EFFECT OF MILK FAT CONTENT ON THE FLOW BEHAVIOUR OF CUSTARD DESSERTS

A. Tárrega , L. González-Tomás and E. Costell
Laboratory of Physical and Sensory Properties
Instituto de Agroquímica y Tecnología de Alimentos (CSIC)
PO Box 73, 46100 Burjassot, Valencia (Spain)

INTRODUCTION

The "natillas", semisolid dairy dessert of wide consumption in Spain, are composed of milk, starch, hydrocolloids, sugars, colorants and aromas. Wide information can be found in the literature on the rheological behaviour of water-starch pastes (1,2) as well as on the effects produced on this behaviour by substituting milk instead of water in starch dispersions (3). However, only a few papers deal with the rheological characterisation of commercial dairy desserts (4), or their corresponding model systems (5). The diverse types and concentrations of starches present in the commercial products and the differences in milk fat content might be responsible in great part for the differences in rheological behaviour of these systems.

The objective of this study was to investigate the effect of milk fat content on the starch gelatinisation and on the flow behaviour of dairy custard desserts with different starch concentrations.

MATERIALS AND METHODS

Sample preparation

Six custard samples with fixed amounts of sucrose (8%), colorant Vegex NC 2c (CHR Hansen S.A.) (0.052%) and vanilla aroma 37548A (Lucta S.A.) (0.016%) were prepared varying in the concentration of modified waxy maize starch C*PolarTex® 06741 (Cerestar Ibérica, Spain) (2.5, 3.25, 4% w/w) and in the fat content of milk (skim milk with 0.1% fat and whole milk with 3.12% fat). Both skim milk and whole milk were prepared 24 h in advance by dissolving milk powder in deionised water.

Thermo-mechanical treatment

A Rapid Visco-Analyser (RVA) (Newport Scientific, Australia) was used to evaluate pasting properties of samples (Fig. 1). RVA Custard Power Pasting Method was applied as follows: each sample was stirred at 960 rpm for 10 s, while heated at 50ºC, and at 160 rpm for the rest of the process. Temperature was held at 50ºC up to 1 min. Then the samples were heated from 50ºC to 95ºC during 3 min 42 s, and the temperature held at 95ºC for 5 min. They were cooled down to 30ºC in 5 min and 48 s, and then held at 30ºC for 4.5 min. Viscosity and temperature data were recorded over time. Each analysis was done in duplicate.

Rheological measurements

After the thermo-mechanical process, samples were kept at 4-5 ºC for 24 hours. Then, the flow behaviour of each system was measured at 5 ±0.5ºC in a Controlled Stress Rheometer RS1 (Thermo Haake, Germany) (Fig.2), using parallel plates geometry of 6 cm diameter and 1mm gap. Samples were allowed to rest for 15 minutes before measurements were done and a fresh sample was loaded for each measurement. Samples flow was measured by recording shear stress values at increasing shear rates from 1 to 200 s^{-1} in 60 s and down in reverse sequence in the same time. Data from the upward segment of the shear cycle were fitted to Herschel-Bulkley model (Eq. 1) using the Rheowin Pro software. The yield stress (σ_0) value, used in the Herschel-Bulkley's model, was previously obtained by fitting the experimental data to the Casson model (Eq. 2) and calculating σ_0 value in the Casson plot and the apparent viscosity values were obtained with the expression (Eq. 3).

$$\sigma = \sigma_0 + K\dot{\gamma}^{n} \qquad \text{(Eq.1)}$$

$$\sigma^{0.5} = \sigma_0^{0.5} + K_c\dot{\gamma}^{0.5} \qquad \text{(Eq.2)}$$

$$\eta_{ap} = \sigma_0/\dot{\gamma} + K\dot{\gamma}^{n-1} \qquad \text{(Eq.3)}$$

Statistical analysis

The effects of starch concentration and milk type on the flow parameters were analysed by ANOVA including three factors with interactions. The Fisher test (α=0.05) was used to calculate the minimum significant difference. All calculations were carried out with the Statgraphics Plus 4.1 software.

RESULTS AND DISCUSSION

Viscosity-temperature profiles

All viscosity profiles of the studied systems showed a similar pattern. The viscosity increased during the heating period at constant temperature (95ºC), continued to increase during cooling and the profile finalized with a plateau region for samples with skim milk, while samples with whole milk showed a slightly decreasing trend at the last two minutes of processing (Fig. 3)

No differences in the swelling temperature (that at which consistency began to increase) were observed among samples with different milk fat content. The viscosity value at the end of heating period, the slope of the increase in viscosity during cooling and the final viscosity at the end of cooling period increased with starch concentration, due to an increase in the volumetric fraction of the starch granules in the dispersion. At the same starch concentration, all three parameters showed higher values for whole milk samples, which can be attributable to the higher viscosity of the dispersing phase.

