ANNUAL TRANSACTIONS OF THE NORDIC RHEOLOGY SOCIETY, VOL. 17, 2009

The Effect of Buttermilk and Micro-Particulated Whey Proteins on the Rheological Properties of a Dairy Custard Model System

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ABSTRACT

Buttermilk (BM) and whey are bi-products of the dairy industry, and have stabilizing and emulsifying properties. Micro-particulated whey proteins (MWP) may act as fat replacers in foods.

Dairy-based custards added BM and MWP were investigated. Addition of MWP increased G′ significantly. Acceptable rheological properties in custards with essentially no fat were obtained.

INTRODUCTION

Dairy-based custards, in which starch is an important ingredient, are popular in a number of European countries including The Netherlands, Spain and France[1]. A typical example of this group of products is the Dutch product Vla, which has gained impressive popularity in The Netherlands. The product has been produced industrially by the Dutch dairy industry since the late 1940s[2]. Yearly consumption of 14 kg per person has been reported[3].

It has been shown that both the flavour and the oral texture of dairy custards are factors determining the amount of the products consumed[4]. Rheological properties of the custards may therefore be regarded as essential for customer evaluation of the overall quality of this type of product. Thixotropic and pseudoplastic flow behaviour combined with viscoelastic properties are regarded as typical for this type of rather weak gel[1]. In general, it is characteristic for these types of product that rheological behaviour is correlated to sensory properties[5,6].

Using sensory evaluation of various attributes connected to the mouthfeel of vanilla dairy custard desserts, de Wijk et al.[3] found that a sensory dimension expressed as rough-creamy/soft was mainly related to the fat content of the custard. High fat custards were evaluated as less rough and creamier than those with zero fat content.

Improving the sensory quality of fat reduced, or even fat free, dairy-based custards is a goal for development within this category of products. Replacement of fat with other components with the aim of obtaining acceptable rheological properties has been investigated in various fat reduced dairy products. Inulin and MWP have been investigated as fat-replacers in products such as yoghurt, ice cream, yoghurt ice cream, fresh cheese and starch-based dairy desserts[1,7-14]. However, we have not found scientific publications reporting the use of MWP as fat replacer in dairy based custards.

The production of MWP and factors influencing the properties of the whey protein aggregates has been described elsewhere[15,16].

Another bi-product from dairy processing, besides whey and whey proteins, is real buttermilk obtained from churning of butter. The potential for the replacement of whole milk or skimmed milk with sweet buttermilk in the formulation of dairy based custards was studied in this work.

Compared to skimmed milk, buttermilk contains a greater amount of phospholipids and specific proteins from the milk fat globule membrane[17-20] and this may increase the emulsifying capacity of solutions where buttermilk is used[21-23]. Lankveld[24] made Vla in which all the milk constituents in the formula were replaced with sweet buttermilk. The product obtained had an improved flavour and a somewhat higher viscosity, but was also less stable. Recent scientific documentation of the effect of replacement of all, or part of, the ordinary milk components with buttermilk in dairy-based custards does not seem to exist.

In this work, a dairy-based custard was made as a model system. A factorial designed experiment was carried out in which 0 w%, 50 w% and 100 w% of the skimmed milk was replaced with sweet buttermilk, and 0 w%, 2.5 w% and 5 w% MWP was added to the formula. The reference formula used whole milk, and all test samples produced were compared with samples where whole milk was used. A standard formula for production of Vla was used as the platform for the experiment. The formula was recalculated according to the composition of the various dairy based ingredients in order to make a fat-reduced dairy based custard.

MATERIALS AND METHODS

Experimental design

Dairy-based custard was made in a factorial experiment. The rheological properties of products based on skimmed milk were compared with products based on whole milk. In the skimmed milk products the skimmed milk was replaced with sweet buttermilk at two levels, and MWP was added at two levels according to the experimental design shown in Table 1.

The various productions were carried out in random order, and the whole experiment was repeated three times.

Dairy-based ingredients

Whole milk, skimmed milk and cream used in the various formulations were supplied by the commercial dairy company TINE Meieriet Øst Oslo. MWP was supplied by TINE R&D as a pilot plant experimental production. The powdered product contains approximately 60 w% protein in dry matter. The commercial dried sweet buttermilk was supplied by the dairy company TINE Midt-Norge Berkåk.

Manufacturing of the products

The various dry ingredients: stabiliser, starch, sugar, MWP and sweet buttermilk, were mixed with the liquid components in the formula: vanilla aroma, colour (β-carotene), water and skimmed milk or whole milk. After solubilisation of the dry components, the mixture was ultra high heat treated (UHT) at 143 ºC for 4 seconds in an APV UHT-pilot equipment before homogenisation at 15 bar at 74 ºC. The products were filled into cartons at 30-35 ºC and kept under refrigerated conditions (< 4 ºC) until examination.

Rheological measurements and instrumental set-up

A Physica UDS 200 rheometer was used in oscillation with a MP31 (25 mm diameter plate) measuring system. A Peltier plate was used for temperature control. The gap distance was 1 mm. The tests were performed at 5 ºC with an angular frequency of 10 rad/s. Strain was increased logarithmically from 0.01% to 500%, and then reduced logarithmically from 500% to 0.01% over a total test time of 670 sec. The instrument operated in direct strain oscillation mode (DSO) during the tests.

