



HAL
open science

Oral consistency and simple rheological measurement of strawberry jams

Sylvie Issanchou, Jean Francois Maingonnat, Elisabeth Guichard, Patrick Etievant

► **To cite this version:**

Sylvie Issanchou, Jean Francois Maingonnat, Elisabeth Guichard, Patrick Etievant. Oral consistency and simple rheological measurement of strawberry jams. *Sciences des aliments = Food science: an international journal of food science and technology*, 1991, 11 (1), pp.85-98. hal-01595037

HAL Id: hal-01595037

<https://hal.science/hal-01595037>

Submitted on 26 Sep 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

ORAL CONSISTENCY AND SIMPLE RHEOLOGICAL MEASUREMENT OF STRAWBERRY JAMS

CONSISTANCE ORALE ET MESURE RHÉOLOGIQUE SIMPLE DE CONFITURES DE FRAISES

Sylvie N. ISSANCHOU (1), J.F. MAINGONNAT (2), Elisabeth A. GUICHARD (1),
P.X. ETIEVANT (1)

with the technical assistance of Denise DEMAIZIERES (1), Nicole FOURNIER (1) and
P. LAVIER (1)

SUMMARY

Six series of strawberry jam samples at different Brix values, with different types of pectins or different sugars were prepared and analyzed. Rheological tests were carried out and the obtained flow curves were modeled with the Herschel-Bulkley model. Apparent viscosity was calculated at 5 different shear rate values. At the same time, the samples were evaluated by a panel of 18 selected and trained subjects. They were asked to rate the oral consistency using an unstructured scale. The effect of the characteristics of the pectin on the consistency of the jam was observed. Our results show that, for a same pectin concentration, viscosity and oral consistency decrease with Brix value, with demethylation and with molecular weight. Relationships between sensory and rheological data were studied. It was shown that the logarithm of apparent viscosity for a shear rate of 50 s⁻¹ is significantly correlated with the oral consistency. This result shows that an easy and quick rheological measurement can give a precise information of the oral consistency of the product.

Key-words: *oral consistency, rheological measurement, correlation, jam, strawberry.*

RÉSUMÉ

Six séries d'échantillons de confitures de fraises préparées à différents degrés Brix, avec différents types de pectine ou différents sucres ont été étudiées (*tableau 1*). Des tests rhéologiques ont été réalisés et les courbes d'écoulement obtenues ont été ajustées à l'aide du modèle d'Herschel-Bulkley.

(1) Institut National de la Recherche Agronomique, Laboratoire de Recherche sur les Arômes, 17 rue Sully, 21034 Dijon cedex, France.

(2) Institut National de la Recherche Agronomique, Laboratoire de Génie Industriel Alimentaire, 369 rue Jules-Guesde, BP 39, 59651 Villeneuve d'Ascq cedex, France.

La viscosité apparente (η) a été calculée pour cinq vitesses de cisaillement ($\dot{\gamma}$) (tableau 2). Parallèlement, des analyses sensorielles ont été réalisées. Les échantillons ont été évalués par un groupe de 18 sujets sélectionnés et entraînés. Ils notaient la consistance orale des échantillons sur une échelle non structurée. L'influence des caractéristiques de la pectine sur la consistance des échantillons a été examinée. Nos résultats montrent que, pour une même concentration de pectine, la viscosité et la consistance orale diminuent avec le degré Brix, avec la déméthylation et avec le poids moléculaire. Les relations entre données sensorielles et données rhéologiques ont été étudiées (tableau 1). Nos résultats montrent qu'environ 76 % des variations de consistance orale peuvent être expliquées par le logarithme de la viscosité apparente calculée pour une vitesse de cisaillement de 50 s^{-1} . Ce résultat montre qu'une mesure rhéologique simple et rapide peut donner une évaluation relativement précise de la consistance orale du produit.

Mots clés : consistance orale, mesure rhéologique, corrélation, confiture, fraise.

