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# INFLUENCE OF HEMICELLULOSE ON SOME RHEOLOGICAL PROPERTIES OF BREAD

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## Abstract

*It was determined from compression tests the young modulus for bread crumb with different contents of hemicellulose. A sigmoid compressive stress-strain relationship is characteristic to bread crumb. Also, the influence of hemicellulose content on viscoelastic characteristics of bread crumb was studied with relaxation tests. The relaxation data could be fitted by equations that derived from generalized Maxwell model and by normalization and linearization of the experimental force relaxation curves.*

***Keywords**: compression, relaxation, Young modulus, viscoelastic properties, bread crumb, hemicellulose.*

## Introduction

Nowadays, the use of additives has become a common practice in the baking industry. The objectives of their use are to improve dough-handling properties, increase quality of fresh bread and extend the shelf life of stored bread. With this objective, a large extent of additives of different chemical structure are used, and lately, the enzymes due to be clean label are preferred by the baking market (Rosell, 2001).

A method of improving the properties of dough and the quality of bread by adding to the dough, dough ingredients, ingredient mixture or dough additives or additive mixture an enzyme preparation comprising hemicellulose. Hemicellulose is a general term for the noncellulose fiber fraction of plant cell walls. The basic structure of hemicellulose is a main chain with side chains attached, both of which can be made from a variety of five and six carbon sugars. Pentosans are the part of the hemicellulose fraction where the main chain is made up of five carbon sugars, usually D-xylose. Pentosan fractions can be soluble or insoluble, depending among other factors on their degree of polymerization. The hemicellulose fraction is usually described as insoluble.

In bread baking, hemicelluloses produce an effect that can result in many desirable benefits including increased extensibility, increased product volume and improved crumb softness. The hemicellulose undergoes a hydrolysis reaction which improves the availability of moisture in the dough (Caballero-Briones, 2000). Studies have confirmed previous findings showing that water-binding capacity and retention in the starch and hemicellulose fractions of the bread, being the substrates of $\alpha$-amylases and xylanases, respectively, to be critical for maintaining softness and elasticity. The recently determined three-dimensional structure of the widely applied amylase for antistaling provided further insight into the mechanism of enzyme action (Dauter, 1999). This amylase is probably capable of degrading amylopectin to a degree that prevents re-crystallization after gelatinization, without completely degrading the amylopectin network which provides the bread with elasticity. (Kirk, 2002).

It were studied the influence of hemicellulose content on rheological properties of bread crumb. Rheological characterization was made by compressive loading tests and relaxation tests. To obtain the Young modulus of dough at little values of Cauchy strain the compressive test was used (Dogaru, 2004). Also, relaxation test was used (Gamero 1993, Steffe, 1996).

## Experimental

*Bread-making procedure*. A straight dough process was carried out for preparing the bread samples. A basic bread formula, based on flour weight, was used: 450 g flour, 56% water, 1.6% yeast, 2% salt, and 0; 0.05; 0.10; 0.15; 0.20; 0.25; and 0.30% hemicellulose. ALASKA BM 2000, a device for whole bread making process was used. For this device the optimal parameters are: mixing – 30 minutes, fermentation – 130 minutes, backing – 50 minutes.

*Evaluation of bread crumb quality*. Parallel to bread bottom a medium slice of about 3 cm was cut from bread, and 3 flat, cylindrical specimens were prepared from them using a cork borer, avoid the crust. The slices were cut from bread after 2 hours staying at room temperature. The specimens had a diameter of 20 mm and their height was adjusted at 15-25 mm. Compression and relaxation tests were conducted as above. Calculus and graphical representation were realized with ORIGIN computer program.

Two replicates were analyzed and averaged.

## Results and Discussions

Compression curves obtained, $\tau = f(\varepsilon)$, express the dependence of compression stress $\boldsymbol{\tau}$ by Cauchy strain $\boldsymbol{\varepsilon}$ (Steffe, 1996). A compression curve for bread crumb with 0.20% hemicellulose is presented in figure 1. As it can be observed there is a sigmoidal dependence, being similarly with compressive stress-strain curves obtained for rye bread (Swyngedau, 1991). From the slope of the first part of the experimental curve ($\varepsilon_c < 0.2$) it was calculated the compression modulus or Young modulus (E).

