Rheological Properties of a Selection of Common Norwegian Food Products

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ABSTRACT

Common Norwegian dairy products involving mysost were tested by oscillation technique in amplitude sweep mode. Viscoelastic properties of dairy products were evaluated based on eight parameters defined from the rheograms.

INTRODUCTION

Fermented dairy products have three main categories: cheese, yoghurt and fermented liquid milk (kefir, sour milk products etc.).

Traditionally cheese is manufactured from milk by adding coagulants (rennin or chymosin) and starter cultures. After curd formation, the curd is cut into small cubes. Then the curd is drained and the whey is removed. From curd casein is recovered and then subjected to fermentation[1, 2]. In Norway the whey is utilized as so callled whey cheese named "mysost" or "prim".

Yoghurt can be considered as a curdled milk product, made of pasteurized milk, by adding starter culture (*Streptococcus thermophilus*) and other ingredients if needed (flavor, sweetener, colorant, stabilizer, gum). The milk is then then incubated at 40 °C for 3 hours, cooled to 15-20 °C, and added live culture. Other forms of yoghurt as frozen or stirred yoghurt and yoghurt drinks are also available and popular products. Fat content, solids-not-fat, flavors and appearance are widely varied in different countries [3,4].

Sour milk products are the most basic fermented liquid milk products. Many variants are made of low fat content, which is pasteurized and added starter culture (*Bifidobacterium bifidum, Lactobacillus acidophilus, Bifidobacterium lactiscultur, Lactobacillus rhamnosus GG etc.*). Then the milk is fermented to pH 4.65-4.55, and cooled to 4-6 °C. Sour milk products may not contain any stabilizer or gum and are considered a health food due to live cultures[3, 5].

Kefir is a fermented liquid milk product characterized by the small amount of alcohol. It contains its inoculant, the kefir grains. The processing technology consists of two main parts: preparation of mother kefir and preparation of drinkable kefir. For the first part pasteurized milk is added to the kefir grains. After 24 hours floating grains are filtered out from the fermented milk. They are then saved for next fermentation, while fermented milk is mixed with fresh, pasteurized milk and fermented for 1-3 days, then cooled, stored and distributed [3].

Mysost ("whey cheese") is a typical Norwegian dairy product, made by concentration of whey by long-time heat treatment, without any fermentation or incubation. Whey proteins are coagulated and a high concentration of carbohydrates is developed. It is more a sort of caramel.

Dairy products represent a wide range of rheological phenomena such as Newtonian behaviors (milk, cultured milk), plastic (kefir, sour milk products), thixotropic and viscoelastic semi-solid (cream cheese, Norwegian prim) and viscoelastic solid (butter, cheese) properties[6,7].

The aim of the present study was to investigate the viscoelastic properties of common Norwegian dairy products by oscillatory technique.

MATERIALS AND METHODS

Characterization of nine different store bought dairy products was performed. Two types of cream cheeses (Philadelphia light: 1PL, Philadelphia original: 2PO) and three types of mysost (whey cheese): prim letago: 3PrL, prim original: 3PrO, prim lettere: 4PrLe and four different sour milk products (skim milk: 6TM, cultured milk: 7Cu, yoghurt: 8Yo, kefir: 9Ke) were investigated.

A Physica UDS 200 (Paar Physica, Physica Messtechnik GmBH, Germany) rheometer was used for measurements. A plate and plate measurement system (MP 31/P plate, 50 mm in diameter and TEK 180 plate measuring cell) with 1.00 mm measuring gap was used. Oscillatory measurements were carried out at 4 °C in amplitude sweep mode (controlled strain), increasing the strain value from 0.01 to 200%, at 10 s^{-1} angular velocity, using five replicates per sample. The rheometer operated in direct strain oscillation mode (DSO) during the tests.

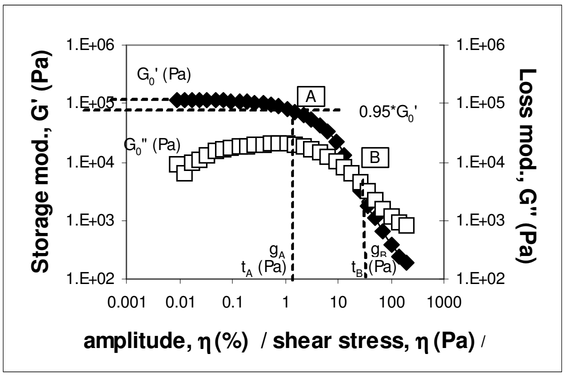

Figure 1. Oscillatory viscogram and its main parameters.

