THE EFFECT OF BIOGEL CONTENT ON THE SOME VISCOELASTIC PROPERTIES OF A SNAIL PATE

VIORICA MIRELA POPA, DANA CAROLINA CRISAN, DIANA NICOLETA RABA, CONSTANTIN MATEESCU

1"Lucian Blaga" University of Sibiu, Faculty of Agricultural Sciences, Food Industry and Environmental Protection, Bd-ul. Victoriei, Nr.10, Sibiu, 550024, România
2Banat's University of Agricultural Sciences and Veterinary Medicine from Timisoara, Dept. Food Processing Technology, 119 Calea Aradului, 300645 Timisoara, Romania,
c.mateescu@usab-tm.ro

ABSTRACT

Four sorts of snail pâté with different contents (0, 1, 2, 3%) of a vegetal protein (biogel) were prepared. The influence of the content of biogel on the viscoelastic characteristics of snail pâté were studied in this paper. These characteristics of snail pâté were derived from stress relaxation tests. The relaxation times and the elastic moduli, as viscoelastic characteristics, were calculated from the relaxation curves by non-linear regression. The best correspondence between experimental data and calculated curves was obtained for a mechanical model with three Maxwell elements in parallel with a lone ideal spring element. Every measurement was made in triplicate. From above viscoelastic parameters, the viscosities were calculated. Correlation between experimental relaxation curves and calculated curves were emphasized by absolute average deviation (AAD), the minimum AAD value being 0.15% and the maximum one 0.82%. The stiffest snail pâté contains 2% biogel, and the snail pâté with 3% biogel is more viscous.

Keywords: snail pâté, rheology, viscoelastic properties, stress relaxation, temperature influence

INTRODUCTION

Snail meat is a delicacy in Japanese and Chinese. In French, North of America and Australia it is consumed also as main meal. In South Africa, land snail is also a traditional food. Snail recipes vary from cuisine to cuisine. Studies on the nutritional value of snail have reported that snail is high in protein but low in fat contents. It is estimated that snail is 15% protein, 2.4% fat and about 80% water. This makes snail healthy alternative food for people with high protein low fat diet requirements. Besides, snail is high in health benefiting essential fatty acids such as linoleic acids and linolenic acids (SU, 2004), Having a low content of lipids and high content of proteins, meat snail is similarly with fish meat.

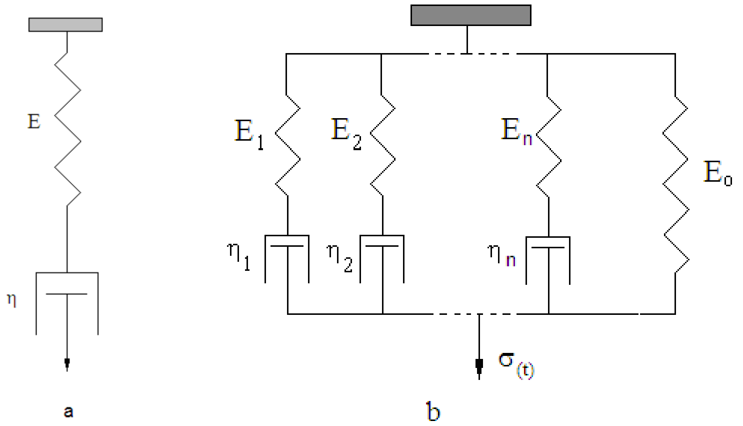
Nowadays, there is an increasing demand for foodstuffs with lower fat content. However, the reduction of fat in meat products or its replacement with a more unsaturated fat might affect their technological or sensory characteristics (MARTIN, 2008), mainly in products in which fat is one of the major components of the formulae, such as frankfurters, sausages, beef patties or liver pâtés (PINHO, 2000) The rheology of pâté is less studied. There are same references on rheology of ham pâté (VIANA, 2005), and of pork liver pâté by textural profile analysis and penetration tests (D'ARRIGO, 2004). In addition, the consistency at 23°C of the refrigerated pâtés was calculated from compression tests (MARTIN, 2008). There are not signaled yet the study of viscoelastic characteristics of different pâté formulae. The similar studies on snail pâté are not signaled. The stress relaxation test (or step strain test) is one of the most important evaluation tools used for determining viscoelastic properties of materials (CAMPUS, 2010, BELLIDO, 2009, OLIVERA, 2009, RODRIGUEZ-SANDOVA, 2009, BHATTACHARYA, 2006, HERRERO, 2005).

In this paper, we try to characterize by stress relaxation tests the viscoelasticity of some variants of snail pâté with different content of vegetal protein.