1 - INTRODUCTION

Texture characteristics and particularly consistency are important factors in the overall acceptability of jams. Pectin is usually added in commercial manufacturing of jams to obtain a certain level of consistency. The quantity of pectin must be adjusted depending on the composition of fruits, the nature of sugar, the fruit and sugar contents. Thus, industrials need a rapid and reproducible method to control texture of the final product. As physical data are easier to obtain than sensory assessments, rheological characteristics have been largely explored. These rheological studies have been performed on model samples (MORRIS *et al.*, 1984) and on different food products (SHAMA and SHERMAN, 1973; KOKINI *et al.*, 1977; BARBOSA CANOVAS and PELEG, 1983). But only two studies reported rheological measurements on jam. COSTELL *et al.* (1987) studied relationships between fruit content in jams and some rheological parameters but did not attempt to relate these rheological parameters with sensory data. HYVÖNEN and TÖRMÄ (1983) studied correlations between sensory scores of texture and spreading length measured with a Bostwick consistometer on 40% and 30% soluble solid jams. However, their sensory data were measurements of distances from the optimal hardness and this optimum may differ between consumers of different countries. The present study was conducted in order to compare and relate parameters from a simple rheological test with sensory notes obtained from a trained panel on a large number of jam samples.

2 - MATERIALS AND METHODS

2.1 Pectin preparation

Three types of pectins, whose characteristics are mentioned in table 1, were used. They are all non standardized citrus pectins von Unipectine (Mero Rousselot Satia). Two are low methoxy pectins (LM 345 and LM 27) and one is a high methoxy pectin (HM: Rapid Set); they are all usually used in the jam manufacturing. For the HM pectin, deesterification and depolymerization were performed separately giving two lots of samples (respectively D and E), according to the following procedure.

2.1.1 Deesterification

Enzymic deesterification was realized with a pectin methyl-esterase (Rapidase CPE von *Aspergillus niger*, 88 UI·ml⁻¹ measured at pH 4.5 and 30°C). Hundred µl of CPE were added to 100 ml of aqueous solution containing 2 g of pectin (pH 4.5; 30°C). The number of moles of produced galacturonic acid was continuously measured by adding known amounts of NaOH (0.1 N) in order to maintain the original pH. Ten ml and 19.7 ml of NaOH solution were added respectively for obtaining degrees of esterification of 66 and 54 (the theoretical values were respectively 62 and 50).

The obtained pectins were precipitated by adding 30 ml of an aqueous copper acetate solution (7%). The coagulum was first washed with a cooled acidic ethanolic solution (80% ethyl alcohol and 1% HCl, 4°C) until no more copper remained, and then with an ethanolic solution (70%) in order to remove chloride ions. The purified pectins were then washed with diethyl ether, dried in a dessicator one night under vacuum, and stored in a dessicator with P₂O₅.

2.1.2 Mechanical degradation of pectin

Three lots of pectin were mechanically milled with ceramic cylinders in a ceramic pot during 3, 6 and 12 hours respectively, as described by VAN DEVENTER-SCHRIEMER *et al.* (1987).

2.1.3 Measure of degree of esterification and molecular weight

The degree of esterification was measured by a titration of the acidic functions on the pectinic chain before and after the saponification of the ester binding. This method was described by Unipectine (Mero Rousselot Satia).

Molecular weight was determined according to OWENS *et al.* (1946) with a viscometer (Ostwald's capillary) at a constant temperature of 25°C, for pectin concentrations from 300 to 600 µg·l⁻¹ in NaCl (0.155 M).

2.2 Jam samples

Six series of samples were prepared and analyzed (table 1).

Table 1
Characteristics of the strawberry jam samples

Experiment	Strawberries		Preparation of jam									Chemical parameters of jams		
	Cultivar	Origin	Fruit (kg)	Sugar		Pectin						Sample name	Soluble solids °Brix	pH
				Type	Quantity (kg)	Type	DE ^a	MW ^b	Methoxy-groups	DA ^c	Level			
A	Senga sengana	Poland	2.0	Sucrose	2.2	HM	83	86 000	9	-	0.05	H5	60	3.10±0.01
											0.20	H20		
											0.40	H40		
B	Senga sengana	Poland	2.0	Sucrose	2.2	LM345	37	59 000	6	12	0.1	LM1	60	3.20±0.01
											0.2	LM2		
											0.4	LM4		
											0.6	LM6		
											0.1	LA1		
											0.2	LA2		
C	Senga sengana	Poland	3.8	Sucrose	1.4	LM345	37	59 000	6	12	0.1	LA1	40	3.20±0.01
											0.2	LA2		
											0.6	LA6		
											0.1	LB1		
											0.2	LB2		
											0.6	LB6		

Table 1 (continued)

