R. Laszlo, et al. Scientifical Researches. Agroalimentary Processes and Technologies, Volume XI, No. 1 (2005), 109-114

INFLUENCE OF FERMENTATION ON RHEOLOGICAL PROPERTIES OF DOUGH AND BREAD CRUMB

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Abstract

From compression tests was determined the influence of duration of fermentation on elasticity of dough and bread crumb. It was established a linear decrease with duration of fermentation for dough Young modulus. From relaxation tests were studied some viscoelsatic properties of dough and bread crumb obtained at different duration of fermentation.

Keywords*: dough, bread crumb, elasticity, viscoleasticity*

Introduction

As a solid, bread is "soft", and like many other foodstuffs, at macroscopic level is comprised of two phases: a fluid (air) and a solid (cell wall material) (Campbell, 1999). The solid structural matrix consists of polymers, which are completing amorphous (gluten) or partially crystalline (starch) (Peleg, 1986). The ingredients that are used to create basic formula dough are: flour, water, leavening agent, and salt. To convert these mix ingredients into final aerated structure, a number of processing operations are performing. The operations are carried out in such way that the dough posses the appropriate mechanical properties that permit to retain gas and thus produce a well-expanded loaf of bread with an even crumb structure (Kokelaar, 1995). The objectives of processing operations are (Scanlon, 2001):

- Mixing and development of the dough (mixing and fermenting);
- Formation of a foam structure in the dough (moulding, proofing and baking);
- Stabilization of a porous structure by altering the molecular configuration of the polymeric components in the cell walls through the application of heat (baking).

In this paper is trying to get answers for two questions:

1. How the duration of fermentation influence the dough rheology?
2. How the duration of fermentation influence the rheological properties of bread crumb?

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, and 2% salt. ALASKA BM 2000, a device for whole bread making process was used.

Evaluation of dough quality. The duration of fermentation was 0, 30, 60, 90, 120, 150, and respectively 180 minutes. During fermentation, dough probes were taken at every 30 minutes. Using a cork borer (20 mm diameter), dough specimens with height of about 20 mm were cut. Taking into consideration that at small values of Cauchy strain dough could be considerate as having elastic behaviour, to determinate Young modulus, by using a compression apparatus JTL Janz, the dough specimens were uniaxial compressed between parallel-lubricated plates at 6 mm $\cdot$ min^{-1}. To study some of viscoelastic properties of dough, the same apparatus was used for stress relaxation tests. In this sense, the specimen, placed between two parallel plates, the upper plate moving downwards with constants speed of 6 mm$\cdot$s^{-1}. When a strain of about 0.5 was attained, the downward moving of upper plate was stopped and variation in time of compression force was registered.

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. For determining crumb density the specimens were weighed with a precision of 0.00 g. 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

Dough rheology. Compression curves obtained express the dependence of compression stress τ by Cauchy strain ε (Steffe, 1996). A compression curve for dough after 70 minutes of fermentation is presented in figure 1. Could be observed 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 initial compression modulus or Young modulus (E). The values of dough Young modulus at different duration of fermentation are presented in table 1. The duration of fermentation decrease the value of Young modulus, this dependence being almost linear (R = -0.98513). The hydration, development of the gluten proteins and occlusion of air contribute to formation of a foam structure in the dough. The decreases of Young modulus could be explained by formation of this foam structure.

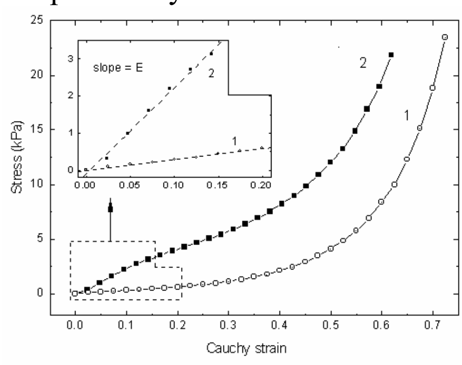

Fig. 1. Compression curves for dough after 120 minutes of fermentation (curve 1) and bread crumb obtained from this dough (2)

Table 1. The influence of duration of fermentation on rheological characteristics (±S.E.) of dough

	Duration of fermentation (min)						
	0	30	60	90	120	150	180
Young modulus (Pa)	4283±311	3843±186	3146±182	2980±273	2548±624	2334±237	2023±242
λ_1 (s)	5.33±0.26	5.10±0.47	4.95±0.38	4.55±0.43	4.33±0.78	3.71±0.20	3.52±0.33
λ_2 (s)	84.4±8.3	81.9±11.1	70.9±6.8	67.3±4.6	62.4±3.3	59.3±4.7	57.6±3.2
k_1 (s)	21.5±1.8	20.3±1.6	18.1±0.9	17.9±0.8	17.2±0.3	16.6±0.9	16.0±0.5
k_2	1.40±0.02	1.41±0.02	1.44±0.02	1.42±0.02	1.40±0.02	1.40±0.01	1.44±0.01
F_e (%)	31.2±2.8	31.5±2.8	32.9±2.4	32.2±1.6	31.2±1.6	31.4±0.8	32.9±1.8

