

**SIK-rapport NR 787
2009**

**Systematic and objective definitions of texture
modified foods in nutritional treatments**

Final report

*Margareta Bülow, Olle Ekberg, Susanne Ekman, Daniel Johansson,
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Summary

Among elderly people suffering from swallowing disorders, i.e, dysphagia and chewing problems, an intake of normal food and liquids may be impossible. Texture modified foods and thickened liquids could be a necessary option for a safe food intake and efficient nutrition. However, in the management of several dysphagic patients a texture modified diet is necessary, but a huge problem is the lack of well defined characteristics of the different modified textures.

This project has been multidisciplinary with participants from Swedish food industry, dieticians and dysphagia speech and language pathologists. In collaboration a guide to classify and describe different texture modified consistencies had been developed. This guide was based on Swedish experiences, and documents from the British Dietetic Association and the Royal College of Speech and Language Therapists.

The aim of this project was to define and describe different modified textures, develop a system of objective, quantitative and well defined guidelines for modified textures used in the management of dysphagic persons. By performing rheological measurements and by sensory and radiologic analyses we have taken the first step in this complicated area. However, from this study it was not possible to conclude upon any generalised recommendations regarding modified textures for patients suffering from moderate/severe pharyngeal dysfunction.

Six soups with different viscosities and nine solids (pâtés, jellied products, timbales a sherbet) have been the samples analysed regarding sensory and rheological characteristics. The analyses were performed at 8°C and/or 60°C.

According to the sensory analysis, the solid products were classified into three predefined groups. Pâtés were mostly differentiated from timbales and jellied products regarding chewing resistance and perceived particles. Timbales were perceived as more porous, wobbly, creamy and melting than pâtés. Jellied products had a lower degree of perceived chewing resistance and firmness but higher degree of melting and creaminess compared to timbales and pâtés. The results from the rheological analysis indicated that the solid products could be separated regarding G' ; pâtés (11000-20000 Pa), timbales (15000-17000 Pa) and jellied products (800-1600 Pa).

The liquids were classified into the two predefined groups according to the sensory analysis. The thickened liquids, consisting of puree and a starch based thickener, were perceived as more melting, easier to swallow and creamy compared to thin liquids. The thin liquids were on the other hand perceived to have a lower degree of chewing resistance, firmness, porosity and wobbly consistence. The results from the rheological analyses implied that the consistence index (K) could be used to distinguish between the classes of low (1.0-3.3 Pasⁿ) and high viscosity liquids (7.6-12.0 Pasⁿ).

The textures described in the Swedish guide could be characterised objectively by a combination of sensory evaluation and rheology measurements. However, there were significant product variations within the categories regarding some sensory attributes and all rheological measurements could not differentiate the analysed products.

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Background

A good nutritional status is of importance for health and for avoidance of illness. For elderly people suffering from swallowing disorders, i.e dysphagia, and/or chewing problems avoidance of specific food and liquid are common (Rothenberg et al, 2007; Ekberg et al, 2002) resulting in an insufficient nutrition status. A texture modified diet may be necessary for dysphagic persons to be able to maintain a sufficient oral intake (Elmståhl et al, 1999; Germain et al, 2006). However, in the management of dysphagic patients, the lack of well defined characteristics of the different modified textures are a problem, and could make the communication between different health care professionals almost impossible. To perform objective measurements of thickened liquids is a complex task (Mark et al, 2007; Steele et al, 2003; Garcia et al 2005; Germain et al, 2006). Comparisons of different research studies within the field are difficult since there is a lack of international consensus language for texture modified consistencies. Addition of sauce has been thought to make swallowing easier. In a review of Penman and Thomson (2008) it was found that there were a wide variation in the recommended modifications, and also numerous definitions of different textures. Diets varied from two to five categories of altered solids and liquid consistencies ranged from one to six grades. In a Swedish project (VINNOVA, 2007) a guide for texture modified food, was developed by dieticians and dysphagia speech and language pathologists in collaboration with the food company, *Findus AB*, specialized in texture modified diets. This guide is a first step towards better and consistent definitions of different consistencies in order to reduce actual pathophysiology and thereby establish a more safe and efficient swallow. The guide is based on different documents such as SLV, 2007 and SoS, 2000, results from a Swedish study (Stefanovic Andersson and Bülow, 2006) and from the British Dietetic Association and the Royal College of Speech and Language Therapists (www.bda.uk.com, 2003). However, there is still a lack of objective and clear definitions.

Aim

The aim of this project was to develop a system of objective, quantitative and well defined food textures needed to diagnose and treat individuals suffering from dysphagia by rheological measurements as well as sensory and videoradiologic analyses. The purpose of the videoradiographic study was to analyse how the different modified textures affect the physiology of the swallowing in dysphagic patients.

Methodology background

Sensory science

Sensory analyses are unique in using human beings as an objective measuring instrument. The test methods can be divided into two main groups, objective (analytical) and subjective (consumer) test. One of the analytical methods is quantitative descriptive analysis (QDA). In such test, a trained sensory panel develops objective descriptions of perceived sensory attributes of products, and thereby making it possible to discover quantitative differences between samples (Lawless and Heymann, 1998). Consumer tests are used to explore consumers' preferences. Subjects who represent the consumers in the target group describe their subjective impressions either in qualitative tests, e.g.

focus group discussions or in quantitative tests where commonly a hedonic scale is used (Lundgren, 1981).

Rheology

Rheology is the study of deformation and flow of materials and can describe the properties of materials ranging from liquids, viscous, to solids, elastic. However, almost all materials, especially true for foods, show behavior which places them between liquids and solids, having both viscous and elastic properties. These are called viscoelastic materials. Many materials also show a dependence on e.g. temperature, deformation rate and time in a range which is relevant for their uses. Methods usually used are viscometry, giving viscosity and how it depends on parameters such as temperature and rate, and oscillatory tests where the material's dependence on time, temperature and frequency can be studied (Mezger, 2006). Rheology can be used for evaluation of food texture by correlation to sensory data.

Video radiography

Video radiography is essential in the evaluation of swallowing and is used to visualize the anatomy and physiology of the oral cavity, pharynx and oesophagus during the entire swallowing sequence. During a videofluoroscopic examination it is possible to analyse how different textures affect the physiology of swallowing. The different tested consistencies are mixed with contrast medium as barium sulphate which makes the food radiopaque. The examination is recorded on videotape or stored on digital equipment. This allows every sequence of the entire swallowing process to be analysed in detail. Thereby it is possible to observe any dysfunction as for example penetration or aspiration of different textures into the airways before, during and after swallowing. Also a delayed initiation of the swallowing, incomplete swallowing movements or weakness in the swallowing muscles can be observed. Based on the actual swallowing dysfunction individual recommendations regarding modified textures and liquids are given, and if necessary sufficient therapeutic techniques are applied (Bülow, 2003; Bülow and Martin Harris, 2003; Smith Hammond et al, 2004).

Material and method

Texture guide

The texture guide, developed in collaboration between dieticians, dysphagia SLP:s and Findus constituted a basis for the project, table 1. Six different texture categories are described in the guide; each gives also examples of recommended foods and dishes.

Table 1. Descriptions of the consistencies in the texture guide

Regular or cut	Normal texture possibly cut into smaller pieces.	Whole or cut meat, whole fish, meat or sausage dishes, vegetables, potatoes and gravy. Fresh fruit or canned fruit with whipped cream or ice cream.
Coarse pâtés	Grainy, porous, soft texture with coarse grains, like a juicy and soft meatloaf. Easy to cut with fork.	Coarsely meat pâté or whole steamed fish, coarse vegetable pâté or well cooked vegetables, whole or pressed potatoes and gravy. Canned fruit in pieces with whipped cream or ice cream.
Timbales	Smooth, soft, short and uniform consistency like omelet. Can be eaten with a fork or spoon.	Meat or fish timbale/soufflé, vegetable timbale / puree, mashed potatoes or pressed potatoes and gravy. Fruit mousse with whipped cream or ice cream.

Jellied products	Soft and slippery food, like mousse. Can be eaten with fork or spoon.	Cold jellied meat or fish, vegetable puree or cold jellied vegetables, mashed potatoes and thick gravy. Jellied fruits with whipped cream or ice cream.
Liquids	Smooth and liquid consistency, as tomato soup. Fluid runs off the spoon. Can not be eaten with fork.	Enriched meat, fish or vegetable soup with whipped cream or creme fraiche. Fruit soup with whipped cream or ice cream.
Thickened liquids	Smooth and viscous, as sour cream. Fluid drops off the spoon. Can not be eaten with fork.	Enriched viscous meat, fish or vegetable soup with whipped cream or creme fraiche. Viscous fruit soup with whipped cream or ice cream.