Experiment	Strawberries		Preparation of jam									Chemical parameters of jams		
	Cultivar	Origin	Fruit (kg)	Sugar		Pectin					Sample name	Soluble solids °Brix	pH	
				Type	Quantity (kg)	Type	DE ^a	MW ^b	Methoxy-groups	DA ^c				Level
D	Blended	France	2.0	Sucrose	2.2	HM	83	86 000	13	-	0.2	D83	60	3.08±0.02
							66	86 000	11			D66		
							54	66 000	9			D54		
E	Blended	France	2.0	Sucrose	2.2	HM	83	86 000	9	-	0.2	D0	60	3.15±0.05
							83	75 000	9			D3		
							83	59 000	9			D6		
							83	32 000	9			D12		
F	Blended	France	2.0	Sucrose+isoglucose	2.2		No pectin added				0	SI	60	3.16±0.04
				Glucose+fructose								GF		
				Isoglucose+sorbitol								BI		
				Isoglucose+xylitol								XI		
				Glucose+fructose+palatinit								PFG		

a : DE = degree of esterification

b : MW = molecular weight

c : DA = degree of amidation

Samples of experiment A consisted of a reference (60° Brix without pectin) and of four jams made from the reference by adding 0.05, 0.1, 0.2 and 0.4% of a high methoxy pectin (HM). Samples of experiment B consisted of a reference (60° Brix without pectin) and of four jams made from this reference by adding 0.1, 0.2, 0.4 and 0.6% of a low methoxy pectin (LM). Samples of experiment C consisted of a reference (40° Brix without pectin) and of six samples prepared from this reference by adding 0.1, 0.2 and 0.6% of two different low methoxy pectins (LM 345 and LM 27). Experiments D and E were respectively conducted to study the effect of a modification of degree of esterification or of the molecular weight on flavor and texture perception of a jam containing 0.2% pectin. Experiment F was conducted to investigate the influence of sugars on flavor and texture of jam; five samples were prepared with different sugar mixtures (55% sucrose and 45% isoglucose syrup; 91% glucose syrup and 9% fructose; 80% isoglucose syrup and 20% sorbitol; 80% isoglucose syrup and 20% xylitol; 60% glucose syrup, 20% fructose and 20% Palatinit).

Jams were prepared following the traditional procedure from three strawberry batches of different origins (see *table 1*). 250 ml of water were heated in a 6 l preserving pan. Fruits were then added and heated until they reached a temperature of 90°C. Sugar was then added. Citric acid was then added in order to obtain a final pH of about 3.1. For LM pectin, this addition was made just after sugar addition whereas it was made at the end of the cooking for HM pectin. Pectin was added as an aqueous solution into the jams as soon as its Brix value was 5° upper the final wanted value. Heating was maintained until the right Brix value was reached.

Immediately after cooking, jam was crushed in a colander with a pestle to obtain an homogeneous medium for sensory analysis. For rheological measurements, the jam was moreover filtered through a chiffon in order to eliminate pieces of fruits and akenes. Jam was poured into 1 000 ml glass jars. The jars were stored for at least one week at 15°C for 60°Brix jams and at 4°C for 40°Brix jams. The analyses took place within eight weeks after the samples had been prepared.

2.3 Rheological measurements

The rheological tests were carried out at 19°C with a controlled stress rheometer (Carrimed CS 100) using a cone-plate geometry. The cone angle is 1° and the cone diameter is 0.02 m. The sample amount was 50 µl. As this amount was very small, it was necessary to prevent evaporation. Preliminary results showed that the best solution was to cover the sample surface with vaseline oil. The freshly loaded sample had been led to rest for 10 minutes before the flow curves were recorded by the PC computer which drives the viscometer. To determine the flow curves the viscometer was operated in an automatic mode involving the following conditions: increasing of shear at 20 Pa per minute up to a maximum of 143 Pa, holding this value during 1 min, decreasing it at 20 Pa per min. Each sample underwent three shearing cycles as shown schematically in figure 1. The sample has been led to rest for 5 min between two consecutive shearing cycles. Such a rheological test was repeated three times for each jam and the 18 flow curves obtained in this way were modeled with the Herschel-Bulkley model:

$$\tau = \tau_0 + K \dot{\gamma}^n$$

in which K and n are respectively the consistency index and the flow index, τ is the shear stress, $\dot{\gamma}$ is the shear rate. τ_0 , the yield stress, is the shear stress value corresponding to the lowest shear rate value measured by our viscometer. Since real liquids with a yield stress are known to have a structure that can be disrupted by shear, the yield stress after shearing is generally lower than before the fluid was forced to flow (LANG and RHA, 1981). The accurate determination of the yield stress before the fluid was forced to flow is not always possible because shearing the sample during its handling is unavailable and because the structural change may be irreversible (BARBOSA CANOVAS and PELEG, 1983; CHENG, 1986). COSTELL *et al.* (1987) have derived the yield stress as the square of the intercept of the regression line between the square root of the shear stress values and the square root of the shear rate values. Apparent viscosity was calculated at five different shear rate values (1, 10, 50, 100 and 500 s^{-1}) according to the following equation:

$$\eta = \frac{\tau}{\dot{\gamma}} = \frac{\tau_0}{\dot{\gamma}} + K \dot{\gamma}^{n-1}$$

The time effect on the apparent viscosity of the jams was determined by shearing the fluid at a fixed shear stress (143 Pa) during 50 min. The reduction in the apparent viscosity causes an increase in the shear rate and as the fluids are shear-thinning a correction was made to take into account this property.

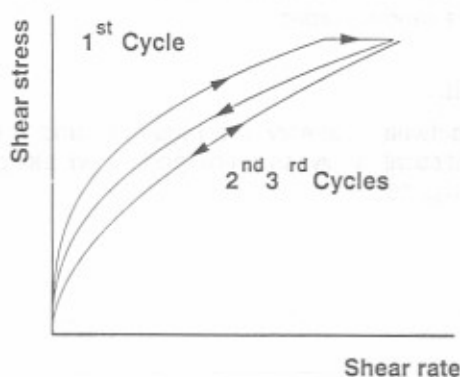


Figure 1
Schematic view of flow curves of the jam for three shearing cycles

2.4 Sensory analysis

2.4.1 Subjects

The candidates were recruited by way of advertisements to participate to a large number of sensory evaluations on strawberry jams. Volunteers were asked to phone to obtain more details on the experiment. At their phone call, they were asked about their name, age, health and disponibility.

After that first stage, 81 persons were asked to attend two sessions of selection of one hour each. They were selected on their ability to memorize and recognize basic tastes and odours, to rank aqueous solutions of different sucrose concentrations on their sweetness intensity and to rank jams with different pectin levels on their oral consistency. Eighteen subjects, eight males and 11 females, 18 to 45 years old, were thus selected and at least 12 persons were present at any specific session. All of them took part in three training sessions for scoring oral consistency.

2.4.2 Evaluation conditions

Evaluations were conducted in individual air conditioned ($20 \pm 0.5^\circ\text{C}$) booths. Red lights were used to mask color differences. Judges rinsed with mineral water between samples; bread was also available.

Twenty grams of jam were presented in white plastic cup. The cups were coded with three digit numbers. The subjects were asked to take a spoon of jam and evaluate its consistency. The oral consistency was rated using an unstructured scale. The scale consisted of a 13 cm long horizontal line with verbal anchor points at each end (left anchor = very soft and right anchor = very hard). The subjects were provided with stimulus end anchors. Stimulus left anchor was jam 60°Brix with no added pectin, stimulus right anchor was jam 60°Brix with 0.4% HM pectin. Responses were digitized for statistical analysis by measuring in millimeters the segment length from the left of the scale to the judge's mark (from 0 to 130).

Each series was presented within one session. The samples were presented one by one and in a random order.

2.5 Data analysis

Relationships between sensory measurement and rheological parameters were studied. Statistical analyses were performed using the SAS statistical package (SAS/STAT_{TM}, 1987).

3 - RESULTS

3.1 Rheological measurements

The curves of the pectin containing jams indicated that a major change in the rheological behaviour occurred during the first shearing cycle (*fig. 1*). This is reflected in a hysteresis loop and a significant difference between the shape of the two first curves and the shape of the four next ones corresponding to the second and the third shearing cycles. The rheological constants of the Herschel-Bulkley model which are presented in table 2 correspond to the "equilibrium" flow curves recorded during the two last shearing cycles. The equilibrium is not necessarily the most pertinent information reflecting the product functionality but it provides a safe reference for rheological comparisons between food products.