Flow behaviour

Rheograms of custard dessert samples were recorded. All samples exhibited time dependent non-Newtonian flow (Fig. 4). Substitution of whole milk for skim milk in the studied samples originated an increase in the registered shear stress values and in the hysteresis loop area. This effect was higher for 3.25% starch samples than for 4% or 2.5% starch concentration samples.

Characterisation of the flow behaviour of samples was based on the experimental data obtained in the upward rheogram. Yield stress was calculated using the Casson model equation. Flow data were fitted to the Herschel-Bulkley model, obtaining R^2 values between 0.947 and 0.997. As expected, in both skim milk and whole milk starch dispersions the consistency coefficient (K) and the yield stress (σ_0) values increased with starch concentration while the flow index (n) values slightly decreased, thus indicating an increase in shear-thinning behaviour. At the same starch concentration, both K and σ_0 showed higher values for whole milk samples while n values were lower (Table 1).

A two-way ANOVA with interaction was used to study the combined effects of the dispersion medium (skim milk or whole milk) and the starch concentration (2.5, 3.25 and 4%) on the yield stress (σ_0), apparent viscosity at $1s^{-1}$ (η_1) and flow index (n) values. The corresponding binary interaction was significant ($\alpha \leq 0.05$) for the three parameters, indicating that the effect of substituting whole milk with skim milk on plasticity (σ_0 values), apparent viscosity (η_1 values) and pseudoplasticity (n values) was different, depending on starch concentration.

Apparent viscosity at $1s^{-1}$ was higher in whole milk model systems, the increment being relatively bigger at 3.25% starch concentration than at the other two starch concentrations (Fig. 5).

These results followed the same trend than those obtained by other authors in dispersions of native starches (3). They observed that the apparent viscosity of 6% wheat starch pastes at 2.2 s^{-1} increased by 15% using high fat (3 %) milk, as compared with using skim milk (0.2% fat), and concluded that besides the effect of milk on the increase in rigidity of the starch granules, the three-dimensional fat polymers contributed to the increase in apparent viscosity of starch milk pastes.

ACKNOWLEDGEMENTS

To MCyT of Spain for the financial support (Project AGL 2003-0052) and for the fellowship awarded to author Tárrega and to CHR Hansen S.A. and Lucta S. A. for providing free samples of colorant and aroma.

REFERENCES

1. Rosalina, I. & Bhattacharya, M., (2002). *Carbohydrate Polymers*, 48, 191–202.

2. Nayouf, M., Loisel, C., & Doublier, J. L. (2003). *Journal of Food Engineering*, 59, 209-219

3. Abu- Jdayil, B., Mohameed, H. & Eassa, A. (2004). *Journal of Food Engineering*, 64, 207-212.

4. Tárrega, A., Durán, L. & Costell, E. (2004). *International Dairy Journal*, 14, 345-353.

5. Depypere, F., Verbeken, D., Thas, O. & Dewettinck, K. (2003). *Food Hydrocolloids*, 17, 311-320.

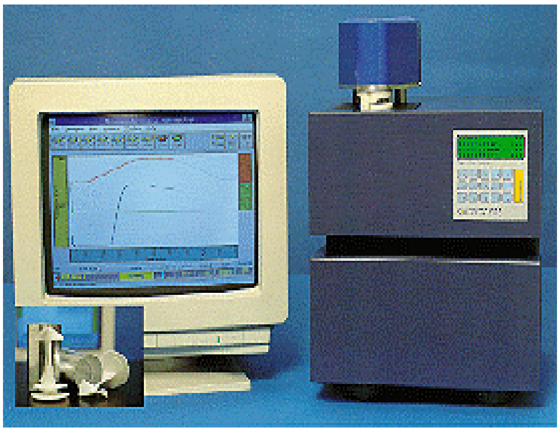

Figure 1. Rapid Visco-analyser (RVA)

Figure 2. Haake RS1 Rheometer

Starch (%)	Milk Type	σ_0 (Pa)	K ($Pa.s^n$)	n
2.50	skim milk	0.80	0.21	0.71
	whole milk	2.50	0.46	0.62
3.25	skim milk	2.91	0.62	0.66
	whole milk	10.47	1.55	0.56
4.00	skim milk	13.09	2.41	0.63
	whole milk	22.16	2.92	0.59

Table 1. Flow behaviour of custard dessert samples at 5ºC. Average values of Herschel-Bulkley parameters.