Test Food Samples

A total number of 15 products, two or three products from five of the six categories, were analysed in the sensory and rheological part, table 2. The products chosen were the extremes ones regarding texture in each category. Four varieties of prefabricated foods, manufactured by Findus AB, Bjuv, Sweden and ingredients to nine other test food samples were delivered deep frozen and stored at -20°C until day of analysis. The fruit cocktail consisted of chopped canned fruit (Del Monte). In addition, mango sherbet (SIA Glass AB, Slöinge, Sweden) was analysed since sherbet often is used as a test food sample in video radiography. The soups, both the thickened and the unthickened ones, were prepared from concentrate (Findus AB) and a starch based thickener (Thick & Easy™, Hormel HealthLabs, GA, USA) was added to achieve the high viscosity soups. The meat and vegetable soups as well as the sauce (used in the radiological analysis) were heated to 80°C in a pan while stirred and then cooled to serving temperature. Jellied products were prepared from concentrates by adding 1.5% of gelatine (AB Törsleff & Co, Stockholm), heat to 80°C and cool to 8°C. Fruit products were analysed at 8°C, while meat and vegetable products were heated in a micro oven and analysed at 60°C. The chosen temperatures were based on the regulations that prepared food need to have a temperature of 60°C and cold foods 8°C for transport from caterers to units (SLV, 2006).

Table 2. Products evaluated in the sensory and rheological analyses*

CATEGORY	PRODUCT (AND ABBREVIATIONS)	DESCRIPTION / INGREDIENTS
Pâté	Fruit cocktail (FCc)	Chopped canned fruit
Pâté	Bean pâté (BPwsp)**	Pâté of minced green beans
Pâté	Beef pâté (BFPwsp)**	Pâté of minced beef meat
Timbale	Broccoli timbale (BRTwap)***	Soufflés of puréed broccoli
Timbale	Beef timbale (BFTwap)***	Soufflés of puréed beef
Jellied products	Fruit mousse (FM)	Fruit dessert set with gelatine
Jellied products	Jellied vegetables (JV)	Puréed broccoli set with gelatine
Jellied products	Jellied meat (JM)	Puréed beef set with gelatine
	Mango sherbet (MS)	Sherbet of mango
Low viscosity fluids	Soup of exotic fruit (SEF)	Soup of puréed fruit / Puréed fruit soup
Low viscosity fluids	Vegetable soup (VS)	Soup of puréed broccoli
Low viscosity fluids	Meat soup (MTS)	Soup of puréed beef
High viscosity fluids	Thickened soup of exotic fruit (TSEF)	Soup of puréed fruit, add. of thicken. agent
High viscosity fluids	Thickened vegetable soup (TVS)	Soup of puréed broccoli, add. of thicken. agent
High viscosity fluids	Thickened meat soup (TMTS)	Soup of puréed beef, add. of thicken. agent

*Beef pâté, Beef timbale and Meat soup were used in the video radiography analyse. **wsp = with small particles, ***wap = without any particles*

In the radiological analyses a selection of the above mentioned products were chosen, in order to cover all texture categories. The selection was necessary out of safety aspects for the participating patients. The tested consistencies were; jellied product, timbale without and with sauce (5 ml), pâté without and with sauce (5 ml), low and high viscosity fluids, and sherbet, all mixed with E-Z- HD barium sulfate (98% W/W). All tested products, except for the sherbet, were based on beef meat, and given 1 x 5 ml. The thin liquid consisted of water mixed with Mixobar HD barium sulfate, 40% W/W.

Sensory evaluation

The sensory evaluation was undertaken by a trained external analytical panel (SIK, Sweden) consisting of 8 judges, selected and trained according to ISO 8586-1993 (ISO, 1993). The analysis was preceded by four training sessions, two hours each. During the first training session, one product from each consistency category was presented to the panel in order to generate a set of texture and mouth feel attributes. During the following sessions, the judges were trained to fully understand the attributes and perform the assessments in the same way. The judges were also trained to evaluate intensities of the attributes by using a continuous 100 mm line-scale, labelled with “low intensity” at 10 mm and “high intensity” at 90 mm. The attributes and definitions are given in Table 3. They were further instructed to rinse their mouths with tap water and neutral wafers between the samples. The samples were coded with three digit random numbers and presented in a randomised order according to Latin square design.

Over three sessions, 45 minutes each, the judges were presented three replicates of each product. The intensity ratings were recorded and converted into numbers by a computerised system (FIZZ Biosystèmes, version 2.31E, France).

Table 3. Attributes related to texture and mouthfeel investigated in the sensory evaluation

ATTRIBUTE	DEFINITION
Chewing resistance	Feeling in oral cavity during chewing 0 = water. Low intensity = fluid, gel. High intensity = solid pâtés.
Grainy (meat products and jellied foods)	Particles in oral cavity 0 = water. Low intensity = small particles. High intensity = large particles
Particles	Particles in oral cavity 0 = water. Low intensity = small pieces. High intensity = large pieces
Porous	Fluffy, containing air 0 = water. Low intensity = fluid. High intensity = mousse
Wobbling	0 = water. Low intensity = fluid. High intensity = gel
Melting	The food becomes thin in the mouth, like gel and sorbet. 0 = water. Low intensity = fluid. High intensity = sorbet
Rough	The opposite to smooth Low intensity = smooth. High intensity = sandpaper
Creamy	Creamy feeling in the oral cavity
Firmness	The opposite to liquid 0 = water. Low intensity = watery. High intensity = firm
Ease of swallow	Degree to which the sample can be swallowed easily.
Homogeneous	Smooth, like a mixed soup Low intensity = pieces in the product. High intensity = gel
Particles	Amount of particles left in oral cavity after swallowing Low intensity = water. High intensity = meat product (pâté/timbale)

Rheological analyses - Solid products

Penetration test

Penetration test with a 4.8 mm cylindrical probe at a rate of 1 mm/min was used for the viscoelastic foods in an Instron 5542 (Instron Ltd, Canton, MA, USA).

Oscillatory test

Oscillatory tests were carried out in a Stresstech rheometer (Reologica Instruments, Lund, Sweden) with stress-controlled oscillation in plate-plate geometry with diameter 30 mm. A stress-sweep, with stress running from 0.02 to 500 Pa, at 1 Hz was made for detection of the linear viscoelastic region. Thereafter, a frequency sweep was performed between 0.1 to 10 Hz at a constant stress well within the linear viscoelastic region. This gives a mechanical spectrum showing the frequency dependence of the storage modulus (G'), the loss modulus (G'') and how viscous or elastic the material is (described by the phase angle δ , where 0° is an entirely elastic material and 90° an entirely viscous material). In addition to the measurements at 8°C and 60°C (see “test food samples”), measurements were performed at 37°C . Temperature sweeps were performed using a constant stress, within the linear viscoelastic region, and constant frequency, 1 Hz, between the serving temperature, 8 or 60°C , and 37°C . Measurements were done in three replicates.

Rheological analyses - liquid products

Shear viscosity

For each sample three flow curves at shear rates, $\dot{\gamma}$, $1\text{-}500\text{ s}^{-1}$ were produced using a Stresstech Rheometer (Reologica Instruments, Lund, Sweden) with a 25 mm diameter bob and cup geometry. The flow curves were fitted to the Power Law model ($\eta = K \dot{\gamma}^{n-1}$) giving the consistency index K and the shear thinning exponent n . K describes the thickness of the sample and n the degree of shear thinning, with $n < 1$ being shear thinning, $n = 1$ newtonian and $n > 1$ shear thickening. In addition to the measurements at 8°C and 60°C (see “test food samples”), measurements were performed at 37°C to mimic the temperature during swallowing.

Extensional viscosity

The extensional properties of the liquid products were measured in a Hyperbolic Contraction Flow device (Wikström and Bohlin, 1999; Stading and Bohlin, 2001) using an Instron 5542 (Instron Corporation, Canton, USA). The hyperbolic contraction flow device comprised a feeding piston, a cylindrical sample cell, and a contraction nozzle at the end. The sample cell with nozzle was attached between the moving head on the Instron and the bottom plate. When the head was moving downwards, the piston was pushed into the sample cell and the stress was recorded by a load cell. The sample cell had a temperature jacket which could be attached to a water bath with circulating water to control the temperature of the sample. The extensional properties of the samples were measured at five extension rates (0.05, 0.1, 0.5, 1 och 5 mm/s) with a feeding length for each rate to give a contraction flow for 2 seconds. The sample cell was loaded with a sufficient amount of sample to measure all five extension rates in one loading. The lowest extension rate was measured first and the transient stress was recorded. Before measuring at the next extension rate, the sample was allowed to relax for 2 minutes and the load was adjusted to zero. Exotic fruits soups were measured at 8°C and 37°C . Meat

and vegetables soups were only measured at 37°C due to instrumental limitations. Measurements were done in three replicates. Input data n and K from the Power law model for shear flow were used to subtract the shear stress contribution from the total measured stress. Power law models were fitted to curves with extensional viscosity plotted as a function of extension rate and the parameters K_{ext} and n_{ext} extracted.