The rheological constants given in literature (FITO *et al.*, 1983; DERVISOGLU and KOKINI, 1986; FORD and STEFFE, 1986; COSTELL *et al.*, 1987) referred to these equilibrium curves. The apparent viscosity at 50 s^{-1} is also presented in table 2. When no hysteresis loop was observed during flow curves experiment, the evaluation of time effect on viscosity was not made. The standard deviation values of the yield stress are high and this result reflects the previously mentioned difficulties met when measuring the yield stress with a routine procedure. The yield stress value increases with increasing pectin concentration, and the highest value is obtained with the HM pectin (experiment A). The standard deviation values of the flow and consistency index are low, showing the flow curves repeatability. As the flow index values are similar, the apparent viscosities at 50 s^{-1} are mainly governed by the consistency index.

No clear conclusion appears when comparing the results of the time effect tests. These results are probably poorly significant because the tests had been carried out at different shear rates, and for most of the products exhibiting a thixotropic behaviour, the equilibrium viscosity is affected by the shear rate (TIU and BOGER, 1974; STEFFE and FORD, 1985). Further tests are to be carried out at constant shear rates if a more complete study and a modelization of the thixotropy are needed. The Herschel-Bulkley parameters obtained from COSTELL *et al.* (1987) by averaging the values for the jams with more than 50% fruit contents and 0.5% pectin are as follows:

$$\begin{aligned}\tau_0 &= 36.6 \text{ Pa} \\ k &= 9.78 \text{ Pa}\cdot\text{s}^n \\ n &= 0.66 \\ \eta_{50} &= 3.3 \text{ Pa}\cdot\text{s}\end{aligned}$$

These results are slightly higher than those we obtained with the 0.4% HM pectin jam.

3.2 Sensory analysis

Judges' performances were determined as follows. After completion of all sessions, the mean distance for the hidden reference is calculated for each subject. Theoretically, the distance should be zero. However, the overall average is equal to 17.6. Two subjects who obtained scores larger than 30 were thus excluded from further calculations.

3.3 Correlation between rheological and sensory measurements

The relation between the perceived consistency (S) and the apparent viscosity (η) was determined by means of linear regression for different shear rate values and two models, the Fechner's model ($S = K \log \eta + \text{constant}$) and the Stevens's one ($\log S = n \log \eta + \text{constant}$). Table 3 gives the value of coefficient of determination for each shear rate value and for the two models. As it can be seen there are no large differences between the two models and the best fit is obtained with a shear rate of 50 s^{-1} and the Fechner model. In these conditions, 76% of the variability in the perceived consistency values is explained by the rheological parameter. The following equation was obtained:

$$S = 1.6 + 1.1 \log \eta$$

Table 2
Rheological parameter values and oral consistency scores of strawberry jam samples

Experiment	Sample name	Pectin content	Flow curves			Time effect on viscosity			
			Yield stress	Consistency index	Flow index	Apparent viscosity	% viscosity loss	Final shear rate	Oral consistency
			τ_o (Pa)	k (Pa·s ⁿ)	n				
(^a)	(%)	X ^b (s) ^c	X ^b (s) ^c	X ^b (s) ^c	η_{50} (Pa·s)	(s ⁻¹)	X ^b ±c·t ^d		
A	R60	0	3.3 (1.2)	1.13 (0.18)	0.78 (0.02)	0.54	7	500	13.0± 4.4
	H5	0.05	6.0 (2.0)	1.67 (0.30)	0.76 (0.03)	0.77	7	400	31.4± 6.9
	H20	0.20	8.0 (3.5)	3.40 (0.60)	0.71 (0.03)	1.41	40	260	92.9± 7.8
	H40	0.40	32.0 (7.0)	8.70 (1.50)	0.63 (0.05)	2.69	30	95	125.5± 2.8
B	R60	0	3.4 (1.7)	0.86 (0.80)	0.78 (0.02)	0.43	15	650	15.4± 4.6
	LM1	0.1	10.0 (3.0)	1.50 (0.04)	0.78 ^a	0.83	35	420	40.0± 6.3
	LM2	0.2	7.6 (2.7)	2.90 (0.80)	0.70 (0.04)	1.05	25	405	53.3± 6.2
	LM4	0.4	22.6 (4.3)	5.30 (0.60)	0.70 (0.03)	2.09	30	50	82.5± 6.1
	LM6	0.6	24.0 (4.8)	8.60 (2.20)	0.70 (0.08)	3.14	63	25	101.7± 5.0
C	R40	0	1.0 ^a	1.80 (0.50)	0.60 (0.03)	0.40			8.7± 2.4
	LA1	0.1	1.5 ^a	1.43 (0.24)	0.61 (0.02)	0.34	10	1 800	11.0± 4.8
	LA2	0.2	1.4 (0.3)	0.98 (0.30)	0.67 (0.05)	0.29	10	2 100	31.7± 9.0
	LA6	0.6	17.7 (10.0)	3.70 (1.50)	0.58 (0.07)	1.07	55	540	72.8± 8.8
	LB1	0.1	4.5 (2.0)	2.50 (0.80)	0.54 (0.05)	0.50	25	750	23.9± 6.4
	LB2	0.2	6.0 (5.0)	2.80 (0.50)	0.55 (0.05)	0.60	25	750	29.2±10.1
	LB6	0.6	22.0 (7.0)	4.96 (2.00)	0.53 (0.08)	1.23	34	120	88.8± 7.1