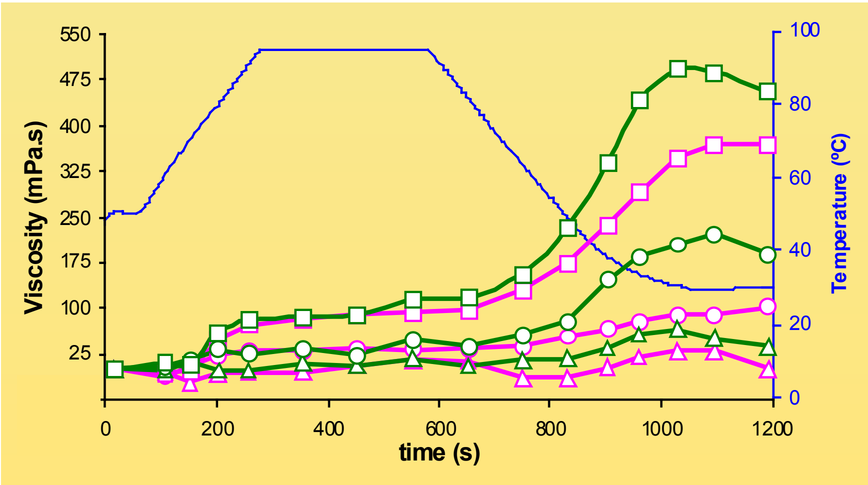

Figure 3. Viscosity variation during thermal process (—) of custard dessert samples with whole milk (▬) and skim milk (▬) for different starch concentrations: 2.5 (△), 3.25 (○)and 4% (□).

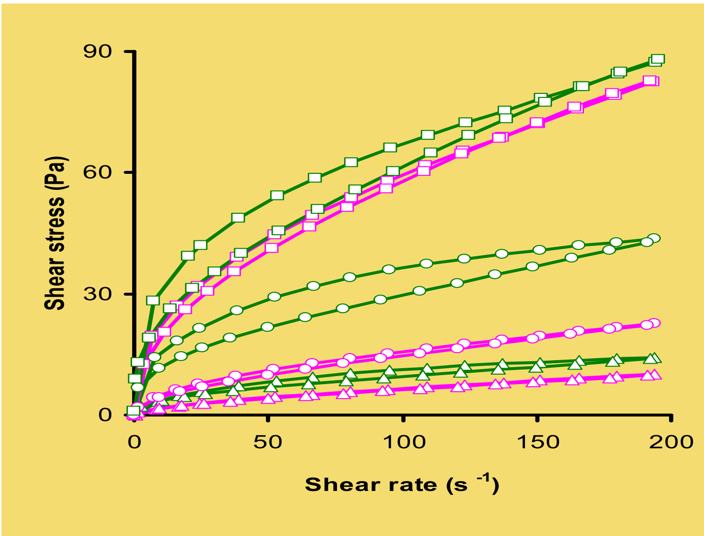

Figure 4. Flow curves registered for custard dessert samples with whole milk (▬) and skim milk (▬) for different starch concentrations: 2.5 (△), 3.25 (○) and 4% (□).

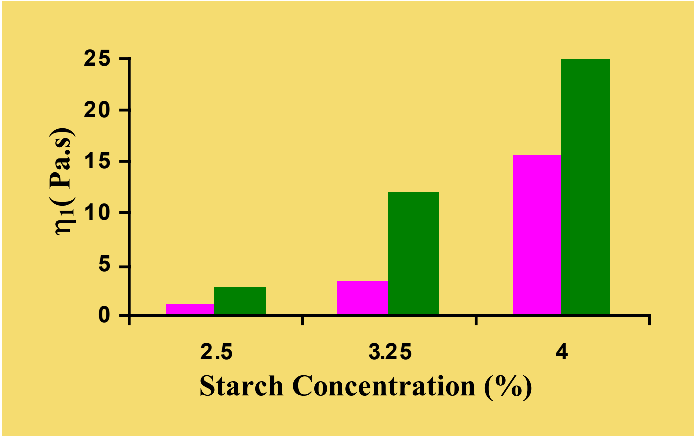

Figure 5. Values of apparent viscosity at $1s^{-1}$ of custard desserts with different starch concentration and with skim milk ( ) or whole milk ( ).

e-mail: atarrega@iata.csic.es, lmgt@iata.csic.es, ecostell@iata.csic.es.

IBEREO'04

ENCUENTRO IBÉRICO DE REOLOGIA

Beja (Portugal), 9-11 Septiembre 2004