The missing link – sensory and rheology study of low fat stirred yoghurt

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ABSTRACT

Twenty low fat stirred yoghurt samples were prepared with varying compositions. They were evaluated by both sensory and rheological methods in order to investigate the link between rheological and sensory properties.

Good correlations were found between sensory attributes and rheological parameters, using simple models.

INTRODUCTION

The general market trend towards healthier products has created a demand for hydrocolloids which compensate for the lack of fat in low fat stirred yoghurt.

Since it is very expensive to train and maintain a sensory panel, there is a need for mechanical measurements that can characterize yoghurt samples in the industry, in order to get a less expensive tool for screening different compositions. Several studies indicate limited correlations between sensory attributes and rheological measurements[1-6]. There is however some disagreement regarding which methods to use. The shear rates ranging from relatively low values 2-10s^{-1}, up to relatively high shear rates from 100 – 241s^{-1}, are all stated to correlate to mouth thickness, oral viscosity or oral perception[1,2,3,5,6]. But also elastic parameters as G' seem to correlate to the oral viscosity and mouth coating attributes[4,5]. The general observation is that it is difficult to find good mechanical methods that describe or predict sensory attributes of low fat stirred yoghurt. The aim of this study is to find correlations between rheological parameters and sensory attributes. It covers both rheological and sensory evaluation of low fat stirred yoghurt prepared with different combinations of texturizers, like pectin, starches and gelatine. The combination results in large differences in texture corresponding to yoghurt seen in both the European and US markets.

MATERIALS AND METHODS

<u>Yoghurt formulation</u>:

Formulation: 2% skimmed milk powder (3.9% protein in yoghurt), 7% sugar, strawberry flavour, one yoghurt contains 3.5% milk fat while the rest contain 0.5% milk fat. The study consists of 20 yoghurt productions with various combinations of texturizers, Table 1.

Starch: Thermtex (modified starch, M) or Novation (native starch, N) both from National Starch). Gelatin: PBG 55 (230 bloom strength) from PB Gelatin, and GENU® pectin types A and B.

<u>Yoghurt process:</u>

Mix dry ingredients and milk, homogenize at 50°C/50 bar, pasteurize at 85°C/15 min., ferment at 42°C, fill at 20°C, store at 5°C.

Table 1. Composition of yoghurt samples, PA = Pectin A, PB = Pectin B, MS = modified starch, NS = native starch, and GT = gelatin.

0.2% PA
0.3% PA
0.2% PA + 1.25% MS
0.2% PA + 1.75% MS
0.2% PA + 1.25% MS + 0.5% GT
0.2% PB
0.2% PB + 1.25% NS
0.2% PB + 1.75% NS
1.25% MS
1.75% MS
1.25% NS
0.75% MS + 0.5% GT
1.25% MS + 0.5% GT (repeated 4 times)
1.75% MS + 0.5% GT
0.5% GT
0.5% fat
3.5% fat

Sensory characterizations:

The sensory evaluation was performed at the Sensory Science Dept., University of Copenhagen. The panel consisted of 10 persons and they agreed on 32 Sensory Attributes that described the samples, the scale used: 0-15 (none-a lot), we selected two important texture parameters for this study, see Table 2. Evaluation temp.: 13°C.

Table 2. Description of the sensory evaluation of OralViscosity and SharpnessEdge.

Sensory evaluation	
OralViscosity	Orally evaluated Viscosity
SharpnessEdge	Sharpness of edge when scooping out the yoghurt

Rheology measurements:

Anton Paar MCR301 Rheometer, equipped with cuvette (CC17) or vane FL1000 geometry. Texture Analyzer SMS TAXT2 equipped with back-extrusion geometry with a 40 mm disc (A/BE40).

Different rheological methods were used to characterize the samples covering non-destructive tests e.g. low strain oscillation and destructive tests e.g. back extrusion on Texture Analyzer, see Table 3.

Table 3. Rheological sequences.