Table 2 (continued)

Experiment	Sample name	Pectin content	Flow curves			Time effect on viscosity			
			Yield stress τ_0 (Pa) X^b (s) ^c	Consistency index k (Pa·s ⁿ) X^b (s) ^c	Flow index n X^b (s) ^c	Apparent viscosity η_{50} (Pa·s)	% viscosity loss	Final shear rate (s ⁻¹)	Oral consistency $X^b \pm c \cdot t^d$
	(^a)	(%)							
D	R60	0	3.0 (1.0)	0.86 (0.20)	0.79 (0.07)	0.50			12.3± 3.9
	D54	0.2	13.0 (3.0)	4.40 (1.00)	0.66 (0.04)	1.42	56	250	36.1± 8.4
	D66	0.2	12.0 (3.0)	6.00 (0.90)	0.58 (0.03)	1.40	25	230	41.0± 6.7
	D83	0.2	16.0 (5.0)	6.40 (1.70)	0.68 (0.07)	2.15	55	210	109.8± 4.1
E	R60	0	1.5 (0.4)	0.58 (0.08)	0.86 (0.02)	0.36			10.9± 4.6
	D0	0.2	17.8 (7.0)	2.38 (0.10)	0.85 (0.02)	1.67	22	120	94.8± 8.0
	D3	0.2	15.3 (3.0)	2.13 (0.35)	0.82 (0.03)	1.35	16	150	75.6± 9.2
	D6	0.2	12.3 (6.0)	1.80 (0.40)	0.74 (0.04)	0.89	10	320	22.1± 4.9
	D12	0.2	9.8 (4.5)	2.00 (0.80)	0.72 (0.10)	0.87			27.2± 7.8
F	SI	0	4.0 (1.5)	1.07 (0.20)	0.81 (0.03)	0.63			37.2± 6.1
	GF	0	6.7 (2.0)	1.10 (0.40)	0.83 (0.06)	0.70			57.5± 7.8
	BI	0	12.3 (3.4)	3.90 (0.55)	0.71 (0.02)	1.49			83.4± 6.1
	XI	0	8.3 (2.3)	2.70 (0.30)	0.79 (0.03)	1.35			76.6± 7.5
	PFG	0	8.6 (4.0)	0.98 (0.25)	0.86 (0.04)	0.74			30.8± 7.5

a : Refer to table 1. R60: reference jam (60°Brix) without added pectin. R40: reference jam (40°Brix) without added pectin

b : X = mean value

c : s = standard deviation

d : c.i. = confidence interval

e : No replicate

Table 3

Coefficients of correlation of linear regression between oral consistency (S) and apparent viscosity (η) for different shear rate values

Shear rate (s^{-1})	Fechner's model ($S = K \log \eta + cst$)	Stevens's model ($\log S = n \log \eta + cst$)
1	0.67	0.72
10	0.70	0.73
50	0.87	0.85
100	0.60	0.63
500	0.51	0.53

4 - DISCUSSION

The apparent viscosity increases with increasing concentration of pectin. As seen in figure 2, the evolution of oral consistency with pectin concentration differs with the Brix degree: a logarithmic shape at 60°Brix and a linear one at 40°Brix.

