy dessert analysed.

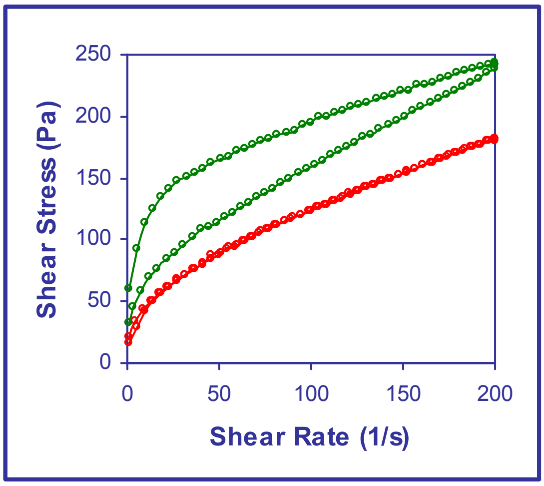

Figure 2. Hysteresis loop obtained at 5ºC for sample 4 without previous shearing (x) and after shearing at 300s^{-1} during 5 minutes (x).

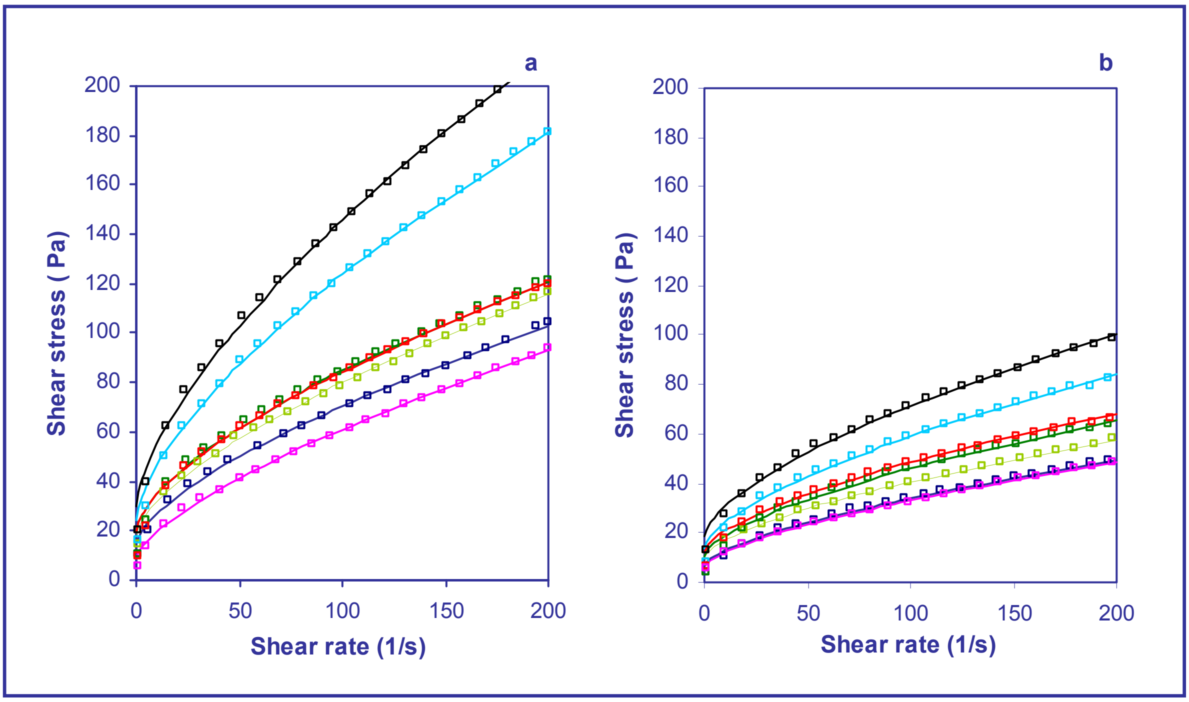

Figure 3. Steady-state flow curves obtained for dairy dessert samples at 5ºC (a) and 25ºC (b). Experimental values (∀) 1, (∀) 2, (∀) 3, (∀) 4, (∀) 5, (∀) 6, (∀) 72, and fits to Herschel-Bulkey model (—). Identification of samples in table 1

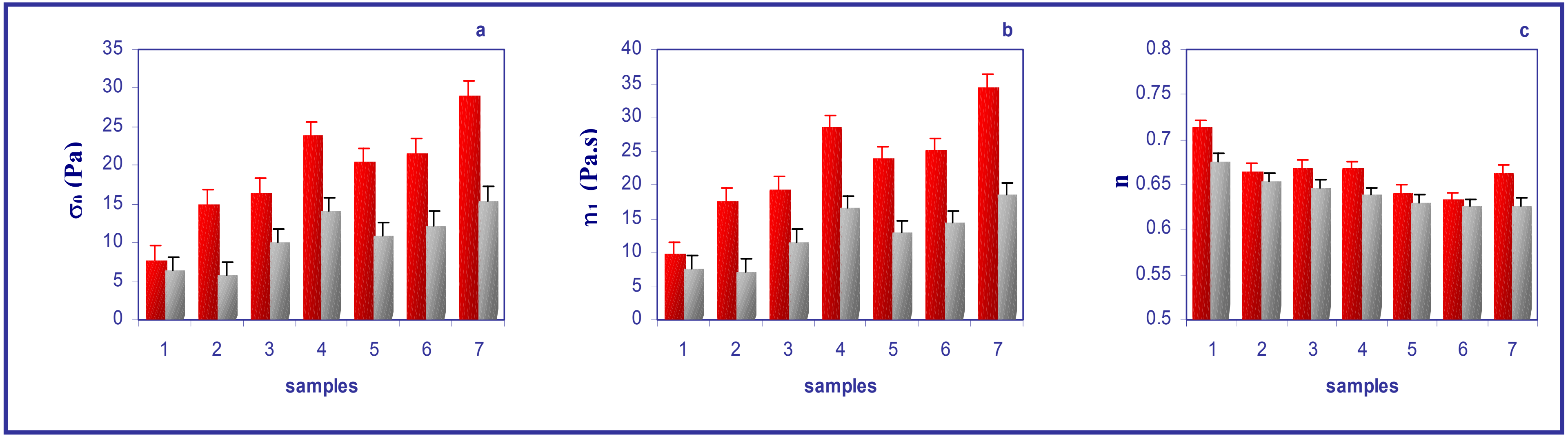

Figure 4. Values of Yield strees (a), apparent viscosity at 1 s^{-1}(b) and flow index (c) obtained for dairy dessert samples at 5ºC (a) and 25ºC (b). Identification of samples in table 1