Table 1. Design of the factorial experiment including 2 levels of skimmed milk, 2 levels of sweet buttermilk for the replacement of skimmed milk, and 2 levels of MWP.
The chemical composition of the samples (w% protein, w% fat, w% total solids).

w% Skimmed milk	**w% Sweet buttermilk**	**w% MWP**	**w% Protein**	**w% Total solids**	**w% Fat**
100	0	0	2.9	17.7	0.9
100	0	2.5	4.0	19.6	0.9
100	0	5.0	5.3	21.6	0.9
50	50	0	2.7	17.1	0.9
50	50	2.5	4.0	19.7	0.9
50	50	5.0	5.2	21.7	0.9
0	100	0	2.6	16.9	0.6
0	100	2.5	3.8	19.0	0.6
0	100	5.0	5.1	21.7	0.6
Whole milk (reference)	**0**	**0**	**2.6**	**24.1**	**3.4**

Table 2. Results from the statistical analysis of the various rheological responses. P-values (p) are marked as + = $p < 0.05$, ++ = $p < 0.01$, +++ = $p < 0.001$. Non- significant levels are marked with -. The same letter represents no significant difference, while different letters shows a significant difference. For replacement of skimmed milk with sweet buttermilk, 0 = 100 w% skimmed milk, 50 = 50 w% skimmed milk and 50 w% buttermilk, 100 = 100 w% buttermilk.

Rheological parameter	Experimental factor							
	Mixture of milk				Addition of MWP in w%			
	p	0	50	100	P	0	2.5	5.0
Initial storage modulus, G'_1	+	a	a	b	+++	a	a	b
Crossover point	+	a	a	b	++	a	a	b
Final storage modulus, G'_4	++	a	a	b	-	-	-	-
$G'_1 – G'_4$ (Thixotrophy)	-	-	-	-	+++	a	a	b

Statistical analysis

Minitab 15 (Minitab Inc., Pennsylvania, USA) was used for the calculation of variance and significant differences in the material. The General Linear Model including both main and interaction effects was used. However, the interactions were not significant for any responses, hence this effect was excluded from the final analysis. Significant differences were ranked by means of Tukey's least significant difference method.

RESULTS

The rheological results were extracted by analysis of data as shown in Fig. 1. The elastic modulus, represented by the storage modulus, G′, was recorded at the points 1, 2 and 4 for the different recipes tested.

The results from the tests are summarized in Fig. 2 showing the variation in G′ for the varying recipes tested. The error bars represent ±1 standard deviation.

In one of the repetitions of the experiment, all samples were analysed for w% protein, w% fat and w% total solids. The composition of the samples is presented in Table 1.

Statistical analysis of the measurements of the various rheological responses (Table 2) show that replacement of all the skimmed milk with sweet buttermilk had a significant effect on the initial storage modulus (G'_1) ($p < 0.05$), crossover point ($p < 0.05$) and final storage modulus (G'_4) ($p < 0.01$).

Sweet buttermilk gave lower values for all these parameters than skimmed milk (Fig. 2). Replacement of 50 w% of the skimmed milk with sweet buttermilk had no significant effect on the observed rheological parameters. The thixotrophic behaviour was not influenced by the replacement of skimmed milk with sweet buttermilk at any level.

Table 2 also shows a rather strong effect of addition of 5 w% MWP on initial storage modulus ($p < 0.001$), crossover point ($p < 0.01$) and G′-change ($G'_1 - G'_4$) which represents thixotrophy ($p < 0.001$). No significant effect was observed by adding 2.5 w% MWP. MWP had no significant effect on the final storage modulus regardless of amount of MWP added. Addition of 5 w% MWP gave higher values for all the parameters where a significant effect was observed (Fig. 2).

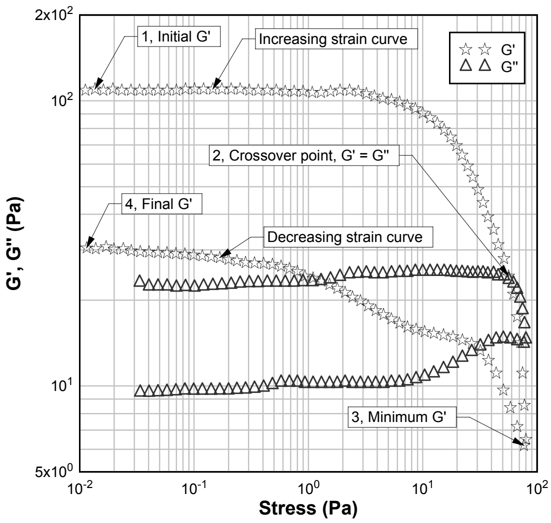

Figure 1. Typical test sequence starting at point 1, increasing the strain to point 2 and 3, then decreasing the strain to point 4.