MATERIAL AND METHOD

Theoretical background

Many food products simultaneously exhibit obvious fluid-like (viscous) and solid-like (elastic) behavior. Manifestations of this behavior, due to a high elastic component, can be very strong and create difficult problems in process engineering (STEFFE, 1996). In the book of Steffe, one of the best books for American food engineers, the subject of viscoelasticity has very well present in chapter 5. One of the most used transient tests for viscoelasticity is stress relaxation (step strain). In stress-relaxation experiments, the test specimen is compressed to a predetermined level of strain that is kept constant, during which time the viscoelastic material shows a declining trend of force/stress as a function of time (YADAV, 2006). Viscoelastic materials are relaxed gradually, the end point depending on the molecular structure of the material being tested. (STEFFE, 1996, TABILO-MUNIZAGA, 2005). Mechanical models or analogues have been developed to predict different patterns of viscoelasticity. The Maxwell model has frequently been used to interpret stress-relaxation data of a viscoelastic material (RODRIGUEZ-SANDOVA, 2009). A Maxwell element consists of a spring and a dashpot arranged in a series (figure 1a). The model involves a parallel coupling of a Hooke's body and *n* Maxwell's bodies (LACHOWICZ, 2003) as shown in figure 1b.



a b

Figure 1. Mechanical models used to solve the experimental data from relaxation tests (a –Maxwell element; b – a mechanical model with *n* Maxwell elements and an ideal spring in parallel)

The stress relaxation equation described by this mechanical model is given by equation 1.

$$\sigma(t) = \varepsilon \cdot \left(E_o + \sum_{i-1}^{n} E_i \exp\left(-\frac{t}{\lambda_i} \right) \right) \qquad (1)$$

In this equation, *(t)* is the stress at any time during the relaxation test, is the initial constant strain. Because testing was conducted in uniaxial compression, E_i is equilibrium modulus (Young's modulus) of the *n* springs from the *n* Maxwell elements, and E_o is the equilibrium modulus for the lone ideal spring element. In addition, $\square_i$ represents the relaxation times, which is defined in terms of the ratio between viscosity of the fluid from the *n* dashpots and the elastic modulus (equation 2):

$$\lambda_i = \frac{\eta_i}{E_i} \qquad (2)$$

Equation 1 could be written as:

$$\frac{\sigma(t)}{\varepsilon} = E(t) = E_o + \sum_{i-1}^{n} E_i \exp\left(-\frac{t}{\lambda_i} \right) \qquad (3)$$

where *E(t)* is the equilibrium module of the sample from snail pâté. It exponentially decreases with the time of relaxation process.
At the initial moment, when t = 0,

$$E_{\text{initial}} = E_o + \sum_{i-1}^{n} E_i \qquad (4)$$

Finally, when t →∞, $E_{\text{final}} = E_o$

Experimental measurements
The ingredients for preparing three variants of pâté with different content of biogel (0; 1; 2; and respectively 3%), are presented in a previous paper (CRISAN, 2011). Cans with snail pâté were storage at 4-6°C in refrigerator. To equilibrate at room temperature cans were maintained 2 hours before measurements. Using a cork borer, cylindrical specimens of snail pâté were prepared. The specimens had a diameter of 20 mm and their height was adjusted at 10-15 mm. The exactly height of the sample had been measured with a digital caliper Black & Decker. To determinate the viscoelastic characteristics, by stress relaxation tests, a compression apparatus JTL Janz was used. Stress relaxation characteristics of the lubricated (using paraffin oil) cylindrical sample were determined by uniaxial compressing the sample up to a Cauchy strain of 0.10 at a compression rate of 6 $mm \cdot min^{-1}$. When the compression was achieved at the desired level, the upper plate (a square with a surface of 9 cm^2) was stopped, and the pâté sample was allowed to relax for 300-400 s. The force at different relaxation times was continuously monitored. Every measurement was made in triplicate. The TableCurve program has been used for non-linear regressions and Origin program to plot experimental data and to draw the calculated stress-relaxation curves.

Statistical analysis
The overall predictive capability of the mechanical model used could be commonly explained by the coefficient of determination (R^2), but R^2 is not a measure of the model's accuracy. Absolute average deviation (AAD) analysis is a direct method for verifying the model's suitability. The AAD is calculated by equation 5:

$$AAD = \left(\left(\sum_{i=1}^{n} \left(\frac{\left| y_{i,exp} - y_{i,cal} \right|}{y_{i,exp}} \right) \right) \cdot \frac{1}{n} \right) \cdot 100 \qquad (5)$$

where $y_{i,exp}$ and $y_{i,cal}$ are the experimental and calculated responses, respectively, and n is the number of the experimental runs. Evaluation of AAD and R^2 values together should check better the accuracy of the mechanical model (BOYACI, 2004).

RESULTS

A typical stress-relaxation curve for snail pâté with 2% biogel is shown in figure 2. The stress-relaxation curves for all variety of snail pâté at the three studied temperatures are similar with the curves from figure 2. The same picture of these stress-relaxation curves for muscle tissues from Gilthead Sea Bream (CAMPUS, 2010), Asian noodles (BELLIDO, 2009), frozen cooked organic pasta (OLIVERA, 2009), cassava dough (RODRIGUEZ-SANDOVA, 2009), ice-stored cod (HERRERO, 2004) and acid milk gel (HOUZE, 2005) had been obtained.
By previous statistical tests, the best correspondence between experimental data and calculated curve (eq. 1) was obtained for a model with three Maxwell elements similar

with the mechanical model from figure 1b.