Flow-behaviour	
Time sweep	Time= 5min (10points), frequency=1Hz, strain=0.2%.
Shear sweep	20 points log distributed, shear rate 75 or 300s^{-1}
Rebuild	35 points log distributed, frequency=1Hz, strain=0.2%.
Yield stress	
CC17	40 points, duration 0.125...0.25 s log distributed. Shear rate=0.2s^{-1}
Vane	40 points, duration 0.125...0.25 s log distributed. Shear rate=1.2s^{-1}
Creep and creep-recovery	
Creep	20 points, stress=0.25Pa or stress applied at 85% of G'max.
recovery	20 points log distributed, stress=0Pa
Strain sweep	
Time sweep	time=300s, frequency=1Hz, strain=0,2 %
Strain sweep	frequency=1Hz, strain=0,1...100 % log distributed.
Consistency measurement	
Back extrusion	100 g yoghurt is placed in the beaker, left undisturbed for 1h. Pre and test speed=0.5mm/s, distance=30mm, post speed=10mm/s

Flow-behaviour: Where the time dependent viscosity is monitored at constant shear rate followed by a rebuild section to determine how much structure is regained after shear is stopped.

Yield stress: The maximum stress measured at constant low shear rate, determined with both CC17 and FL1000 geometries.

Creep and creep-recovery test: The strain measured as a function of time, when subjected to low stress (0.25Pa) within the viscoelastic linear region.

Strain sweep: The elastic and viscous moduli monitored as a function of strain until rupture.

TAXT2 back extrusion: Force as a function of time when moving at constant speed.

The rheological measurement and sensory evaluation were done on the same day and evaluated or measured at 13°C.

Modelling data

MODDE v.8.0 and Simca v.12 from Umetrics were used for data treatment.

RESULTS

The results are looked upon as a triangle, going from composition to rheology as one element, from composition to sensory as another element and finally the link between sensory and rheology is evaluated as illustrated in Fig. 1.

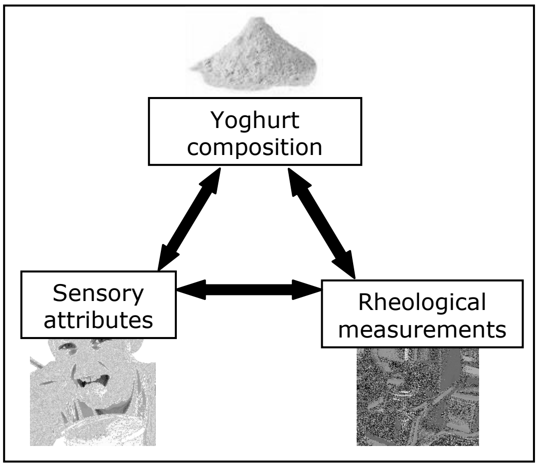

Figure 1. Triangle evaluation set-up for the experiment.

Rheological data

Rheological parameters were extracted from the rheological measurements (data not shown). Several of the parameters were highly correlated, as illustrated e.g. for the viscosity at different times or shear rates see Fig. 2.

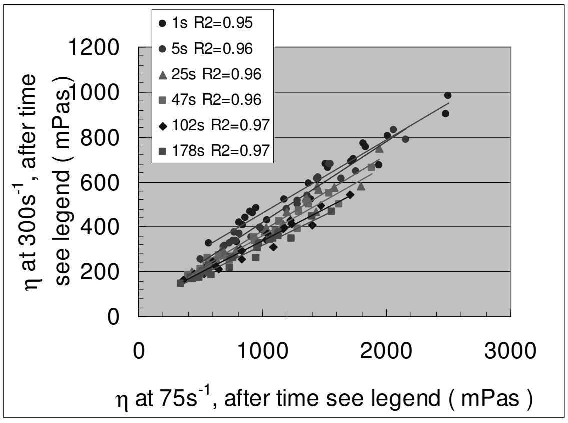

Figure 2. Viscosity of yoghurt samples measured at different time scales, see legend, at a shear rate of 75 or 300 s^{-1}.