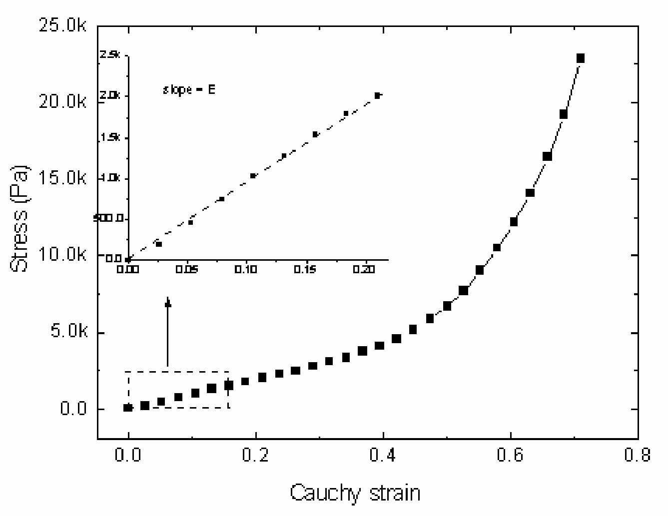


**Fig. 1**. Compression curve for bread crumb with 0.20% hemicellulose

The variation of values of Young modulus for bread crumbs with different hemicellulose content is presented in figure 2.

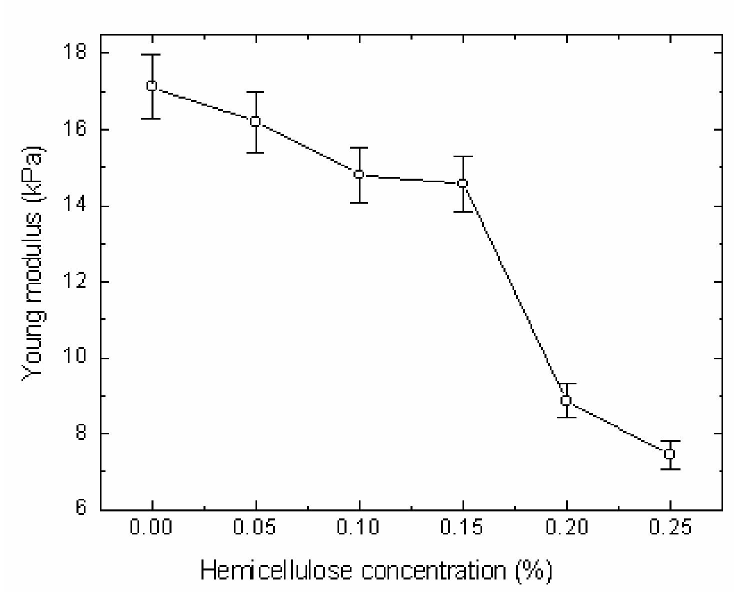


**Fig. 2.** The influence of hemicellulose content on the values of Young modulus of bread crumb

From figure 2 could be observed the influence of hemicellulose on the elastic properties of bread crumb. For concentration of hemicellulose from 0 – 0.15% there is a little decrease in Young modulus values, from 17.1 kPa to 14.6 kPa. For concentration in hemicellulose greater than 0.15% the values of Young modulus decreases to 8.8 kPa for a content of 0.20% hemicelluose, respectively to 7.5 kPa for a content of 0.25% hemicelluose. It is evident the great influence of hemicellulose on the bread crumb elasticity and texture, and on the improving of dough gluten network and on gas retention.

The relaxation test is a static procedure used to characterization viscolelastic properties of studied bread crumb. The obtained relaxation data could be excellent fitted by equations that were derived from generalized Maxwell model, consists of two parallel Maxwell element connected in parallel with a spring (Steffe, 1996):

$$F(t) = F_e + A_1 \cdot \exp\left(-\frac{t}{\lambda_1}\right) + A_2 \cdot \exp\left(-\frac{t}{\lambda_2}\right) \quad (1)$$

In this relation $F_e$ (equilibrium force) represents the value of relaxation force at high values of time (t), $A_1$ and $A_2$ are the initial values of force on Maxwell elements, and $\lambda_1$ and $\lambda_2$ are relaxation times for dough.

A way to overcome some of the difficulties of the Maxwellian models is by normalization and linearization of the experimental force relaxation curves using an empirical equation proposed by Peleg (Steffe, 1996):

$$\frac{F_{(o)} \cdot t}{F_{(o)} - F_{(t)}} = k_1 + k_2 \cdot t \quad (2)$$

where $F_{(o)}$ is the force at time zero, $F_{(t)}$ the force after time t, $1/k_1$ is related to the initial stress decay rate, and$1/k_2$ to a hypothetical asymptotic level of stress not relaxed at long time constants (Gamero, 1993).

The values of $\lambda_1$, $\lambda_2$, $k_1$ and $k_2$ for all contents in hemicellulose are presented in table 1.