The mechanical answer against an imposed deformation is described by equation 6, derived from equation 1:

$$\sigma(t) = \varepsilon\left(E_o + E_1 \exp\left(-\frac{t}{\lambda_1}\right) + E_2 \exp\left(-\frac{t}{\lambda_2}\right) + E_3 \exp\left(-\frac{t}{\lambda_3}\right)\right) \qquad (6)$$

The same model was used to analyze stress relaxation curves for muscle tissues from Gilthead Sea Bream *(Sparus aurata* L.) (CAMPUS, 2010), frozen cooked organic pasta (OLIVERA, 2009), and frozen stored Cape hake (*M. capensis* and *M. paradoxus*) (HERRERO, 2005).

In the stress-relaxation curves presented in figure 2, stress depends on time, with three zones: The initial portion shows a high slope, the third zone has the lowest slope and appears to approach a residual or an equilibrium value, whereas the second zone is intermediate between these two zones (YADAV, 2006). In the stress-relaxation curve of samples with 2% biogel, these three zones are showed clearly in figure 2. As an example, from the curve with AAD = 0.59% the first zone was in the range of 550–750 Pa, the second zone ranged from 550 and 450 Pa, and the third zone was between 450 to 400 Pa.

The parameters obtained by non-linear regression from the above mentioned model, E_1, E_2, E_3, E_o, λ_1, λ_2, and λ_3 are detailed in Table 1. From these values $E_{initial}$, $\frac{E_o}{E_{initial}}$, and the viscosities η_1, η_2, and η_3, were calculated and presented in the same table. It can be observed all values are influenced by the content of biogel in snail pâté. At the same content of biogel the values of the relaxation times increase in order $\lambda_1 < \lambda_2 < \lambda_3$. The first relaxation process occurs in the first portion of relaxation curve (figure 2) for $\lambda_1 < 0.5$ seconds, portion where is a marked reduction of the relaxation stress. The third relaxation process happens in the final portion of the relaxation curve where a small reduction of the stress occurs.

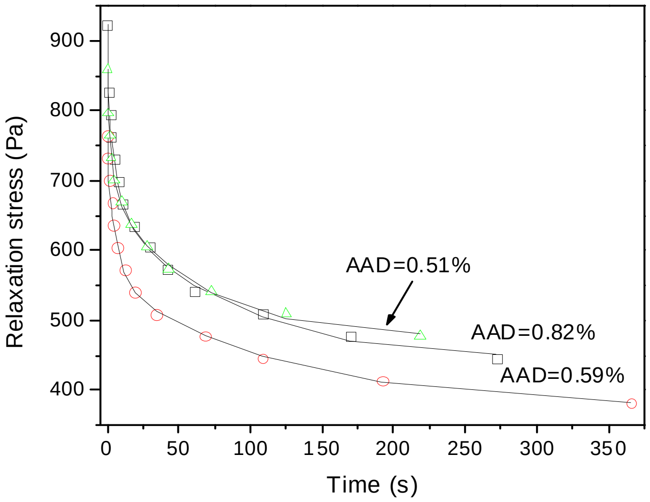


Figure 2. A typical experimental data and stress-relaxation curve for samples of snail pâté with 2% biogel, fitted by the Maxwell model. Experimental data (□,○, Δ), fitted curve (continuous line)

The elastic moduli E_1, E_2 and E_3 were affected significantly by the content of added biogel. The magnitude of $_o$, calculated as product of imposed deformation of the sample and the equilibrium modulus for the lone ideal spring element ($□_o = E_o \cdot □$), can be taken as a measure of the stiffness of the material (Campus, 2010). Because for all samples the deformation was the same (□ = 0.1) the samples with the highest elastic modulus values are the stiffest materials. Appears from the table 2 the stiffest material is the snail pâté with 2% biogel. The absence of biogel corresponds to a less stiffness material.

For all varieties of snail pâté, the calculated viscosities increase in the order $_1 < \; _2 < \; _3$. The highest values of viscosities have the samples without biogel and the samples with 3% biogel. The lower values for viscosities were found in the samples with 2% biogel. The ratio of the equilibrium modulus (E_o) to $E_{initial}$ (equation 4) could gives an information of viscoelastic characteristics of snail pâté. A less values of this ratio, means a more pregnant viscous nature of the sample. A greater value of the ratio, signify a greater elastic nature of the material (Steffe, 1996). Therefore, the snail pâté with 3% biogel is more viscous and snail pâté with 1% biogel is less viscous.

CONCLUSIONS

A mechanic model with three Maxwell elements and an ideal spring in parallel is the best solution to analyze the relaxation curves. By nonlinear regression with a mathematical model corresponding to mechanical model was determined the values of the relaxation times and of the elastic moduli. From these viscoelastic characteristics was calculated the values of the viscosities. From the equilibrium modulus for the lone ideal spring element appears as the stiffest material is the snail pâté with 2% biogel. The snail pâté with 3% biogel is material that is more viscous.

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