The PCA based on the rheological parameters resulted in the score plot shown in Fig. 3. The samples span the window but appear to group in two areas in the PC2 direction which is due to the presence of gelatin in the composition.

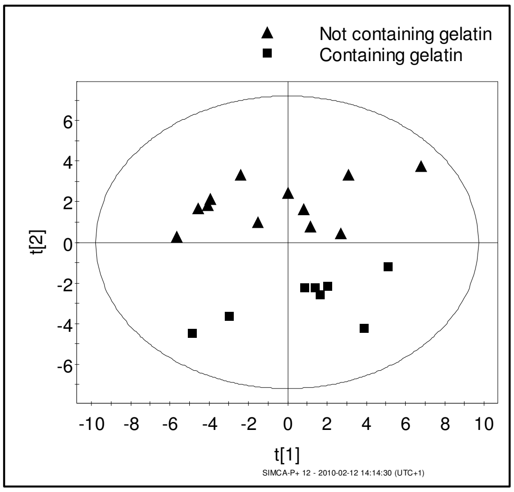

Figure 3. PCA of the rheological parameters extracted from the measurements together with the samples measured.

In order to simplify the data analysis the composition was narrowed down to the most important factors; gelatin, pectin (not differentiating between types A and B, and starch (not differentiating between modified or native). Using these factors in a DOE (design of experiment) showed that some of the rheological parameters could be predicted quite well. For instance Firmness predicted from pectin, starch and gelatin, Fig. 4. The model is able to explain 91% of the variation in data and that all factors are significant and positive, Fig. 5.

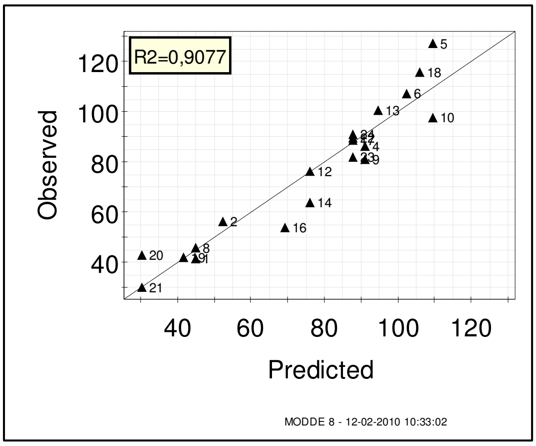

Figure 4. The observed Firmness versus the predicted Firmness from a model based on the composition (pectin, starch and gelatin).

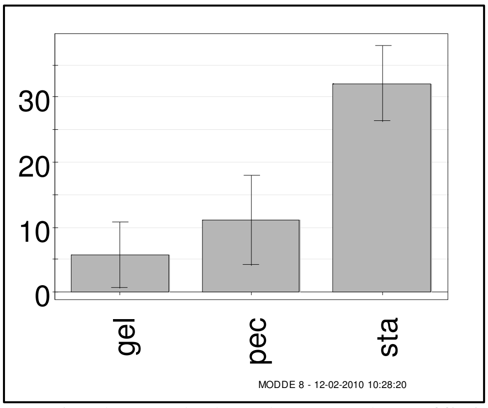

Figure 5. The scaled and centred coefficients for gelatin (gel), pectin (pec) and starch (sta). The model explains 91% of the variance in data.

The rheological parameters deemed most important to predict the selected sensory attributes are listed in Table 4. Both models are able to explain 91% of the variance in data based on starch, gelatin and pectin. Pectin, however, is an insignificant factor in the model predicting Calculated Yield Strain.

Table 4. Models predicting Firmness and Calculated Yield Strain based on the composition of yoghurt, pectin [P], starch [S] and gelatin [G]. Bold marks insignificant factor.