At the same concentration, HM pectin gives a harder gel than the LM pectin. The oral consistency of the jam made with 0.6% of LM pectin is equivalent to that made with 0.25% of HM pectin. This fact is confirmed by Unipectine (Mero Rousselot Satia) which advises to use this HM pectin at a level of 0.2% and this LM pectin at a level of 0.4 to 0.6% to obtain a quite similar gel strength for a

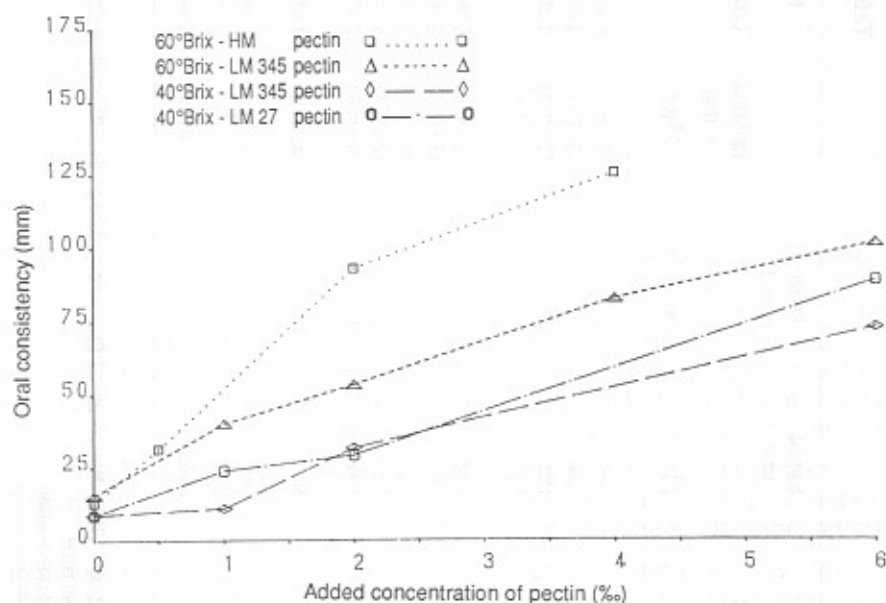


Figure 2

Evolution of oral consistency with pectin concentration

60°Brix jam. Moreover, as it can be seen in table 2, the viscosity and oral consistency decrease with decreasing molecular weight. This was also assessed by PANCHEV *et al.* (1988) but it was a simultaneous effect of decreasing the molecular weight and the degree of esterification. In dairy products, GREGORY (1986) showed that a higher viscosity was obtained with a Mex pectin (with a high molecular weight) compared to the currently used pectin at the same concentration. MITCHELL and BLANSHARD (1979) and later CRANDALL and WICKER (1986) related that the breaking strength is largely dependent on the molecular weight. Pectin with high molecular weight contains more flexible chains which remain cross linked after the short stiff chains have ruptured. This is in agreement with our observations, because the yield stress (τ_0), which gives a good evaluation of the breaking strength, increases with the molecular weight. It is more difficult to conclude about the influence of degree of esterification as only three pectins were studied and as, for one sample, the molecular weight was simultaneously modified. However these results does not confirm those of CRANDALL and WICKER (1986) and those of PILNIK (1970) who assessed that, at a given pH, the viscosity increases by decreasing the degree of esterification.

In the jams prepared with mixtures of different sugars and without pectin (experiment F), the highest apparent viscosity is obtained with the sorbitol-isoglucose 2:8 and the xylitol-isoglucose 2:8 mixtures. It is of interest to note that the apparent viscosity of these jams is close to that of the 0.2% HM pectin jam.

This study, which was performed on a large number of jam samples, seems to demonstrate that an easy and quick rheological measurement of jam can give a precise information of the oral consistency of the product. The correlation, that we observed between the apparent viscosity at 50 s^{-1} and the perceived consistency, was previously reported by MORRIS (1987) for disordered polysaccharide systems. The small amount of jam needed for rheological measurement permits a rapid cooling of the sample. It is thus possible to obtain a result in a short time whereas sensory analysis is more time consuming. This method can be of great use in industries to evaluate quickly the texture of a jam made for each new batch of fruits and to optimize manufacturing parameters.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. A. Baron (Recherches Cidricoles et Biotransformation des Fruits et Légumes, INRA, Le Rheu), M. Petit (Mero Rousselot) and T. Kravtchenko (Wageningen, The Netherlands) for providing respectively the enzyme, the pectin samples and the milled pectin.

Great thanks are also expressed to J.F. Thibault (Laboratoire de Biochimie et Technologie des Glucides, INRA, Nantes) and Pr. Pilnik (Wageningen, The Netherlands) for very helpful discussions.