Particle size measurement

The sizes of the particles in the liquid and jellied products were measured by sieving the particles. 100 g of each product was dissolved in 900 g water and was passed through a set of sieves. The sieves were arranged in downward decreasing mesh diameters (stacking sieves on top of one another in ascending degrees of coarseness). The sieves were mechanically vibrated for 15 minutes and water washed through the sieves. The weight of particles retained on each sieve was measured and converted into a percentage of the total sample. The maximal diameter of each particle was measured in this way.

Video radiography

Dysphagic subjects referred to the Radiologic suite for a therapeutic videoradiographic swallowing study have been enrolled in the study (Bülow, 2003; Bülow and Martin Harris, 2003).

The inclusion criterions were:

- problems in handling normal food and liquids
- be able to initiate a pharyngeal swallow

Exclusion criterions were:

- absent pharyngeal swallow

20 patients were included in the study, 11 men and 9 women, aged 20 – 92 years, mean age 75.7 years. Their diagnosis were classified as either neurology (CVA (10), dementia (1), Parkinson's disease (1), mentally retarded (1), status post op meningioma (1)) or others (colon cancer (1), aspiration pneumonia (1), dysphagia (1), globus (1), hypertension (1), COPD (1)).

Every patient had to perform 13 swallows. The radiological evaluations/examinations were documented on video or in a digital modality. The examination covered the oral cavity including the tongue, the pharynx, and the cervical esophagus. Patients were examined in a sitting position or (were) if necessary supine with elevated table head. *Oral transit time* was measured as start of preparation of bolus in the oral cavity until the bolus apex reached the faucial isthmus. *Pharyngeal transit time* was measured as the time between the bolus head passing into the pharynx and until the bolus tail passed into the cervical Esophagus. *Dissociation between oral and pharyngeal stage* was measured as start of the anterior movement of the hyoid bone. This was correlated to the position of the apex of the bolus. In normal patients the apex of the bolus should not pass beyond the facial isthmus more than 0.5 s before the hyoid starts to move anteriorely. This timing was given in msec. *Penetration/Aspiration* was classified as: “no”, “subepiglottic”, “supraglottic” or “tracheal”. *Pharyngeal Retention* was classified as: “no”, “mild”, “moderate” or “severe”.

Statistical analyses

Mean values were calculated for each sensory attribute, rheological measurement and radiological examination within each sample (Excel Microsoft Office, 2003). Two-way analysis of variance (ANOVA) with samples and assessors as fixed factors was performed on the sensory data (SYSTAT, version 10.0, SPSS Inc., Chicago). One-way ANOVA was performed on rheological data. Tukey's multiple comparison tests were performed for which effect significant differences were found in the ANOVAs. Differences were stated as significant when $p \leq 0.05$.

Sensory and rheological data were further evaluated with principal component analysis (PCA) and partial least square (PLS) (SIMCA-P+, version 11.0.0.0, Umetrics, Sweden). Averaged data, for all products together and for liquid and solid products respectively, were used. PCA was undertaken to visualise the variation in sensory and rheological data.

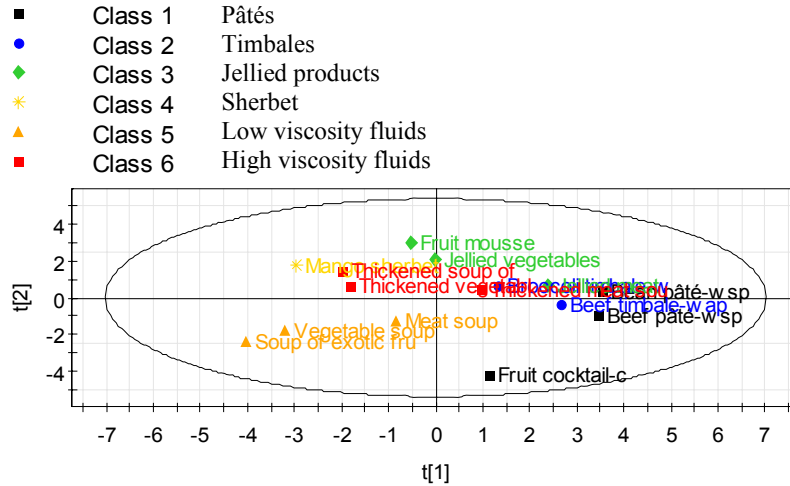
Results

Sensory analysis

To give an overview of all the samples in one picture, the result from the PCA is shown in figure 1 (score plot) and 2 (loading plot). The total variation (79%) is explained by the two first principal components.

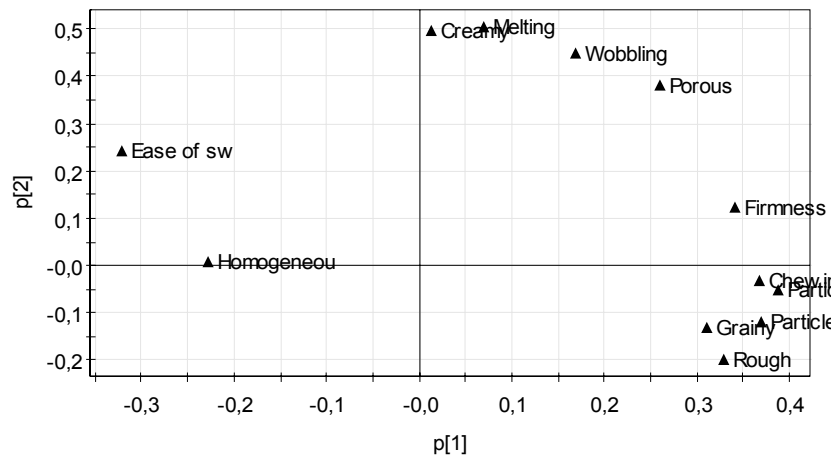
Although the products in each category were "extreme", the soups could be classified into two different groups, the jellied products into a third one and the timbales into another one. However the jellied meat tended to be different from the other two jellied products. The plot further indicated that the variance in the category "pâtés" seemed to be higher compared to the other groups. It should though be noted that the fruit cocktail was not made with the same texture agent (egg) nor had the same milling degree as the other two products in this category.

The attributes chewing resistance and particles explained mainly the variation along PC1, creamy and melting and homogenous along PC2. Homogenous was further negatively correlated to grainy and particles, while grainy and particles were positively correlated.



R2X[1] = 0,501945 R2X[2] = 0,289

Figure 1. Principal component analysis (PCA) of sensory data. Score plot for all products



R2X[1] = 0,501945 F SIMCA-P+ 11 - 2008-09-16 16:01:40

Figure 2. Principal component analysis (PCA) of sensory data. Loading plot

The results of the analysis of variance and Tukey's test are show in table 4. All product categories (except the sherbet) were significant separated in perceived chewing resistance. The attribute homogenous differed between least categories. The pâtés and jellied products differed from the other products in most properties, while the thickened soups differed in least numbers of properties.

Table 4. Sensory results of the ANOVA. Significant differences in attributes between categories*.

	SOUPS	THICKENED SOUPS	SHERBET	JELLIED PRODUCTS	TIMBALES	PÂTÉS
Chewing resistance	a	b	ab	c	d	e
Grainy	a	b	a	bcd	cd	d
Particles	ab	abc	a	abc	c	d
Porous	a	bc	bc	d	d	c
Wobbling	a	cd	ab	e	d	bc
Melting	a	b	c	d	b	e
Rough	ab	ab	a	bc	cd	d
Creamy	a	b	c	b	c	a
Firmness	a	b	b	c	d	d
Ease of swallow	a	b	b	c	d	d
Homogeneous	a	a	a	a	a	b
Particles after swallowing	ab	ab	a	bc	c	d

*Significant differences ($P \leq 0.05$) between the six product categories are shown with different letters. Product categories do not differ significantly, if the same letter appears in the boxes corresponding to an attribute.

Mean values for samples in the each category are presented in spider plots, figures 3-7.

Pâtés: All pâtés were characterised to have a *high chewing resistance* and degree of *firmness* in comparison to the other texture categories. The degree of perceived particles, graininess, roughness, porosity, creaminess and homogenous were significantly different (at 5%) between the three products. The degree of melting and wobbling was moderate for the meat and bean pâté.