	Model	R2
Firmness	74.1*[P]+36.8*[S]+22.9*[G]+30.3	0.91
Cal.Yield Strain	**0.025*[P]**+0.018*[S]+0.027*[G] +0.023	0.91

Sensory data

Although the panel agreed on 32 sensory attributes for characterizing the yoghurt samples, many of the attributes were correlated. We selected OralViscosity and SharpnessEdge as they describe the initial textural properties, and are some of the important sensory attributes describing texture properties based on interviews with customers and our internal sensory panel.

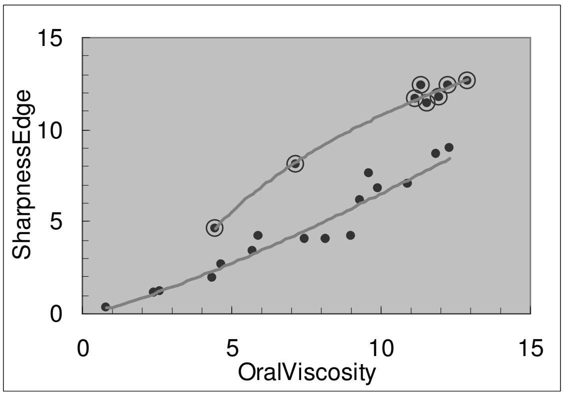

Figure 6. SharpnessEdge versus OralVisvosity. The samples containing gelatin are marked with a circle.

It is evident that gelatin containing samples behave differently than samples not containing gelatin, Fig. 6. For a given OralViscosity the visually determined SharpnessEdge is higher when samples contain gelatin. This is further supported when data is modelled in MODDE showing that all factors are significant, Fig. 7, but the gelatin affects SharpnessEdge much more than OralViscosity. The models explain 97% of the variance in data.

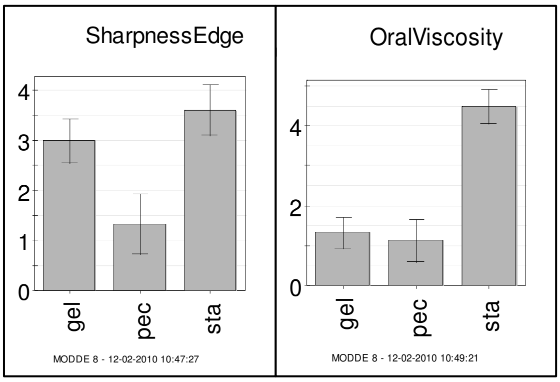

Figure 7. The scaled and centred co-efficients for SharpnessEdge (left Plot) and OralViscosity (right plot). Factors are pectin (pec), gelatin (gel) and starch (sta).

The models are listed in Table 5 together with the sensory attributes evaluated after the yoghurt sample has been stirred 10 times with a spoon and re-evaluated. It is seen that the effect of gelatin becomes small and insignificant after stirring the sample, indicating that the structure provided by gelatin is broken down after mechanical stirring of the sample. Also the other factors lose structure but not to the same extent.

Table 5. Models predicting OralViscosity, SharpnessEdge before and after stirring the yoghurt based on the composition of yoghurt, pectin [P], starch [S] and gelatin [G]. Bold marks an insignificant factor.

	Model	R2
SharpnessEdge	8.9*[P]+4.1*[S]+12.0*[G]-0.07	0.97
OralViscosity	7.5*[P]+5.1*[S]+5.3*[G]+1.9	0.97
SharpnessEdge After stirring	5.5*[P]+2.9*[S]**–0.6*[G]**+0.4	0.92
OralViscosity After stirring	7.5*[P]+3.9*[S]**+1.5*[G]+**1.9	0.91

Link between sensory and rheology

The main focus was to link the mechanical measurements to the sensory attributes that described the texture, and we selected SharpnessEdge and OralViscosity for this study.

OralViscosity could be predicted from several rheological parameters. We found, however, the best correlation to Firmness, which was able to predict OralViscosity by explaining 95% of the variance in data, Fig. 8.