Based on the oscillatory viscograms (Fig. 1) eight different parameters were determined: initial storage modulus (G'_0, Pa), initial loss modulus (G''_0, Pa); end of linear viscoelastic range which is the strain at storage modulus decrease to 95% of its initial value (γ_A, %), strength which is the shear stress at storage modulus decrease to 95% of its initial value (τ_A, Pa), cross over point (B, Pa), the strain (γ_B, %), the shear stress (τ_B, Pa), and the complex viscosity (η^*_B, Pa.s) at cross over point.

RESULTS AND DISCUSSION

All of the dairy products investigated in this experiment proved to be viscoelastic as indicated by high G' and G" values. Samples with lower levels of viscosity than 1 Pa.s and Newtonian liquids were not measurable by this method.

Viscograms of cream cheeses (Fig. 2), Norwegian prims (Fig. 3) and cultured milk products (Fig. 4) could be sorted into characteristic groups based on its characteristic shapes and range of storage and loss modulus.

Storage modulus (G') of cheese creams was constant, while loss modulus (G") slightly increased at low shear rate values and behind a certain shear stress value both of them decreased sharply then reached the cross over point (B). (Fig. 2)

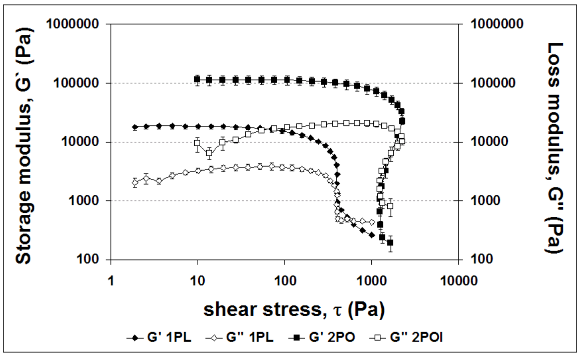

Figure 2. Oscillatory viscograms of cheese creams.

Rheograms of whey cheese creams were similar to rheograms of cheese creams. However storage and loss modulus values decreased to a lesser extent compared to cheese creams. Both of them slightly increased behind crossover point. (Fig. 3)

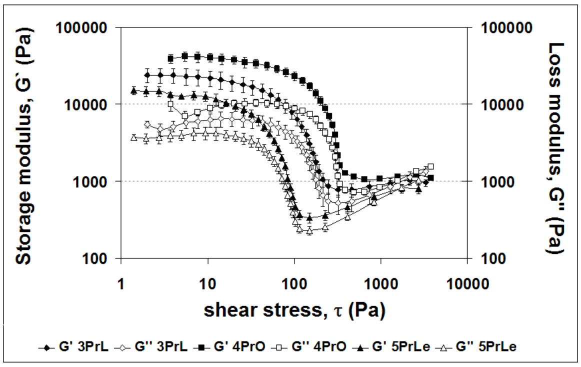

Figure 3. Oscillatory viscograms of whey cheese creams.

Oscillatory viscograms of sour milk products (kefir, yoghurt, and skim milk products) proved to be similar in shape. Both the storage and loss modulus was constant at low shear rate values, afterward showed marked decrease and reached cross over point. (Fig. 4)

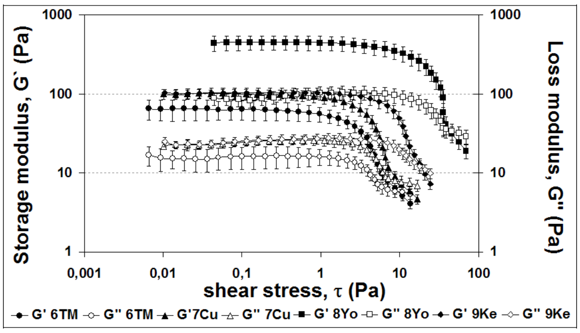

Figure 4. Oscillatory viscograms of sour milk products.