**Table 2**. Influence of hemicellulose content on bread crumb relaxation values

| Hemicellulose content (%) | $\lambda_1$ (s) | $\lambda_2$ (s) | $k_1$ (s) | $k_2$ |
|---|---|---|---|---|
| 0 | 18.70 | 217.4 | 118.5 | 2.61 |
| 0.05 | 12.06 | 128.5 | 83.0 | 2.58 |
| 0.10 | 10.68 | 133.8 | 85.3 | 2.58 |
| 0.15 | 9.92 | 105.7 | 63.7 | 2.53 |
| 0.20 | 8.65 | 104.2 | 75.7 | 2.77 |
| 0.25 | 8.13 | 102.8 | 69.9 | 2.65 |

It is clear from the table 1 that hemicellulose important influences viscoelastic properties of bread crumb. The smaller values of first relaxation time $\lambda_1$, 8.13 – 12.06 s in presence of hemicellulose, suggest fewer values for initial stress decay, namely more pronounced bread elastic properties. The second Maxwell relaxation time $\lambda_2$, corresponding to the curve stabilization zone, represents the rate of relaxation of the main gluten bread structure. A hemicellulose content of 0.15-0.25% (table 1) assures the best values for these times.

In figure 2 there is experimental stress relaxation curve obtained for specimens from bread with 0.20% hemicellulose. Also is presented normalized stress relaxation curve.

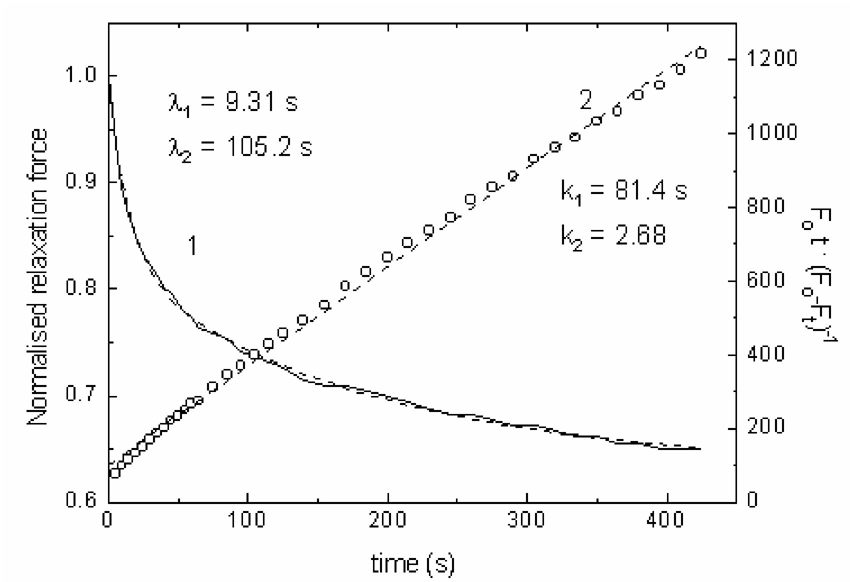


**Fig. 2**. Stress relaxation curves (1) and normalized stress relaxation curve (2) for bread crumb with 0.20% hemicellulose (dot line – calculated curve)

Parameters $k_1$ and $k_2$ were calculated from Peleg's equation (Eq. 2) by linear regression. The smallest values for Peleg parameter $k_1$ are attained at a hemicellulose content of 0.15-0.25%, when are obtained the smallest values for initial stress decay. Probably, hemicellulose induces a weakening effect of dough gluten structure.

The proportion of relaxed initial force is represented by $k_2$. The greatest values of $k_2$ which show the highest "solidity" of bread are observed at a hemicellulose content of 0.20-0.25% similar with the best elastic properties of bread crumb.

For all studied rheological parameters of bread crumb were calculated the Pearson coefficients for linear correlations (table 2). The best linear fitting was obtained for dependence $\lambda_1 - \lambda_2$ (R = 0.980) and for dependence $k_1$ - $\lambda_2$ (R = 0.975). Also, good dependence (R = 0.935) there is for $\lambda_1$ and $k_1$. This suggests that the both mathematical treatment of relaxation data, by equations 1 and 2 are strong means for interpretation stress relaxation tests.

**Table 2**. Pearson coefficients for linear correlations between studied rheological parameters

| | $\lambda_1$ | $\lambda_2$ | $k_1$ | $k_2$ | E |
|---|---|---|---|---|---|
| $\lambda_1$ | - | **0.97977** | *0.93553* | -0.27790 | 0.74917 |
| $\lambda_2$ | **0.97977** | - | **0.97521** | -0.00036 | 0.65797 |
| $k_1$ | *0.93553* | **0.97521** | - | -0.00011 | 0.11996 |
| $k_2$ | -0.2779 | -0.00036 | -0.00011 | - | -0.69822 |
| E | 0.74917 | 0.65797 | 0.11996 | -0.69822 | - |

## Conclusions

Taking into consideration all experimental data presented in table 1, results that a hemicellulose content of 0.15-0.20% assure the best quality for bread, from rheological point of view.

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