Rheological characterization of non-fat yoghurt

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ABSTRACT

A rheological method was developed for measuring the stability of yoghurts. Increasing stress was applied in order to simulate harsh transportation conditions and elevated temperatures were applied to simulate insufficient temperature control.

Non-fat yoghurts stabilized with 0.25% GENU® texturizer type YA-100 and 0.40% gelatine SG-720N 250 Bloom type A, respectively were characterized. The zero shear viscosity was higher for the pectin-stabilized (25,000 Pas) than for the gelatine-stabilized yoghurt (8,100 Pas).

The pectin-stabilized yoghurt could be exposed to higher forces (5.2–5.6 Pa) than the gelatine-stabilized yoghurt (2.0–2.3 Pa) before structure break-down. Despite the difference in critical stress the yoghurts break down at the same critical deformation.

When increasing the temperature from 10 to 40°C, the elastic and viscous moduli decrease. For the yoghurt stabilized with gelatine, the texture changed from being predominantly elastic to being more viscous at 26.2°C, whereas for the pectin-stabilized yoghurt, there was no crossover.

INTRODUCTION

Traditionally, yoghurt is added different stabilizers, the most commonly used being gelatine and modified starch[1].

For various reasons and concerns there is an increasing desire to replace gelatine with other hydrocolloids, preferably of green label origin. A pectin has therefore been developed which is especially well-suited for stabilization of non-fat stirred yoghurt, i.e. GENU® texturizer type YA-100.

The market for yoghurt has been steadily increasing, especially in countries with hot climates, e.g. in Latin America. It is well-known that the infrastructure and thus distribution chains in Latin America is not as developed as in Western Europe. Combined with the fact that the climate in Latin America is characterized by significantly higher temperatures than Europe, this calls for products that are stable towards elevated temperatures. Also there has been a trend within Europe for consolidation of the dairy industries, i.e. fewer and larger companies. This has led to longer transportation times and therefore the need for products that are more robust towards mechanical stress. It was therefore decided to develop a method for characterization of the robustness of yoghurts with regard to temperature and stress.

METHODS

Non-fat stirred yoghurts were prepared in the pilot plant. To commercial skim milk (MD Foods) was added 3% medium heat skim milk powder (MD Foods), and 6% sugar. Two different stabilizers were added: 0.40% gelatine (SG-720N 250 Bloom type A from Extraco) and 0.25% GENU® texturizer type YA-100 from Copenhagen Pectin. The yoghurt milk was heated to

70°C, homogenized at 100 bars and pasteurized at 90°C for 10 minutes. The pasteurized milk was then cooled to the fermentation temperature, i.e. 42°C and inoculated with 2% commercial yoghurt. At pH 4.2, the yoghurt was stirred and the fermentation stopped by cooling to 5°C.

Rheological measurements were conducted on a Haake Controlled Stress rheometer of the type RheoStress RS100, with a cup/bob geometry Z20. The temperature was 10°C except for the temperature sweep.

Viscosity was measured by recording steady state flow curves increasing the stress from 0.01 to 20 Pa, with a maximum waiting time of 30 sec. Furthermore for the pectin-stabilized yoghurt the complex viscosity was measured running a frequency sweep from 0.1 to 10 Hz.

The elastic modulus was measured by a stress sweep increasing the stress from 0.1 to 446 Pa at a frequency of 1 Hz. The linear elastic modulus was determined by extrapolating the elastic modulus to zero stress.

At a certain stress the gel structure breaks down. The yield point was determined by steady state flow curves and by stress sweeps, respectively.

From the steady state flow curves, log-log plots of strain vs. stress were generated, with the intercept of the two lines giving the critical stress, $\tau_{crit.flow}$, and the corresponding critical strain, $\gamma_{crit.flow}$, see Fig. 1.

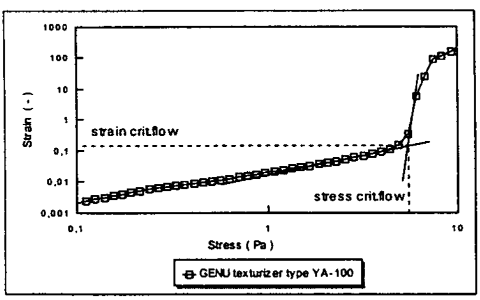

Figure 1. Critical stress and strain determined by steady state flow curve.