This work is a part of a collaborative study (Action Incitative Programmée, AIP) organized and financed by Institut National de la Recherche Agronomique (INRA).

Received January 26, 1990; accepted July 10, 1990.

REFERENCES

- BARBOSA CANOVAS G.V., PELEG M., 1983. Flow parameters of selected commercial semi-liquid food products. *J. Texture Studies*, **14**, 213-234.
- CHENG D.-C.H., 1986. Yield stress: a time dependent property and how to measure it. *Rheologica Acta*, **25**, 542-554.
- COSTELL E., CARBONELL E., DURAN L., 1987. Chemical composition and rheological behaviour of strawberry jams. Relation with fruit content. *Acta Alimentaria*, **16**, 319-330.
- CRANDALL P.G., WICKER L., 1986. Pectin internal gel strength: theory, measurement and methodology. In: FISHMAN M.L., JEN J.J. (eds), *Chemistry and function of pectins*, 88-102, ACS Symposium Series. American Chemical Society, Washington DC.
- DERVISOGLU M., KOKINI J.L., 1986. Steady shear rheology and fluid mechanics of four semi-solid foods. *J. Food Sci.*, **51**, 541-546.
- FITO P.J., CLEMENTE G., SANZ F.J., 1983. Rheological behaviour of tomato concentrate (hot break and cold break). *J. Food Eng.*, **2**, 51-62.
- FORD E.W., STEFFE J.F., 1986. Quantifying thixotropy in starch thickened strained apricots using mixer viscometry technics. *J. Texture Studies*, **17**, 71-85.
- GREGORY D.J.H., 1986. The functional properties of pectins in various food systems. In: BIRCH G.C., LINDLEY M.G. (eds), *Interactions of food components*, 211-240, Elsevier, London.
- HYVÖNEN L., TÖRMÄ R., 1983. Examination of sugars, sugar alcohols and artificial sweeteners as substitutes for sucrose in strawberry jam. Product development. *J. Food Sci.*, **48**, 183-192.
- KOKINI J.L., KADANE J.B., CUSSLER E.L., 1977. Liquid texture perceived in the mouth. *J. Texture Studies*, **8**, 195-218.
- LANG E.R., RHA C., 1981. Determination of the yield stress of hydrocolloid dispersions. *J. Texture Studies*, **12**, 47-62.
- MITCHELL J.R., BLANSHARD J.M.V., 1979. On the nature of the relationship between the structure and rheology of food gels. In: SHERMAN P. (ed.), *Food texture and rheology*, 425-435, Academic Press, London.
- MORRIS E.R., 1987. Organoleptic properties of food polysaccharides in thickened systems. *Prog. Biotechnol.*, **3**, 225-238.
- MORRIS R.K., RICHARDSON R.K., TAYLOR L.J., 1984. Correlation of the perceived texture of random coil polysaccharide solutions with objective parameters. *Carbohydrate Polymers*, **4**, 175-191.
- OWENS H.S., LOTZKAR H., SCHULTZ T.H., MACLAY W.D., 1946. Shape and size of pectinic acid molecules deduced from viscosimetric measurements. *J. Am. Chem. Soc.*, **68**, 1628-1632.
- PANCHEV I.N., KIRTCEV N.A., KRATCHANOV C.G., PROICHEV T., 1988. On the molecular weight of pectic substances and its relation to their gel strength. *Carbohydrate Polymers*, **8**, 257-269.
- PILNIK W., 1970. Pektine. *Gordian*, **70**, 202-204.
- SAS/STATTM, 1987. *Guide for personal computers, version 6 Edition*. Cary, NC: SAS Institute Inc., 1 028 p.
- SHAMA F., SHERMAN P., 1973. Identification of stimuli controlling the sensory evaluation of viscosity. II: Oral methods. *J. Texture Studies*, **4**, 111-118.
- STEFFE J.F., FORD E.W., 1985. Rheological techniques to evaluate the shelf-stability of starch-thickened, strained apricots. *J. Texture Studies*, **16**, 179-192.
- TIU C., BOGER D.V., 1974. Complete rheological characterization of time-dependant food products. *J. Texture Studies*, **5**, 329-338.
- VAN DEVENTER-SCHRIEMER W.H., PILNIK W., 1987. Studies on pectin degradation. *Acta Alimentaria*, **16**, 143-153.