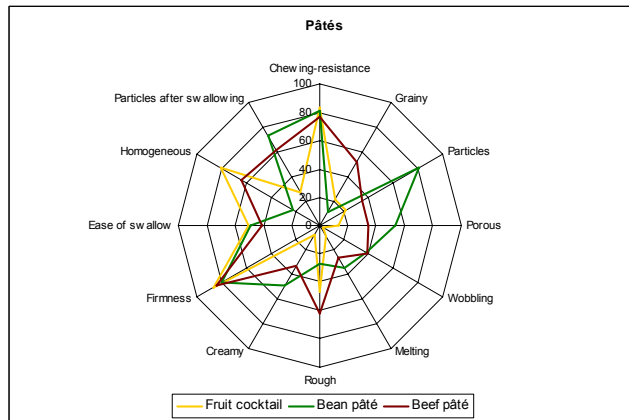


Figure 3. Spider plot for pâtés – mean values

Timbales: The products were characterised to have a relatively *high degree of firmness* and *homogenous consistency*. The perceived *chewing resistance*, *porosity*, *creaminess*, *wobbling* and *ease of swallow* were moderate. The degree of perceived particles (during chewing and after swallowing), graininess, and roughness was significantly higher for the meat timbale compared to the broccoli timbale.

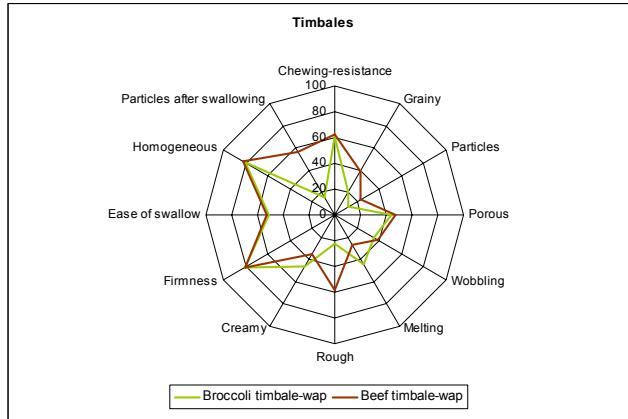


Figure 4. Spider plot for timbales – mean values

Jellied products: the jellied meat and vegetable product were characterised by having a *high degree of wobbly and homogenous consistency*. The perceived *porosity, degree of melting, creaminess, firmness and easy to swallow* were moderate for those two products. The jellied meat had a significantly higher chewing resistance, degree of graininess, particles, roughness compared to the jellied vegetable product. The fruit mousse differed from the other two products in being more porous, but less wobbling and firm.

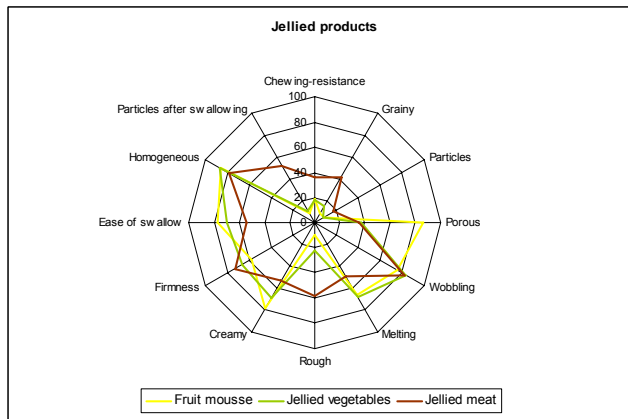


Figure 5. Spider plot for jellied products – mean values

Thickened soups: All thickened soups had a *low degree of chewing resistance and porosity*. The degree of *creaminess and ease of swallowing* was moderate (however, the mean value for ease of swallow was highest in comparison to the other product categories). The thickened meat soup differed significantly from the other two soups in being perceived as more rough, grainy, having more particles (during chewing and after swallowing) but having lower homogenous consistency.

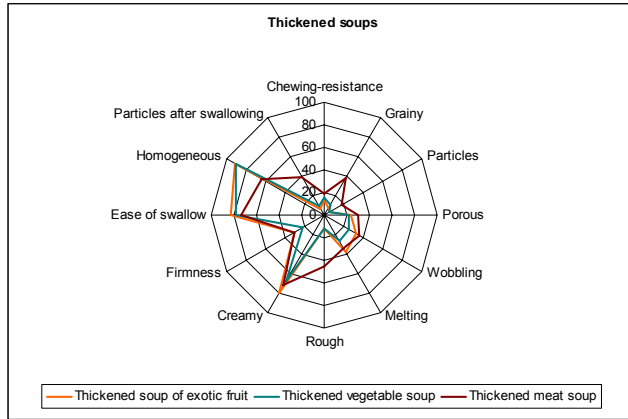


Figure 6. Spider plot for thickened soups – mean values

Soups: The three tested soups had a *low chewing resistance, low degree of particles and melting and firmness*. The *ease of swallowing* was perceived as moderate. The meat soup was perceived as more grainy, rough, having more particles (during chewing and after swallowing), but less homogenous.

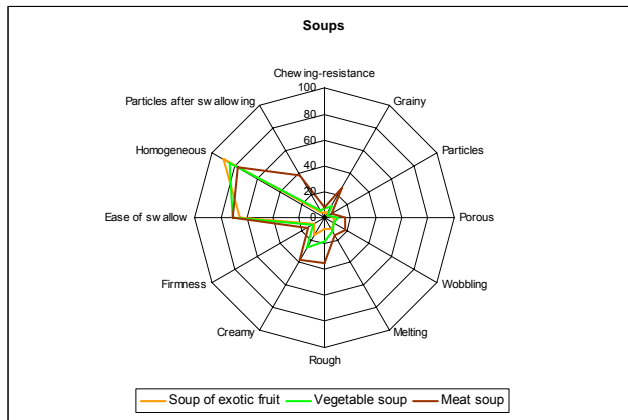


Figure 7. Spider plot for soups – mean values

Rheology - solid products

To give an overview of all products, the result from the PCA is shown in figure 8 and 9. The total variation, 83%, is explained by the two first principal components. The texture modified products could be separated into groups according to the rheological analysis, as seen in the score plot and loading plot.

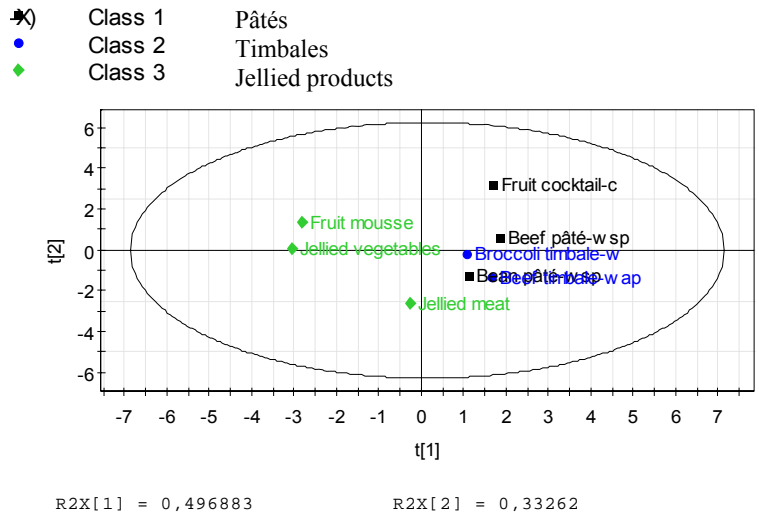


Figure 8. Principal component analysis (PCA) of rheology and particle data. Score plot for solid products

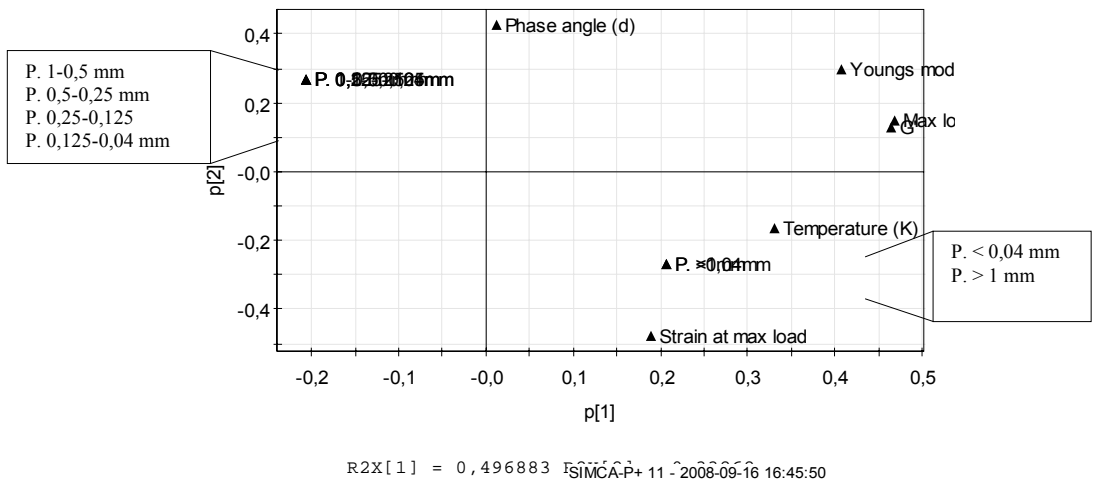


Figure 9. Principal component analysis (PCA) of rheology and particle data. Loading plot

Penetration test

According to mean values from the penetration test, the fruit cocktail caused the highest force during deformation, while the jellied products caused the lowest figure 10. However, no significant differences in Max load, Strain at max load, figure 11, or Young's modulus were found between the different product categories.