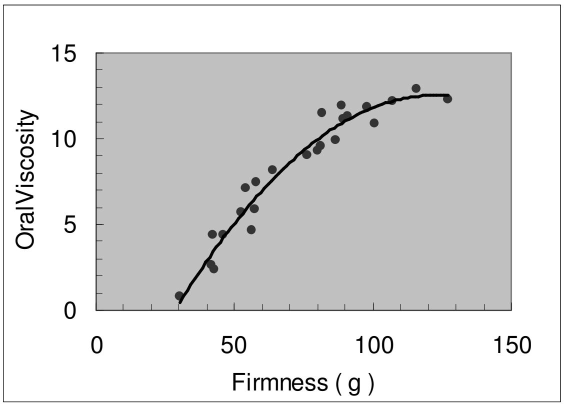

Figure 8. OralViscosity as a function of Firmness of stirred yoghurt.

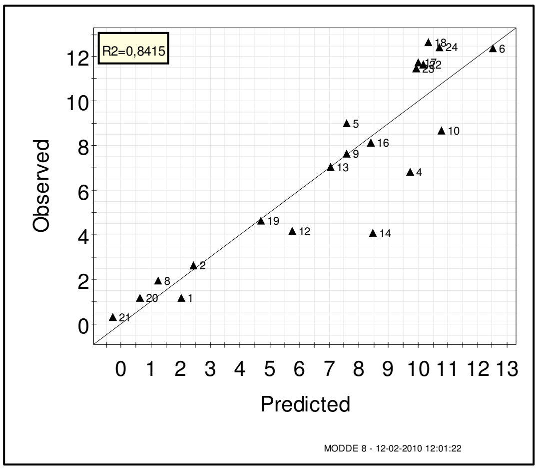

Figure 9. Observed SharpnessEdge versus SharpnessEdge predicted from Calculated Yield Strain, the model can explain 84% of the variance in data.

