CHARACTERIZING THE TEXTURE OF FRANKFURTERS

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Abstract

The squeezing flow of frankfurter material was studied, using lubrication, at constant compression rate (1 mm/s) and area, on three formulation variants containing, respectively, high, medium and low protein contents (relatively).

The recipe and manufacturing method were those normally used in small-to-medium Chilean sausage factories using horse meat.

The model which best represented the characterization of frankfurters and the discrimination between their formulation was the Peleg model.

The final product made in this way exhibited the characteristics of a non-ideal solid of the generalized Maxwell type (asymptotic level of relaxation 0,5 N; corresponding to Peleg's model: a = 0,65, b = 0,04 s^{-1}. The associated characteristic textural properties are: maximal compression force = 1,62 N, elastic modulus = 0,64 N/mm (medium protein).

The rupture shear stress changed from 441 kPa for high protein through to 245 kPa for low protein.

From the models studied it was possible to characterize the texture of the three formulations used and to identify differences between them.

1. Introduction

In the rheology of materials which display solid and/or liquid behavior, an ideal solid can be represented as a spring with a modulus of deformability K, and an ideal liquid by viscous element (dashpot) with a Newtonian coefficient of dynamic viscosity, μ.

Penetration and compression tests are the most usual methods of characterization of solid properties.

The compression test is preferred as it gives more qualitative and quantitative information in the form of compression and relaxation curves. Frankfurters have a high fat content and provide viscous autolubrication during coaxial viscosimeter and compression tests. This lubricated slip is considered in the methodology of squeezing flow between lubricated plates and suitable considerations are incorporated in the analysis (Peleg, 1979).

Theoretical solutions are not the answer to the complete interpretation of the observed facts because the experimental procedures and/or instruments affect the rheological data obtained. For this study lubricated squeezing flow with a constant deformation rate and area was used.

1.1. Generalized viscoelastic models

The viscoelastic behavior of materials is conventionally represented by springs and dashpots in series and/or in parallel. The single pair of a spring in parallel with a dashpot is called a Kelvin element and the single pair spring/dashpot in series is called a Maxwell element. The expression for a generalized Maxwell model of n springs and m dashpots in series is (Fiszman et al., 1983; Peleg y Calzada, 1976):

$$\sigma_t = a_o + \sum_{i=1}^{m} a_i \exp{-t/\tau_i}, \qquad (1)$$

where:

a_i : relaxation coefficient for the Maxwell element i,

σ_t : relaxation stress at time t,

τ_i : relaxation time for the Maxwell element i.

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1.2. Peleg linearization

Peleg (1979) has developed a simplified model for experimental viscoelastic relaxation curves. The relaxation curve can be linearized by the following analytical expression (Peleg, 1979):

$$Y_{(t)} = \frac{\sigma_o t}{\sigma_o - \sigma_t} = \frac{1}{(a)\ (b)} + \frac{t}{b}, \qquad (2)$$

where:

σ_o : initial stress.

The constant "a" corresponds to the amount by which the stress fall during the relaxation. If a = 0, the stress does not relax at all (ideal elastic solid); if a = 1, the stress relaxes completely (i.a. a liquid) and for intermediate values of "a", the asymptotic residual stress values = Y(∞).

The constant "b" represents the relaxation rate in reciprocal time units [time^{-1}] (1/b is the time necessary for a= 1/2). If b = 0, the stress does not relax at all.

1.3. Characterization of solid products by compression test

Mechanical properties can be measured by different procedures such as shear (Damasio et al., 1990b), penetration (Damasio et al., 1990a) and compression (Fiszman et al., 1985, 1987).

Tests made with an universal rheometer can provide: stress-vs-time curves, stress-displacement curves, rupture stress and gel strength. Textural characteristics such us, "rigidity", "cohesiveness", "chewiness", "adhesiveness", derived to represent sensory attributes (Bourne, 1978) can also be determined from them.

The objetive of this present work was the textural characterization of frankfurters, a low-cost product widely consumed in Chile.

A textural properties analysis was carried out following the graphical method of Fiszman et al. (1985) and Damasio et al. (1990a,b). (See Fig. 1)

According to Bourne (1978) statements the following parameters can be define:

maximum Compresion stress	:	A [N],
cohesiveness	:	C [mm],
rigidity	:	A/C [N/mm],
elasticity	:	D/e [N/mm].