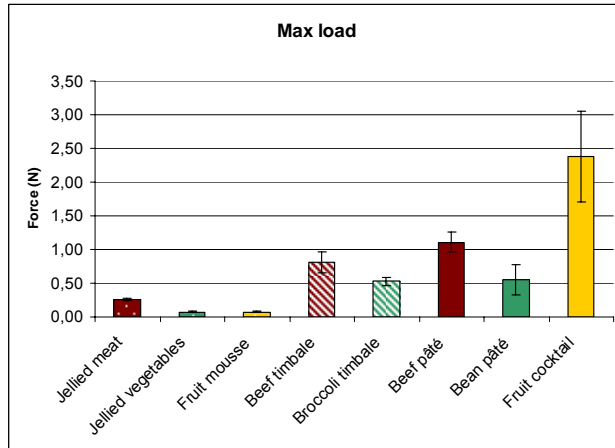


Figure 10. Penetration force for the solid foods

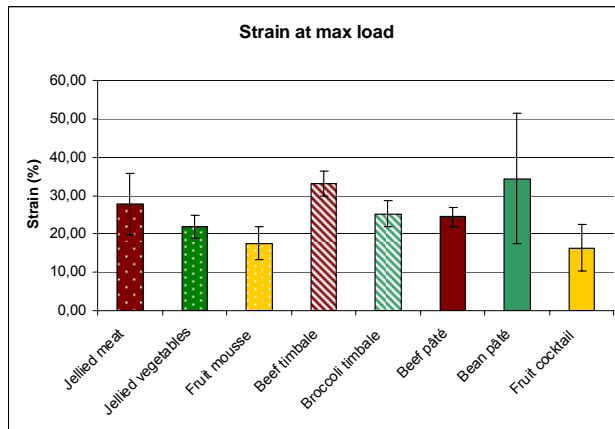


Figure 11. Strain at max load for the solid foods

Frequency sweep test

As shown in figure 12, the products were more elastic than viscous ($G' > G''$). The three solid product categories belonged to two statistically different G' intervals; interval 1 (jellied products) had $G' \sim 1200$ Pa, interval 2 (timbales and pâté) had $G' \sim 17000$ Pa. In terms of G'' , the categories were grouped in a similar way. The similar rheological properties (measured as G' and G'') indicated similar network structures of the timbales and pâtés. Products in the first interval were rather soft products made of gelatine while products in interval 2 were more compact.

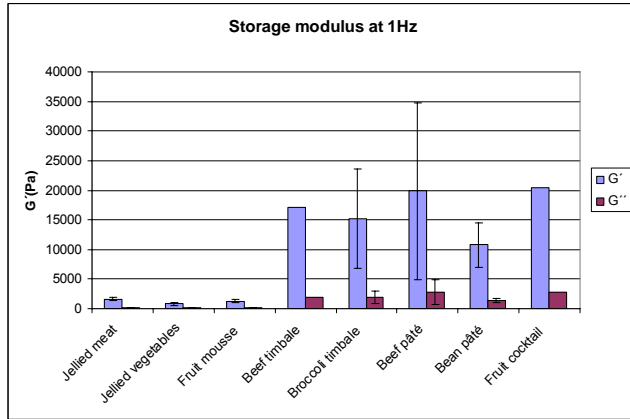


Figure 12. G' (blue) and G'' (purple) for the solid products. Mean values are calculated from two replicates.

Temperature sweeps

Figure 13 and 14 shows the temperature dependence of the jellied products and the timbales respectively. All jellied products showed strong temperature dependence and melt at around 30°C, seen as a drop in elastic modulus and an increase in phase angle, while the timbales showed very little temperature dependence between 37°C and 60°C.

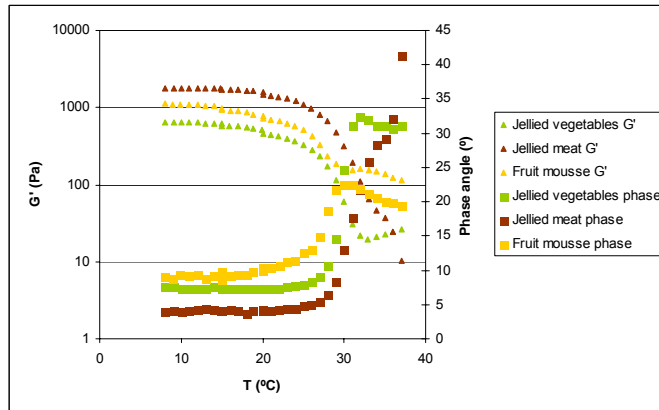


Figure 13. G' is indicated by triangles and phase angle by squares.

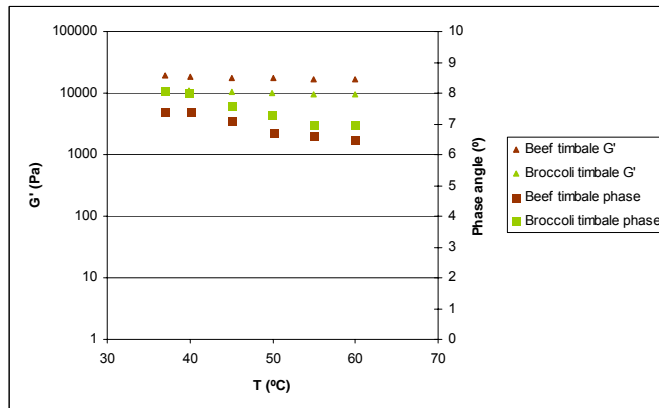


Figure 14. G' is indicated by triangles and phase angle by squares.

Particle size measurement - solid products

The distribution of particles of the jellied products is shown in figure 15. The mean values indicated that the meat product had more particles in the range >1 mm compared to the vegetable product.

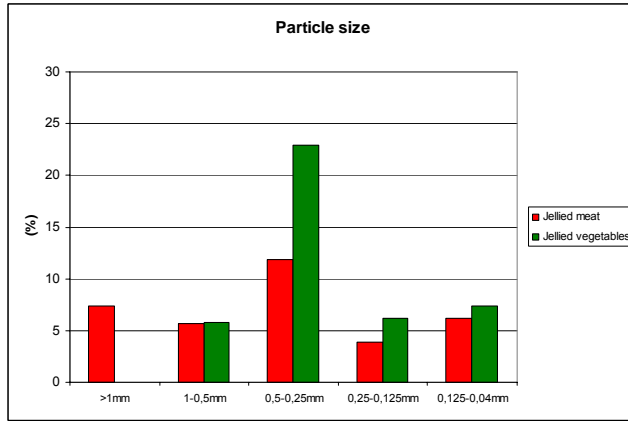
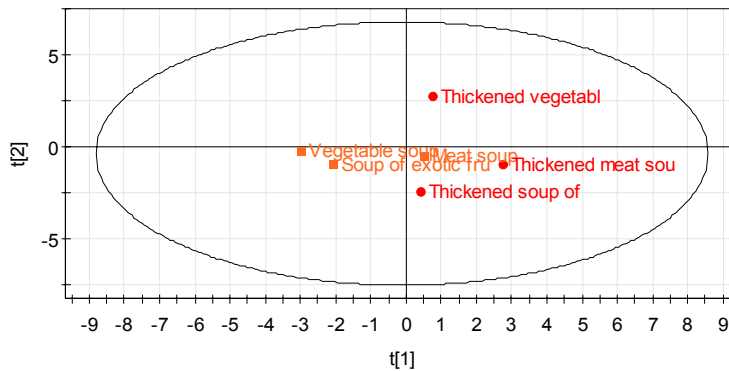


Figure 15. Distribution of particles according to size in the interval <0.04->1mm

Rheology - liquid products

To give an overview of all liquid samples, the result from the PCA is shown in figure 16 and 17. The total variation (73%) was explained by the two first principal components.