Initial storage and loss modulus of samples tested are shown in Table 1. Storage modulus was higher than loss modulus in case of all samples, indicating that dairy products are viscoelastic solids at low shear stress values. G_0' was in different range of order for different types of products. Highest value was observed in case of normal fat content cheese cream (2PO) in range of 10^5Pa. Low fat content cheese cream and whey cheese creams had lesser extent of elasticity, as indicated by the their G' values in range of 10^4 Pa. Yoghurt also showed marked elastic property (G' at 440 Pa), kefir and cultured milk (both of them made without any gum) had the same value around 100 Pa, and Tinemelk had the lowest in range of 10^1 Pa.

Table 1. Initial storage modulus G' (Pa) and loss modulus G" (Pa) and their standard deviation of dairy products.

product	G_0' [Pa]	G_0" [Pa]	G'_0/ G''_0
1PL	17880 ±2393	2036 ±134	8.8
2PO	112820 ±24478	9342 ±259	12.1
3PrL	23833 ±4895	5486 ±580	4.3
4PrO	38800 ±5243	9940 ±495	3.9
5PrLe	15000 ±1732	3706 ±362	4.0
6TM	65 ±18.5	17 ±4.5	3.8
7Cu	99 ±14.7	22 ±2.1	4.5
8Yo	440 ±93.6	88 ±15	5.0
9Ke	102 ±11.7	25 ±3.4	4.1

Loss modulus, G", was highest for prim original and Philadelphia original indicating strong viscous properties of these products.

Philadelphia light and other whey cheese creams showed lower values in range of 10^3 Pa. Liquid sour milk products showed very low loss modulus values, in range of 10^2 Pa.

Ratio of G'_0 and G''_0 was similar for all of the samples tested around 4, except for cheese creams which showed twice higher values, indicating their stronger elastic behaviour caused by additives used during processing technology.

End of linear viscoelastic region -shear stress and strain values at 95% of initial storage modulus- are shown in Table 2.

Table 2. End of linear viscoelastic range (γ_A, %), and strength (τ_A, Pa) of dairy products.

product	τ_A [%]	γ_A, [Pa]
1PL	0.30	52
2PO	0.19	206
3PrL	0.038	7.8
4PrO	0.053	20
5PrLe	0.038	5.0
6TM	0.60	0.38
7Cu	0.85	0.81
8Yo	0.60	2.61
9Ke	2.36	2.37

γ_A refers to the maximum deformation that the material can stand without irreversible structural changes, so the stronger structure is indicated by higher value[6]. The highest value was observed in case of kefir (2.36%), followed by liquid sour milk products with values between 0.6-0.85%, probably due to lack of artificial stabilizers.

Cheese creams showed lower values (0.19-0.30%) than sour milk products, and the lowest values were observed for whey cheese creams in range of 10^{-2}% which may be caused by that the thick texture of these products developed by high concentration of carbohydrates and can be easily disrupted.

τ_A is a parameter for strength and showed highest values in case of cheese creams (52-206 Pa) followed by whey cheese creams (5.0-20), yoghurt and kefir (2.37-2.61 Pa), and cultured milk products (0.38-0.81 Pa) at the end.

Crossover point (Table 3) of G' and G" curves indicates the turning point between viscoelastic solid and liquid. As expected, highest G' and G" values were observed in case of cheese creams and whey cheese creams (529- 6431 Pa), and these values were in a lower range of order as initial G' and G" values. Strain value at cross over point was similar for all products (72-142 %) except for normal fat content cheese cream (2PO) which showed a low value at 18 Pa. However, shear stress values at crossover point were different in case of cheese products (525-1730 Pa) and in case of cultured milk products (8.6-47 Pa).

Table 3. Crossover point of dairy products. *(B: G' and G" value at crossover point [Pa], γ_B: strain at crossover point [%], τ_B shear stress at crossover point [Pa]).*

product	B [Pa]	γ_B [%]	τ_B [Pa]
1PL	529	72	525
2PO	6431	18	1670
3PrL	939	102	1286
4PrO	1136	102	1563
5PrLe	800	143	1730
6TM	5.2	142	11
7Cu	9.0	72	8.6
8Yo	31	101	47
9Ke	13	101	18

In summary, dairy products developed by different processing technologies and by using several cultures and additives could be characterized by the method used. All of the samples proved to be viscoelastic, showing marked elasticity.

CONCLUSION

Objective oscillatory measurements of dairy products provided extensive qualification of physical- and textural properties and performed with high reproducibility.

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