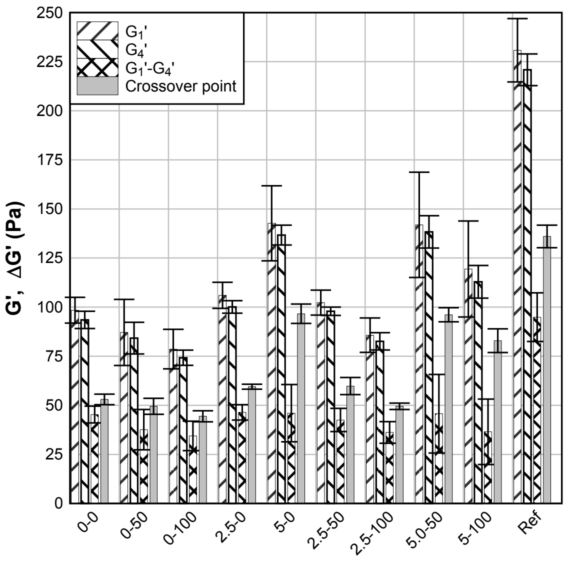

Figure 2. G_1', G_4', G_1'-G_4' and $G'_{Crossover}$ for the different recipes. The error bars indicate plus/minus 1 standard deviation.

No effects of interactions between the amount of sweet buttermilk and the amount of MWP were observed.

DISCUSSION

Fat-reduced products in the dairy dessert product segment have been on the agenda for research and product development for many years. The replacement of fat in dairy dessert products with other components like MWP has been investigated[11-14]. However, no publications appear to deal with the replacement of fat in dairy based custards by introducing MWP in the formula. Adding 5 w% MWP gave a significantly higher initial storage modulus (G'_1) and crossover point in the fat- reduced model custard system than 2.5 w% MWP addition and non addition of this type of fat replacer. Although the amount of MWP necessary to give a significant increase in these two rheological values was higher than the amount of fat replaced (Table 1), the effect was very clear and positive and sensory evaluation of consistency properties showed the product to be comparable with the full fat reference product. (Sensory profiling results not shown). Addition of more than 5 w% MWP than would probably have given rheological values even closer to those obtained for the reference full fat product. The final storage modulus (G'_4) was however not influenced significantly by the increased amount of MWP.

The observations of significantly higher differences for $G'_1 - G'_4$ in samples with 5 w% MWP were therefore expected, meaning that the thixotropy in these samples was less than for the other samples. This might be regarded as a somewhat negative observation since the decrease in viscosity following mechanical stress forced upon the product during serving and consumption would give the impression of a slightly thinner product. Whether the product containing 5 w% MWP would regain more of its elastic modulus after a longer period of storage has not been investigated, since all the observations in the experiments were done after a defined maximum time.

Replacement of all the skimmed milk with sweet buttermilk led to significantly lower values for the rheological parameters "Initial storage modulus", "Crossover point" and "Final storage modulus" but not "Thixotrophy". The influenced parameters all showed lower values when all the skimmed milk was replaced with sweet buttermilk. Replacement of 50 w% of the skimmed milk with sweet buttermilk also gave a reduction in the observed values, but this reduction was not significant. A reduction of the mentioned values may be considered at as negatively for the rheological properties of this type of product.

Only one previous publication has been found dealing with the possibility of replacing milk constituents in a similar product with buttermilk[24]. In this work, Lankveld obtained a product with a higher viscosity. His results are however not directly comparable to the results presented here but may indicate an improvement of the consistency of the product after addition of buttermilk. This is not supported by our rheological measurements.

One of the possible positive effects of using buttermilk in the formula for a dairy-based custard could be related to an improvement in the stability of the emulsion[21-23]. Lankeveld[24] did however observe a somewhat reduced stability of the dairy based custard where milk constituents were replaced by buttermilk. The results presented in this paper give no direct information concerning the stability of the product or of the emulsifying capacity of the formulas, but the observation of thixotropic properties may give an indication of a property related to the stability of the product. The replacement of skimmed milk with sweet buttermilk did not influence the thixotropic properties measured in this experiment

CONCLUSIONS

In a model system for dairy-based custards, acceptable rheological parameters as "Initial storage modulus" and "Crossover point" were obtained in fat-reduced samples by replacing fat with 5% MWP.

Samples added 5% MWP showed however a lower thixotrophy.

Replacement of all the skimmed milk in the formula with sweet buttermilk gave reduced values for the observations of "Initial storage modulus", "Crossover point" and "Final storage modulus", while the thixotropic behavior of the products was not influenced by the sweet buttermilk.

Dairy based custard with 0.6-0.9% fat could be produced with rheological properties comparable to those in samples with 3.4% fat, although the values in the fat reduced samples was somewhat lower that in the "full fat" samples.

ACKNOWLEDGMENTS

The authors would like to thank Mr. O.K. Steinbekken, TINE BA, R&D Department, for valuable supervision and assistance during production of samples. Thanks are also due to TINE BA, R&D Department for sensory evaluation of the products. The technical assistance supported by the technical staff at the Department of Chemistry, Biotechnology and Food Science is greatly acknowledged.

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