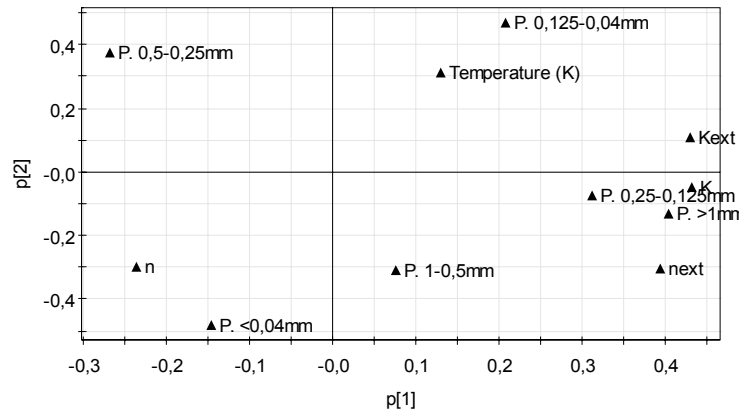
- ✕ Class 1 High viscosity fluids
- Class 2 Low viscosity fluids



R2X[1] = 0,466117

R2X[2] = 0,265723

Figure 16. Principal component analysis of rheology and particle data. Score plot for liquid products



R2X[1] = 0,466117 SIMCA-P+ 11 2008-09-16 16:15:00

Figure 17. Principal component analysis (PCA) of rheology and particle data. Loading plot

Shear viscosity

The viscosities from four flow curves were averaged for each sample and plotted against the shear rate, figure 18. The flow curves for the soups and the Power Law index ($n \approx 0.4$), table 5, showed that all samples were shear thinning (i.e. the samples had a lower viscosity at higher rate) and there were no significant differences in n between the two different product categories. The soups with no thickening agent had however significant lower viscosities (K) than the soups with added thickening agent, despite sometimes high standard deviation values.

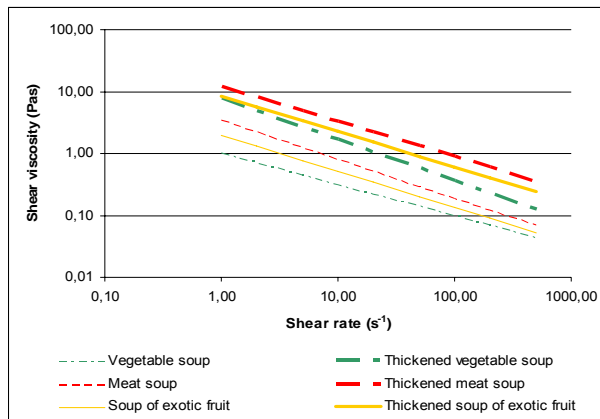


Figure 18. Flow curves in shear for the liquid products

Table 5. Power Law parameters

Product	T (°C)	n	K (Pa ^s)
Soup of exotic fruit	8	0.42	1.94
Thickened soup of exotic fruit	8	0.43	8.50
Vegetable soup	60	0.49	1.00
Thickened vegetable soup	60	0.34	7.61
Meat soup	60	0.37	3.33
Thickened meat soup	60	0.43	12.04

Extensional viscosity

The transient extensional viscosity was measured for each extension rate and was compensated for the contribution of shear stress. The extensional viscosity was plotted as a function of extension rate for each product, figure 19. As can be seen from the graph, all samples had a decreasing extensional viscosity with increasing extension rate, i.e. all samples were tension thinning. There were no significant differences in K_{ext} or n_{ext} between thickened and not thickened soups, table 6. The extensional viscosity showed similar results as the shear viscosity. However, the meat soup had unexpected high extensional viscosity placing it close to the thickened soups. The vegetable soup and the soup of exotic fruit showed a more pronounced dependence on extension rate (steeper slope) compared to their thickened counterpart.

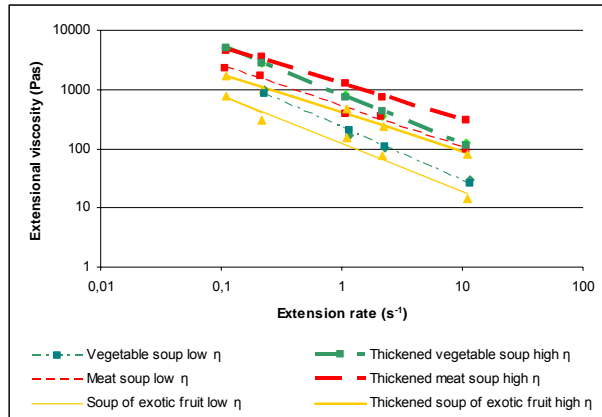


Figure 19. Extensional viscosity for the liquid products

Table 6. Extensional parameters

Product	T (°C)	n_{ext}	K_{ext} (Pas)
Soup of exotic fruit	8	0.19	122
Thickened soup of exotic fruit	8	0.35	412
Vegetable soup	60	0.11	230
Thickened vegetable soup	60	0.18	803
Meat soup	60	0.31	518
Thickened meat soup	60	0.39	1261

Particle size - liquid products

The distribution of particles of the liquid products is shown in figure 20. The mean values indicated that the meat products had more particles in the range >1 mm compared to the vegetable products. However, the statistical analyses showed no significant differences in distribution of particle size between the soups.

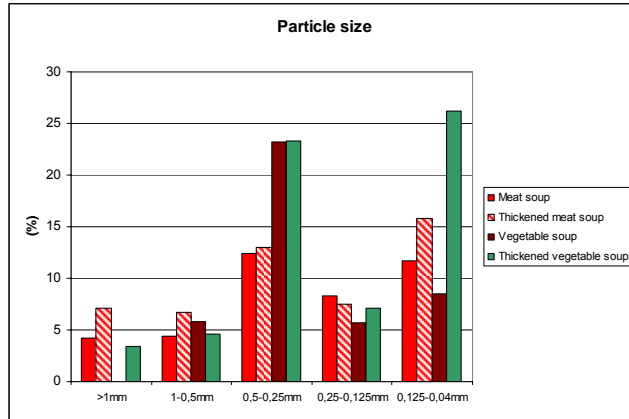


Figure 20. Distribution of particles according to size in the interval $<0.04-1\text{mm}</math>.$

Correlation of sensory and rheology results

PLS - Liquid products

For liquid products, PLS analysis indicated that the sensory attributes; ease of swallow, was positively related to K_{ext} . Furthermore, K_{ext} , K , particles $>1\text{ mm}$ and n_{ext} was the most important positive factors for increased chewing resistance, firmness, graininess, rough, perceived particles (before and after swallowing), porous, wobbling, melting, creaminess and ease of swallow. On the other hand, these factors had a negative influence on the attribute homogenous.

PLS - Solid products

In the present study, the PLS analysis for solid products indicated that the sensory attributes; firmness and chewing resistance were positively related to G' , Max Load and Young's modulus. For example; firmness increased with increased G' . The attributes rough, grainy, particles and particles after swallow were highly correlated to particles $>1\text{mm}$ and $<0.04\text{ mm}$. Melting, porosity, wobbling and creaminess were on the other hand negatively correlated to G' , Young's modulus and Max load.

Max load, G' , Young's module and Strain at max load proved to be the most important positive factors for increased chewing resistance, perceived firmness, degree of graininess, roughness, perceived size of particles before and after swallowing. On the other hand these factors were the most important negative factors for the creaminess, wobbling, porous, and melting and ease of swallow. For example; a high max load was highly correlated to a high chewing resistance but low creaminess.

Video radiography

20 patients performed each 13 swallows, in all 260 swallows. One of the patients could only perform 9 swallows. Oral problems with difficulties in handling the different textures in the oral cavity were the most frequent dysfunction.

The oral transit time varied from 1 sec to 60 sec (figure 21). Three patients had an oral transit time of 60 seconds. Two of the patients had the diagnose CVA, one had dementia.