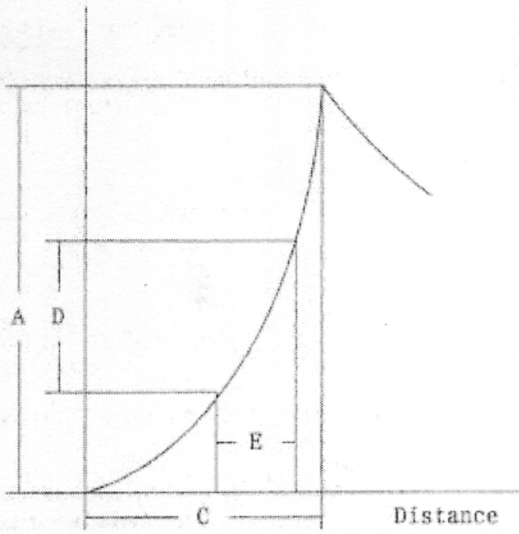

Figure 1: Typical stress-distance experimental curve for compression test.

2. Materials and method

The horse meat was obtained from the Chilean meat market and was stored under refrigeration. The additives were donated by Carlos Cramer Productos Aromáticos S.A.C.I., a specialized Chilean supplier.

Three differents formulations of increasing protein content were used, as given in Table 1.

The formulation with the higest protein ("High") and zero soya protein is typical of the more expensive type. The "medium" formulation is of a low-to-medium cost type most popular in Chile. The "low" formulation has least protein, more water and most and most soya protein.

2.1. Sample preparation

The common method typical of Chilean industry was used to prepare the samples. The meat paste was prepared in a 12 L capacity "Stephan " cutter, model VM 12, with two knives. The emulsions were stuffed into 25 mm diameter cellulose casings using a hand stuffer, linked to 13 cm lengths.

The frankfurters were smoked over burning sawdust for e.g. 10 minutes until temperature of 60°C was reached at the centre. The frankfurters were cooled with water. The units without skin were maintained under refrigeration (5°C).

Table 1 : *Composition of the Three Different Frankfurter Formulations*

Formulation Component	Composition Wt % "High"	"Medium"	"Low"
Fat "back" pork ("tocino")	19,50	20,70	22,10
Lean horse meat	48,00	41,10	32,10
Ice	29,10	30,70	31,40
Soybean isolate gel (Samprosoy MP 90 S 967 SO+)	0,00	4,14	11,04
Antioxidant (Frescolan #1150-57+includes ascorbic acid)	0,16	0,14	0,17
Sodium polyphosphate (Binderfos liga#11950 +)	0,07	0,07	0,06
Carrageenan (type Genugel CHP-200-c*)	0,32	0,31	0,33
Curing salt (Palacura R#11658+)	2,11	2,11	2,21
Traditional Chilean Seasoning (condimento #11624+includes onion, garlic)	0,74	0,73	0,66
TOTAL	100,00	100,00	100,00

* Trade name of Algas marinas S.A.
\+ Trade name of Carlos Cramer Productos Aromáticos S.A.C.I.

2.2. Frankfurter compression test

The measuring procedure was adapted from Campanella and Peleg (1987). A Rheotex 305-SD (Sun Scientific Co. Ltd., Tokyo) was used and the compression and relaxation rates were registered on a chart recorder Rikadenki (Kogyo, Co. Ltd. Japan).

The measurements were made after the samples had been equilibrated to 15°C.

Dimensions of samples wich were used for compression tests were 20 mm long sections, and with the same frankfurter diameter. The extremes of the frankfurters were discarded due to some residual forces at the ends.

Beilken et al. (1991), removed the cooked outer crust in their works. In the present investigation we work including the crusts to reproduce normal conditions under which frankfurters are commonly consumed.

The measurements were made with three replications, using two different heights in accordance with Campanella and Peleg (1987).

2.3. Rupture shear stress

Rupture shear stress was measured with a "Martin" tenderometer (Dietrich et al., 1957; Castro et al., 1992) using a Kramer shear cell with three replications. The frankfurter samples were orientated at right angles to the grid and blades of the cell and the tests were made with three replications.