The relaxation test is a static procedure could be used to characterization viscolelastic properties of dough. 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 λ_1 and λ_2 are relaxation times for dough. The values of F_e, λ_1 and λ_2 are presented in table 1. The greater values for equilibrium force suggest more elastic properties of dough, and the smaller suggests more viscous properties. There is a very weak association between equilibrium force and time (R = 0.32418). The smaller values of first relaxation time λ_1, suggest greater values for initial stress decay, namely more pronounced dough viscoelastic properties. The second Maxwell relaxation time λ_2, corresponding to the curve stabilization zone, represents the rate of relaxation of the main gluten dough structure. The zone of stabilization relaxation is final portion of relaxation curve (figure 2). As are observed from table 1, both λ_1 and λ_2 linear decrease with duration of fermentation (R = -0.98548 for λ_1 and R = -0.97357 for λ_2. When mixing optimally develops the dough, the proteins form a coherent viscoelastic mass encapsulating air, starch granules and other filler materials. Optimal gluten development is vital to the development of structure in the crumb.

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 (Steff, 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). Also, the values of k_1 and k_2 are presented in table 1. Parameters k_1 and k_2 were calculated from Peleg's equation (Eq. 2) by linear regression, coefficients of correlation ranging between 0.998 and 0.999. As for λ_1 and λ_2, k_1 and k_2 are strongly influenced of time. But if in the case of k_1 there is a strong negative association (R = -0.96081), in case of k_2 there is no association (R = 0.25538).

In figure 2 there is experimental stress relaxation curve obtained for specimens from dough after 120 minutes of fermentation. Also is presented normalized stress relaxation curve.

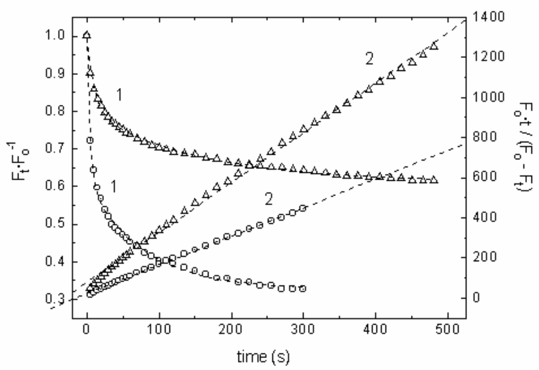

Fig. 2. Stress relaxation curves (1) and normalized stress relaxation curve (2) for dough after 120 minutes of fermentation (open circles) and obtained bread crumb (open up triangles) (dot line – calculated curve)

Bread crumb rheology. Compressive testing of bread crumb shoved that the rheological properties of bread crumb are anisotropic. From the first portion ($\varepsilon < 0.2$) of stress-strain curve for bread crumb (like in figure 1) the Young modulus for bread crumb were calculated (table 2). These vales are similar with Hibberd (1985) data for white bread crumb.

Table 2. The influence of duration of fermentation on rheological characteristics (±S.E.) of bread crumb

	Duration of fermentation (min)						
	0	30	60	90	120	150	180
Young modulus (kPa)	63.3±6.5	14.5±2.5	18.4±2.1	12.3±2.1	16.8±2.2	11.7±1.5	16.3±1.9
Density ($g \cdot cm^{-3}$)	0.776± 0.014	0.362± 0.029	0.437± 0.023	0.483± 0.028	0.352± 0.015	-	0.350± 0.021
λ_1 (s)	17.26±2.84	14.94±1.59	13.50±1.64	16.59±2.36	10.66±0.03	11.65±0.62	10.00±0.21
λ_2 (s)	217.0±20.7	272.5±24.3	199.4±9.5	223.3±24.1	137.7±10.7	136.6±1.7	138.5±7.8
k_1 (s)	127.3±16.2	130.2±7.0	103.7±2.3	109.3±4.3	73.4±3.3	82.3±6.9	94.8±2.8
k_2	2.95±0.04	2.55±0.01	2.46±0.02	2.55±0.09	2.52±0.02	2.59±0.18	2.61±0.07
F_e (%)	66.8±0.2	61.7±0.4	60.7±0.5	61.7±1.9	61.6±0.4	62.6±3.3	63.4±1.5

It could be observed that after 30 minutes of fermentation Young modulus decrease by 3-5 times. That means a minimum of 30 minutes of fermentation is necessary for obtaining bread with very good elastic properties. There is a very good linear correlation between Young modulus and crumb density (R = 0.9254).

Regarding viscoelastic properties of bread crumb, for bread obtained after 120 – 150 minutes of fermentation, the viscous properties are more pronounced (the smallest values for λ_1, λ_2 and k_1). As a consequence, fermentation process in this device, for this sort of bread could be smaller than 120 minutes.

Conclusions

Both elastic and viscoelastic properties of dough are influenced by duration of fermentation, generally being a linear dependence with time (R > 0.96). To obtain very good elastic properties for the bread crumb duration of fermentation has to be greater than 30 minutes, but no more than 120 minutes.

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