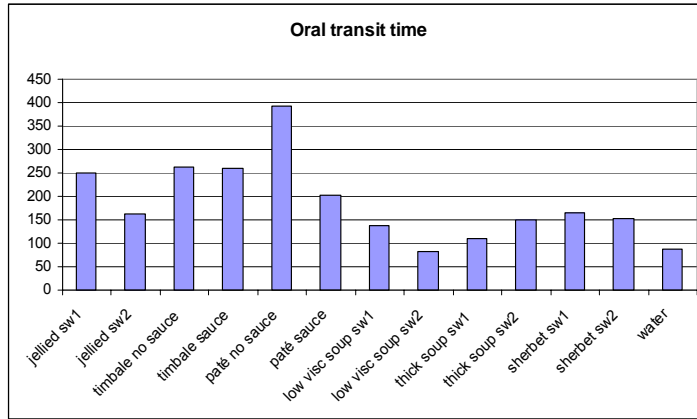


Figure 21. Oral transit time

The pharyngeal transit time varied between 0.5-4 sec, out of 256 swallows 219 varied between 0.5-1 sec, figure 22.

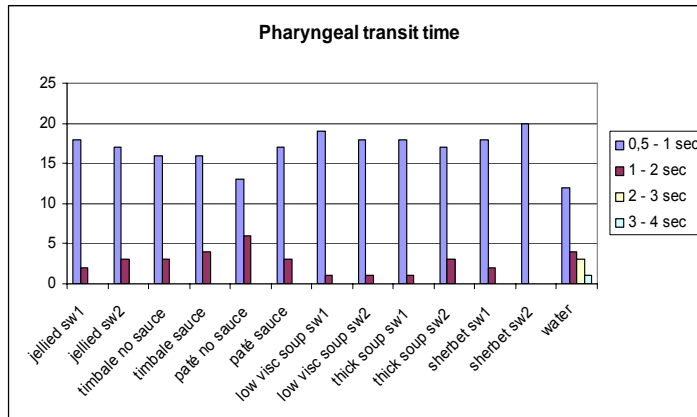


Figure 22. Pharyngeal transit time

Almost no dissociation occurred in any patient, figure 23.

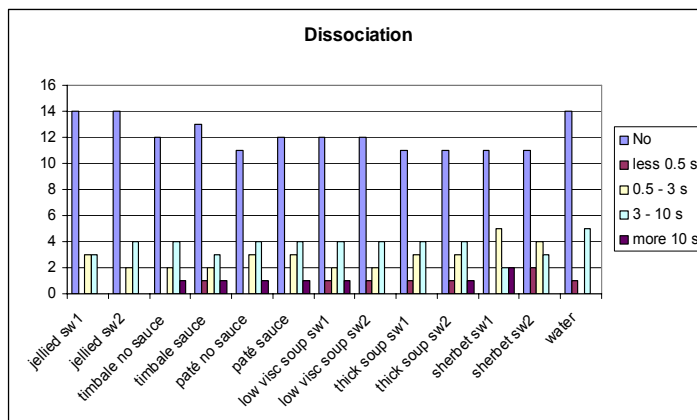


Figure 23. Dissociation

In most cases no penetration, subepiglottic, supraglottic, and tracheal penetration were seen, figure 24.

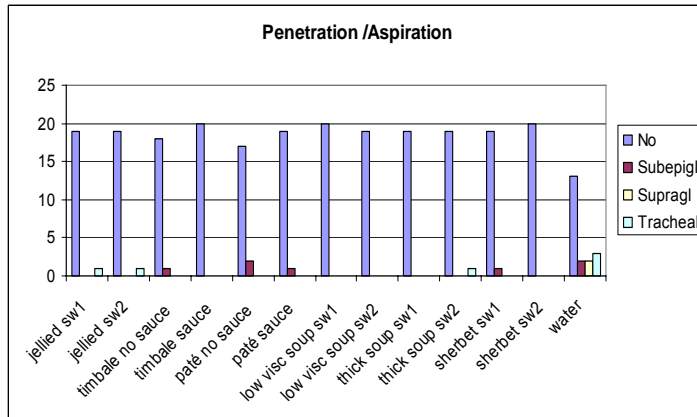


Figure 24. Penetration/Aspiration

No or in some cases mild pharyngeal retention could be observed, figure 25.

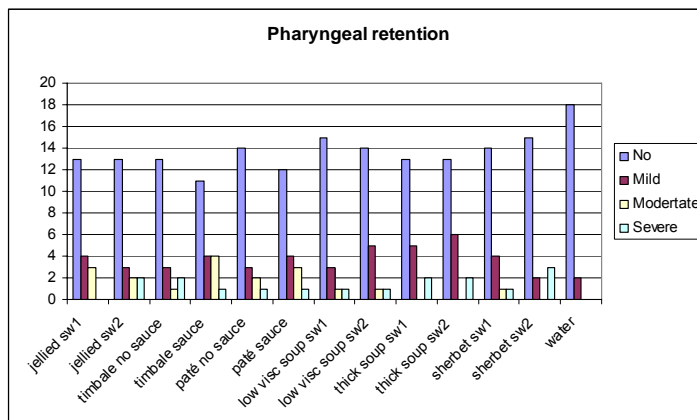


Figure 25. Pharyngeal retention

Definition of textures - new guidelines

In table 7 the results of the objective sensory description and texture measurement are summarised. The radiological results showed that swallowing dysfunction indicated individual characterization and could not be taken into account in a generalized summary. The intention is that care facilities and food product developer will find these definitions additional to the other descriptions and implement the system and definitions developed. In focus groups within this project it was found that the explanations of the existing guide in a combination with the new sensory descriptions resulted in a better understanding of the different textures (Ekman, 2009). This could facilitate the ordination of appropriate food texture to elderly with chewing and swallowing dysfunctions.

Table 7. Definitions of textures – summary of sensory and rheological analyses

	OBJECTIVE SENSORY DESCRIPTION	TEXTURE MEASUREMENT
Pâtés	Higher degree of chewing resistance and larger particles compared to timbales and jellied products	Max load: 0.6-2.4 N Young's modulus: 100-1500 kPa G' should stay within 10000-30000 Pa and $\delta < 10^\circ$ between 0.1-10 Hz
Timbales	Moderate degree of chewing resistance, creaminess and wobbling. More porous, wobbly, creamy and melting than pâtés	Max load: 0.5-0.8 N Young's modulus: 100-200 kPa G' should stay within 15000-17000 Pa and $\delta < 10^\circ$ between 0.1-10 Hz
Jellied products	Wobbly, homogenous and creamy. Lower degree of chewing resistance and firmness but higher degree of melting and creaminess compared to timbales and pâtés.	Max load: 0.1-0.3 N Young's modulus: 20-60 kPa G' should stay within 800-1600 Pa and $\delta < 10^\circ$ between 0.1-10 Hz
Low viscosity fluids (Soups)	Lower degree of chewing resistance, firmness, porosity and wobbling compared to high viscosity fluids	Consistence index in shear: 1.0-3.3 (Pas ⁿ) in tension: 120-520 (Pas ⁿ) Shear thinning exponent: 0.4-0.5 Tension thinning exponent: 0.1-0.3
High viscosity fluids (Thickened soups)	More melting, easier to swallow and creamy compared to low viscosity fluids	Consistence index in shear: 7.6-12.0 (Pas ⁿ) in tension: 410-1260 (Pas ⁿ) Shear thinning exponent: 0.3-0.4 Tension thinning exponent: 0.2-0.4

Max load: *The maximum force reached when pushing a probe through the sample. This value correlates with chewing resistance.*

Young's modulus: *A measure of the stiffness of the sample derived from the penetration test. Correlates with chewing resistance.*

G': *A measure of the stiffness of the sample. Measured with a non-destructive oscillative method and is frequency dependent. Correlates with chewing resistance.*

δ : *Degree of viscous or elastic behaviour. 0° is a completely elastic material and 90° a completely viscous material. Based on the relation between the storage modulus G' and the loss modulus G''.*

Consistence index: *A measure of a fluids thickness. Used in conjunction with the shear/tension thinning exponent to describe a fluids viscosity over a range of shear/extension rates.*

Shear thinning exponent: *Describes a fluid's behaviour depending on shear/extension rates. 1: newtonian, <1: shear/tension thinning, >1 shear/tension thickening.*

Discussion

Material and methods

Two different methods; sensory evaluation and rheology measurement were used to describe texture properties of the texture modified foods. Using a quantitative descriptive analysis, discrimination between the texture modified products was obtained in many of the selected sensory textural and mouth feel properties. While sensory texture attributes were evaluated by healthy humans that sensed and measured the food samples, rheological measurements were physical properties measured with instruments. Various attempts have been reported in the literature to quantify the sensory properties of a food material on the basis of physical and chemical measurements of the product (van Vliet, 2002; Szczesniak, 1963). However, for fluids and soft foods the structure and rheological behaviour in the mouth can strongly be affected by oral processing and conditions in the mouth (Hutchings & Lillford, 1988; De Wijk et al, 2003). Casanovas, et al 2008 suggested texture classification based on rheological measurements. However

in this study, correlations of sensory and rheological data showed that both sensory evaluation and rheology measurements are needed in order to characterise the classes. Results from the correlations could further be used in both quality assurance of texture modified products and development of new products.