From the stress sweeps, log-log plots of the elastic modulus, G' vs. stress or strain were generated, with the intercept of the two lines giving the critical stress, $\tau_{crit.osc}$, and the corresponding critical strain, $\gamma_{crit.osc}$.

A temperature sweep was conducted with increasing/decreasing temperature from 10 to 40°C (0.5°C/min), a stress of 1 Pa and a frequency of 1 Hz.

RESULTS AND DISCUSSION

Viscosity

The yoghurt containing 0.25% GENU® texturizer type YA-100 had a zero shear viscosity of 25,000 Pas whereas the 0.40% gelatine-stabilized yoghurt had a zero shear viscosity of 8,100 Pas, see Fig. 2. A sensory analysis confirmed that the gelatine-stabilized yoghurt had a significantly lower viscosity compared to the pectin-stabilized yoghurt.

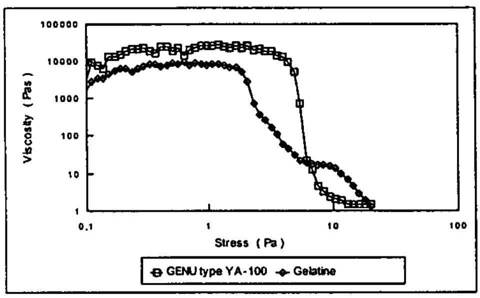

Figure 2. Steady state flow curves.

A frequency sweep (0.1-10 Hz) confirmed that the complex viscosity decreased with increasing frequency. This indicates that the oscillatory measurements were performed in the Power law region. Comparison between the viscosity and the complex viscosity reveals that the Cox-Merz rule is not obeyed[2]. This indicates that structure is irreversibly broken down in the viscosity measurements. The viscosity is lower than the complex viscosity, indicating that yoghurt is a weak gel, see Fig. 3. Therefore, a steady state flow curve may not be the optimal method for characterization of yoghurt.

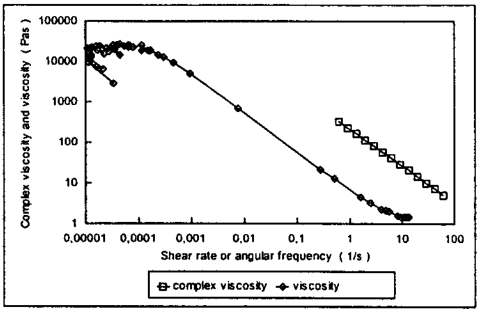

Figure 3. Comparison of complex viscosity vs. angular frequency and viscosity vs. shear rate for GENU® texturizer type YA-100.

Elastic modulus

The pectin-stabilized yoghurt was characterized by a higher linear elastic modulus, G'_{lin} than the gelatine-stabilized yoghurt. G'_{lin} for the yoghurt stabilized with 0.25% GENU® texturizer type YA-100 was approx. 200 Pa, whereas G'_{lin} for the yoghurt containing 0.40% gelatine SG-720N 250 Bloom type A was approx. 100 Pa, see Fig. 4. Furthermore it was observed that the pectin-stabilized sample maintained its elasticity over a wide stress range whereas this was not the case for the gelatine-stabilized sample.

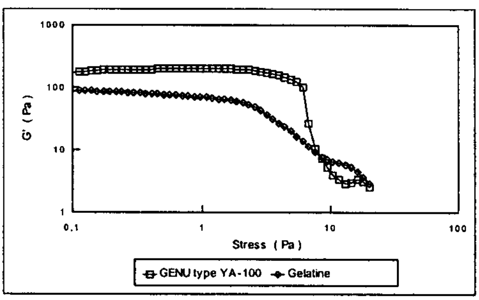

Figure 4. G' vs. stress.

Yield point

A yield point determined by a steady state flow curve indicated that the same strain (0.10) can be applied to both yoghurts. It is, however, necessary to apply more stress to the pectin-stabilized yoghurt than to the yoghurt with gelatine, ie $\tau_{crit.flow}$ = 5.2 Pa vs. 2.0 Pa to obtain the same deformation, see Table 1. This indicates that we can deform both yoghurts to the same extent but more force is needed to break the gel structure in the pectin-stabilized yoghurt.