3. Results and discusion

Most authors work with deformations rate in the range of 1 mm/s. In this work a 10 mm/s deformation rate was used and the form of the resulting compression curves (Fig. 2) are in general.

3.1. Peleg model

Results indicated that the "a" values were within the range 0.5-0.66 (Table 2) increasing with protein content, and "b" values increased from 0.023 to 0.048. Both quantities showed that the frankfurter was characterized as a solid (0< a <1) with a slow relaxation rate. This was in accordance with Ker and Toledo (1992) who tested frankfurters containing whey protein isolate.

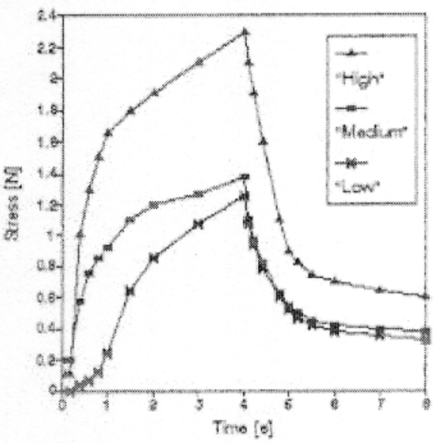

Figure 2: Representative experimental composition-relaxation curves for the three types of frankfurter at 1 mm/sec (formulations "High", "Medium", "Low" protein content).

3.2. Generalized Maxwell model analysis

The coefficients obtained from this analysis, presented in Table 2, show no trends or correlations of value. Maxwell model correlations to describe influence of protein contents are fairly good, but they are no significant due to even though all the R^2 values are high they do not change as a function of protein content. However, the relaxation curves shown in Fig. 3, which is not significant for this research, show a very close conformity between the measures values and the three-element Maxwell model curves.

Table 2: *Summary of Textural Constants*

Peleg Model		Generalized Maxwell Model							Maximum Compression Stress	Cohesiveness*	Rigidity+	Elasticity+
a	b	a_0	a_1	b_1	a_2	b_2	a_3	b_3	(N)	(mm)	(N/mm)	(N/mm)
Formulations "High"												
0,663	0,049	0,486	0,381	0,002	0,539	0,022	0,497	0,854	1,91±0,20	4,00±0,01	4,46±0,81	0,72±0,09
Formulations "Medium"												
0,654	0,035	0,495	0,510	0,005	0,370	0,303	0,241	2,148	1,62±0,14	4,00±0,01	0,62±0,09	0,64±0,06
Formulations "Low"												
0,506	0,023	0,594	0,265	0,002	0,241	0,025	0,264	0,627	1,37±0,16	4,00±0,01	0,35±0,05	0,52±0,07

* Imposed by nature of test
\+ Defined by Bourne (1978)

3.3. Textural characteristics

The maximum compression stress and elasticity values showed an increased with increased protein content (Table 2), that is not the case of Ker and Toledo (1992). Least favorable statistical data are shown in Table 3.

Peleg model (1979) analysis was fitted and it is easier to be used than generalized Maxwell model and besides it gave much more information and a better goodness of fit as well.

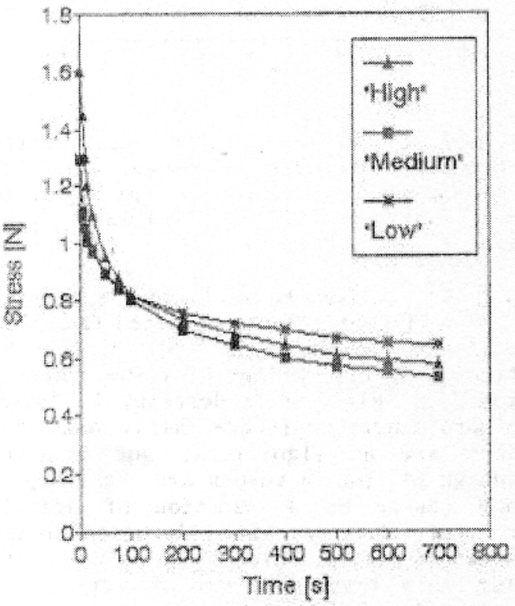

Figure 3: Generalized Maxwell model, 3 elements (formulations "High", "Medium", "Low" protein content).