Particle size measurement

The results indicated that the method had some limitations, since the samples had to be dissolved in water and there after water was washed through the sieves. This procedure might have caused absorption of water, thereby resulting in an overestimation of particles. Furthermore, it was difficult to dissolve the thickener agent which might explain that particles >1 mm were measured in the thickened vegetable soup.

Examination of dysfunction

The results showed most frequent problems in the oral stage of swallowing. Several patients had difficulties in handling the different textures in the oral cavity probably due to actual dysfunction. From this study it was not possible to give any generalised recommendations regarding modified textures for patients suffering from moderate/severe pharyngeal dysfunction. This since every swallowing dysfunction showed individual characterization.

Limitations

Time and resource limitations restricted to analyse more than 15 product samples of texture modified foods. The choice of products in each category was based on extremes in each category to cover the whole range. Furthermore, there was no possibility to perform the viscosity measurements over time to detect if the thickener was time-dependent. Concerning the radiological examinations the base of patients was limited according to difficulties in recruitment. Therefore the results in this case are to be regarded as indications.

Definition of textures - new guidelines

Solid food

The four solid texture levels in the Swedish guide are the same as in the USA and Australian food texture scale (Atherton et al, 2007) but less than the UK scale (British Dietetic Association, 2002) which consists of six different levels. Due to different cultural aspects of food habits it is not possible to adopt a texture level guide from another country. Food and textures that people in America or in Australia have preferences for may in Sweden be impossible for people to accept.

According to the sensory analysis, the solid texture modified products could be separated into three predefined groups (no samples from the fourth group, “regular or cut”, were analysed in this project). Pâtés were mostly differentiated from timbales and jellied products regarding chewing resistance and perceived particles. This is in line with the ingredients used; the meat or vegetable raw materials in timbales and jellied products were based on purees while the raw materials in pâtés were ground (milling degree of 5 or 8 mm). Larger particles might have produced a decreased perception of melting and creaminess. In a study by Kaufmann (2006) it was found that particle size influenced the perception of the attribute melting in texture modified carrot products

and that perception of melting might have been related to homogeneity. This supports the results of this study since timbales were perceived as being more homogenous and melting than pâtés. The perceived larger particles in the pâtés had however no negative impact on ease of swallowing. However, the pâté without sauce was the texture that for some patients showed to be most difficult to handle in the oral cavity and to swallow, probably due to its dryness. “Dry” solids may for some dysphagic persons be impossible to handle in the oral cavity and thereby to swallow.

The jellied products contained gelatine, which had a melting temperature of 28 °C shown in the rheological analysis. This could explain the high degree of perceived melting and creaminess in these products compared to timbales and pâtés. Gilseman et al (2000) found however a variation in melting point with gelatin concentration.

It is of interest to note that meat as ingredient resulted in higher degree of perceived: graininess, roughness, and larger particles compared to the vegetable counterpart for timbales and jellied products. However, meat as ingredient did not affect the ease of swallowing in a negative way, except for jellied products. In a sensory study on meat by Martens et al (1982) it was found that firmness increased but juiciness decreased with thermal denaturation.

Products within the category timbales were most similar to each other in respect of sensory texture and mouth feel characteristics, while products within jellied products differed most. The difference between the jellied vegetable product and the meat product was also noted in the rheology analyses, showing that the meat product had higher Strain at max load and also an indication of more particles >1mm compared to the vegetable product. The perception of larger particles could also be due to meat particles were distributed in a simple gel system and not mixed with egg proteins like in timbales or pâtés. Egg contains a high amount of protein which contributes significantly to the food texture through their ability to build or stabilize gels, foams, emulsions and fibrillar structures (Weder et al, 2003).

The results from the rheological analysis indicated that the solid products could be separated regarding G' , implicating that the jellied products were significantly different to timbales and pâtés in their textural characteristics. The bean pâté had however a structure that did not keep together which might explain that no significant difference in G' was found between pâtés and timbales. In a former project it was found that a coarsely ground meat ingredient resulted in more elastic product (VINNOVA, 2007), expecting that a frequency sweep test (G') could be used to classify products into categories.

No significant differences were found between the three classes of solid textures in Max load, Strain at max load or Young's modulus. The bean pâté had however a structure that did not keep together when deformed resulting in aggregates of the vegetable constituents fell apart, and thus causing an overall low penetration force. In the PLS analysis it was however shown that the sensory attribute *chewing resistance* was correlated to Max load. Therefore these results indicated that the three types of solid products were different in their textural characteristics, and a combination of frequency sweep test and penetration test are needed for a proper differentiation.

Fluid products

The two fluid texture levels in the Swedish guide is less than the four levels used in USA and in Australia (Atherton et al, 2007) and the five levels in UK (British Dietetic Association, 2002).

The liquid products could be separated into the two predefined groups according to the sensory attributes. The thickened liquid contained a starch based thickener which was perceived as easier to swallow and more creamy than the low viscosity soup. It has earlier been shown that creaminess could be related to viscosity according to sensory and rheological studies (Wendin et al, 1997). The effect of saliva for the perception of texture was demonstrated by De Wijk et al (2003). Mixing of starch-thickened food with saliva in the mouth leads to a fast digestion of the starch, resulting in a loss in viscosity of the product. Because of this, liquids thickened by starch are perceived as “melting” in the mouth. For the high viscosity fluids, it should be noted that meat as ingredient resulted in higher degree of perceived: graininess, roughness, and larger particles compared to the vegetable counterpart. However, meat as ingredient did not affect the ease of swallowing.

The results from the rheological analyses implied that the two categories of liquids were significantly different in their textural characteristics and might therefore respond to different dysphagic requirements. The consistence index (K) could be used to distinguish between the classes of low and high viscosity food. The high viscosity soups showed however a relatively high standard deviation probably depending on the temperature dependence of the thickening agent. Variations in preparation and temperature might also have caused viscosity variations.

The viscosities of the soups were measured at either 60°C or 8°C depending on regulated distribution temperature and with a shear rate of (1-500 s⁻¹). It should be noted that there is variability in the viscosity range for thickened fluids described in the literature (Steele et al, 2003). It has been reported that the viscosity level can be dependent of the specific thickener and liquid used and that viscosity can rise in density during time after mixing (Gracia et al, 2005; Dewar et al, 2006). According to the analyses in this project the texture guide could be used as a guideline and to relate products in one category to products in another one. In the future viscosity levels might be defined according to evidence based clinical texture studies. Accurate descriptions and training of relevant individuals would be necessary when varying degrees of thickened fluids to prevent discrepancies in liquid textures since it has been shown that is it difficult to detect higher relative viscosity on the basis of stirring and oral manipulation (Steele et al, 2003). According to this, there is a need for development of standards of relative liquid consistency to aid an understanding of the relative viscosities of different products.

The vegetable soup and the soup of exotic fruit showed a more pronounced dependence on extension rate (steeper slope) compared to their thickened counterpart. This could have an effect at relatively high extension rates present in the mouth and during swallowing. The products would most likely be perceived as less viscous when swallowed and this might affect the ability of the bolus to deform during swallowing.

For liquid products, PLS analysis indicated that the sensory attributes ease of swallow was positively related to K_{ext} . This was in accordance with Ekberg et al, 2008; in the mouth the food was squeezed between the tongue and the palate which also caused mainly an extensional flow. The extensional flow during transport might explain the strong correlation between perceived ease of swallow and extensional viscosity. It should be noted that the perception of ease of swallowing was the judges' impression of the ingested products and that the panel consisted of healthy persons. A medical investigation of a dysphagic patient is highly required in providing a diet recommendation.

Conclusion

The textures in the Swedish guide could be characterised objectively by a combination of sensory evaluation and rheology measurements. However, there were significant product variations within the categories regarding some sensory attributes. Further, all rheological measurements did not succeed in differentiate between the analysed products. Out of the videoradiographic study the swallowing dysfunctions showed individual variation, therefore no generalised recommendations regarding modified textures could be given.

Future outlook

It is of high relevance to develop viscosity levels according to evidence based clinical texture studies and to develop standard measurements of fluid viscosity. It is also of high relevance to develop standard recipes for texture-modified foods and fluids.

Further studies are needed to maintain a valid and quantitatively defined scale of different food and fluid textures. Such scale must be tested on patients suffering from different kind of dysphagic problems during clinical condition.

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