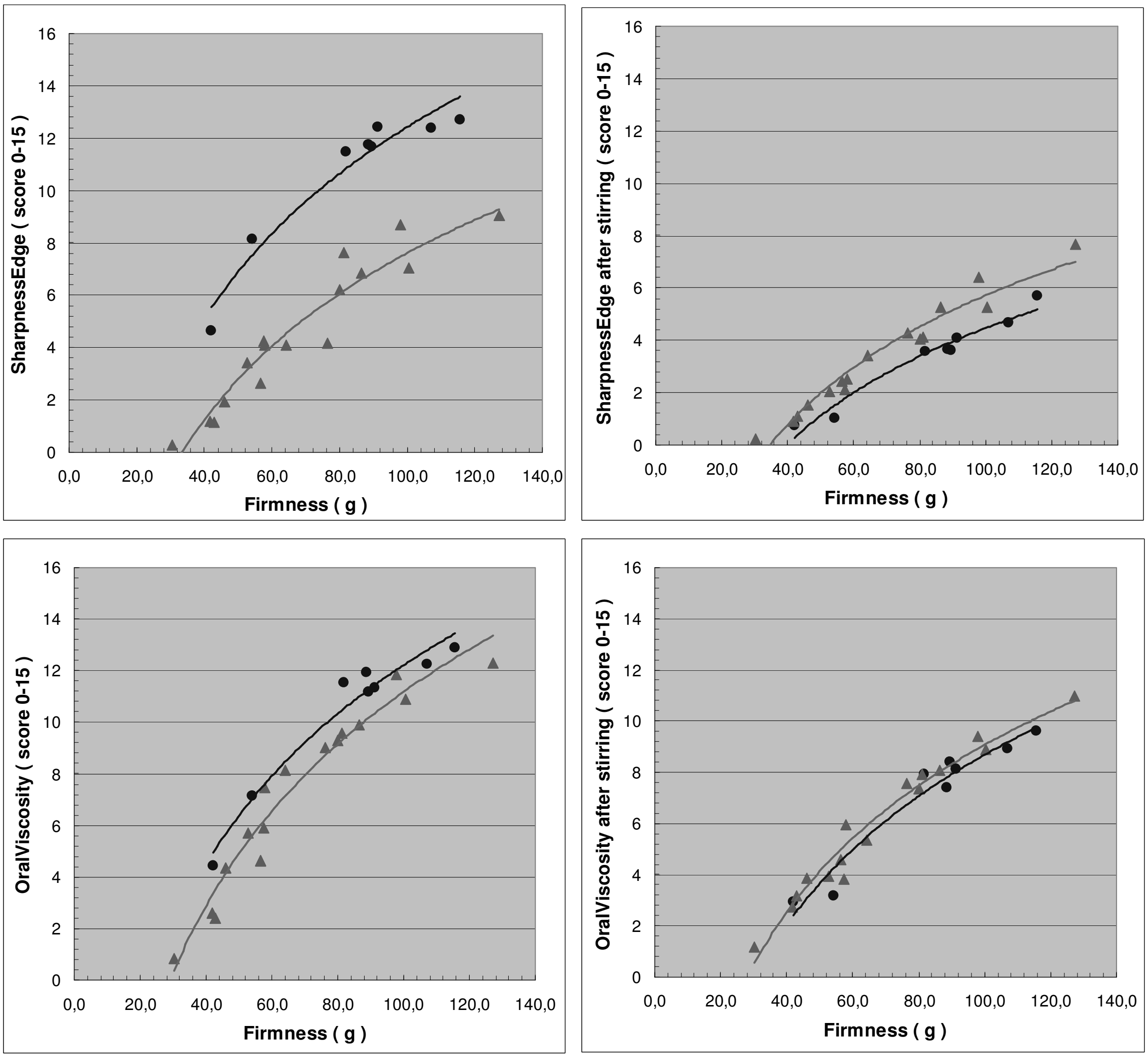

Figure 10. SharpnessEdge and OralViscosity before and after stirring as a function of Firmness. Gelatin containing samples are marked with circles, whereas yoghurt not containing gelatin are marked with triangles.

Also SharpnessEdge could be predicted from the rheological parameters. Firmness, however, could not predict the attribute alone as the gelatin containing samples clearly differentiated from the other samples. Calculated Yield Strain, however, accounted for the different behaviour of gelatin and was able to predict SharpnessEdge quite well explaining 84% of the variation in data.

It is obvious that gelatin in a yoghurt provides a structure observed as SharpnessEdge but not detected in the same matter when OralViscosity is sensorially evaluated. This difference is not detected by measuring Firmness, which corresponds more to OralViscosity than SharpnessEdge. When the structure provided by gelatin is broken down during shear (by stirring the sample 10 times with a spoon) the observed SharpnessEdge and OralViscosity are reduced for all samples. However, SharpnessEdge becomes even lower than would be expected when compared to Firmness when the sample contains gelatin. This is also seen for OralViscosity, but to a lesser extent.

The best correlations found in this study between the selected sensory attributes and rheological parameters are listed in Table 6.

Table 6. Models predicting OralViscosity, SharpnessEdge before and after stirring the yoghurt based on the rheology. F= Firmness and CYS = Calculated Yield Strain. R2 indicates the goodness of fit.

	Model	R2
SharpnessEdge	255.6 [CYS]-5.15	0.84
OralViscosity	$-0.0014[F]^2 + 0.35[F] - 8.92$	0.96
SharpnessEdge After stirring	$0.071[F] - 1.93$	0.90
OralViscosity After stirring	$-0.00057[F]^2 + 0.19[F] - 4.05$	0.97

CONCLUSION

For low fat stirred yoghurt samples evaluated in this study a good correlation is found between Firmness measured on Texture Analyzer and OralViscosity. A model based on Firmness is capable of predicting OralViscosity with very high R^2 (0.97) independent of composition.

Composition of the yoghurt samples proved important for SharpnessEdge, particularly with samples containing gelatin. Evenso, it was possible to establish a model to predict SharpnessEdge based on Calculated Yield Strain with an R^2 of 0.84.

ACKNOWLEDGMENTS

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