3.4. Rupture shear stress

The Martin tenderometer tests showed increased rupture stress with protein content (Table 4).

Table 3: *Least favourable statistics for these tests*

Statistical parameter	Peleg model	Generalized Maxwell model
Standard Deviation for Y (in Peleg model Y, Maxwell model σ [N])	32,8	-
Standard Deviation for X (time, [N])	0,02	-
Correlation Coefficient	0,9972	-
Variance	-	0,00014
Regression Coefficient	-	0,99690

Table 4: *Kramer Cell rupture stress for the three frankfurter types*

Formulations	Shear stress (kPa)
"High"	441,0 ± 49,0
"Medium"	411,6 ± 9,8
"Low"	245,0 ± 49,0

4. Conclusions

Peleg model analysis clearly gave the most useful information, the best correlation with protein content and quickest results.

Maxwell analysis gave results closely in accordance with the measurements on the three types of sausage but provided no information on or correlation with differences between them.

The lowest cost system, the Martin tenderometer, provides measurements wich correlate with the differences in these particular sausage types but are, of course, empirical.

From the directly-measured stress time compression plots it is possible to obtain information and immediate visual parameters of the different sausage types, which can be valuable to an operator on the factory floor (Fig. 3).

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References

Beilken S. L., Eadie L. M., Jones P. H. and Harris P. V., "Objetive and subjetive assesment of australian sausages", *J. Food Sci.* 56 (3), 636-642 (1991).

Bourne M. C., "Texture pofile analysis", *Food Technology* 32 (7), 62-66 (1978).

Campanella O.H. and Peleg M., "Squeezing flow viscosimetry of peanut butter", *J. Food Sci.* 52, 180-184 (1987).

Castro E., Koch F., Guarda A., Wittig E. and López L., "Papas pre-fritas congeladas", *Alimentos*, 17 (4), 23-24 (1992).

Damasio M. H., Capilla C., Costell E., and Durán L., "Influencia de la composición en las propiedades mecánicas de geles mixtos de kappa-carragenato, goma de garrofín y goma guar. Resistencia a la penetración", *Rev. Agroquím. Tecnol. Aliment.* 30 (1), 109-121 (1990a).

Damasio M. H., Capilla C., Costell E. and Durán L.,"Influencia de la composición en las propiedades mecánicas de geles mixtos de kappa-carragenato, goma de garrofín y goma guar. Resistencia al corte", *Rev. Agroquím.Tecnol. Aliment.* 30 (2), 254-265 (1990b).

Dietrich M. H., Lindquist F. E., Mildred M. and Boggs, "Effect of madurity and storage temperature on quality of frozen peas", Food Technology, 11 (19), 485-489 (1957).

Fiszman S. M., Costell E. and Durán L., "Medida del comportamiento reológico de los alimentos sólidos: I. Bases teóricas", *Rev. Agroquím. Tecnol. Aliment.* 23 (2), 164-172 (1983).

Fiszman S. M., Costell E., Durán L., "Efecto de la concentración y de la adición de iota-carragenato y de goma garrofín en la resistencia a la compresión de geles de kappa-carragenato", *Rev. Agroquím. Tecnol. Aliment.* 25 (4), 591-596 (1985).

Fiszman S. M., Baidón S., Costell E. and Durán L., "Propiedades funcionales de la goma de garrofín. Influencia en la resistencia a la compresión de geles de agar y de kappa-carragenato", *Rev. Agroquím. Tecnol. Aliment.* 27 (4), 519-529 (1987).

Ker Y. C. and Toledo R. T., "Influence of shear treatment on consistency and gelling properties of whey protein isolate suspensions", *J. Food Sci.* 57, 82-90 (1992).

Peleg M. and Calzada J. F., "Stress relaxation of deformed fruits and vegetables", *J. Food Sci.* 41, 1325-1329 (1976).

Peleg M., "Characterization of the stress relaxation curves of solid foods", *J. Food Sci.* 44 (1), 277-281 (1979).