Table 1. Critical stress and strain from flow curves and oscillatory measurements.

Stabilizer type	$\tau_{crit.flow}$	$\gamma_{crit.flow}$	$\tau_{crit.osc}$	$\gamma_{crit.osc}$
	Pa	-	Pa	-
	Flow curve		Oscillation	
Gelatine	2.0	0.11	2.3	0.026
GENU type YA-100	5.2	0.10	5.6	0.034

From the oscillatory measurement a similar observation was made, see Table 1. $\tau_{crit.osc}$ for the yoghurt containing 0.25% GENU® texturizer type YA-100 was 5.6 Pa whereas for the yoghurt with 0.40% gelatine SG-720N 250 Bloom type A the value was 2.3 Pa. $\tau_{crit.osc}$ was slightly higher than $\tau_{crit.flow}$. This was, in turn, expected since the stress sweep is based on a non-destructive measurement.

For yoghurt stabilized with gelatine $\gamma_{crit.osc}$ was 0.026 whereas for the pectin-stabilized yoghurt the value was 0.034. A comparison of $\gamma_{crit.osc}$ and $\gamma_{crit.flow}$ showed that the critical strain in the oscillatory method was very low compared to the flow method. This is ascribed to the fact that with the non-destructive measurement, the yoghurt is able to retain the original network structure whereas with the flow method a partial breakdown is observed.

Temperature sweep

For all measurements, the elastic and viscous moduli, G' and G'' decrease with increasing temperature. G' was higher than G'' in the whole temperature range for the pectin-stabilized yoghurt. For the gelatine-stabilized yoghurt, in turn, a G'-G'' crossover was exhibited at 26.2°C indicating that the gelatine-based yoghurt becomes predominantly viscous at this temperature, see Fig. 5 and 6.

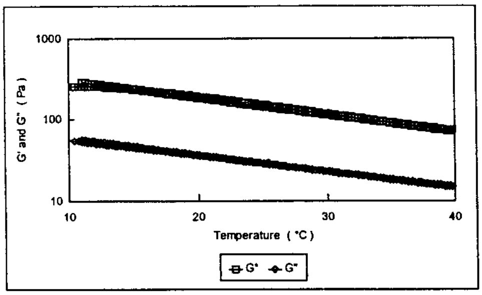

Figure 5. G' and G'' vs. temperature (10 - 40°C with an up/down gradient) for yoghurt stabilized with 0.25% GENU® texturizer type YA-100.

It was observed that the yoghurt containing pectin fully regained its original texture, see Fig. 5. The gelatine-stabilized yoghurt, in turn, regained part of its structure only, but even at 10°C the viscous modulus was still dominating, see Fig. 6.

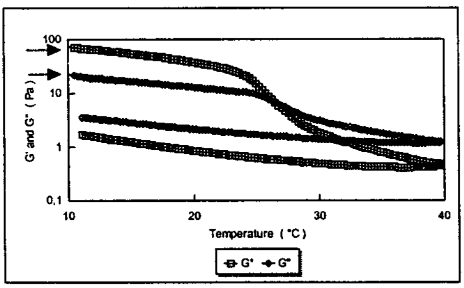

Figure 6. G' and G'' vs. temperature (10 - 40°C with an up/down gradient) for yoghurt stabilized with 0.40% gelatine SG-720N 250 Bloom type A. The arrows indicate starting point of gradient.

CONCLUSION

0.25% GENU® texturizer type YA-100 seems to be superior to 0.40% gelatine SG-720N 250 Bloom type A for stabilization of non-fat stirred yoghurts. In the study described the pectin-stabilized yoghurt was more robust towards stress compared to the gelatine-stabilized yoghurt. Furthermore the pectin-stabilized yoghurt was more stable towards elevated temperatures. An interesting observation was also that the pectin-stabilized yoghurt did not exhibit a crossover of G' and G'' when increasing the temperature from 10 to 40°C whereas the gelatine-stabilized yoghurt had a crossover point of 26.2°C.

The study will be extended to include different pectin and gelatine types and different use levels.

REFERENCES

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