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INFLUENCE OF α-AMYLASE ON RHEOLOGICAL PROPERTIES OF DOUGH

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Abstract

It was determined from compression tests the young modulus for dough with different contents of α-amylase at different duration of fermentation. A sigmoid compressive stress-strain relationship is characteristic of dough. Also, the influence of α-amylase content on viscoelstic characteristics of dough 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, dough, α-amylase.*

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).

Endoamylases are able to cleave α,1-4 glycosidic bonds present in the inner part (endo-) of the amylose or amylopectin chain. α-Amylase is a well-known endoamylase. It is found in a wide variety of microorganisms, belonging to the Archaea as well as the Bacteria (Pandey, 2000). The end products of α-amylase action are oligosaccharides with varying length with a α- configuration and α-limit dextrins, which constitute branched oligosaccharides. (Maarel, 2002). Gujral (2004) was established that α-amylase could be used for improving the texture of rice flour chapatti (a thin flat loaf of unleavened bread).

It were studied the influence of α-amylase content on rheological properties of wheat flour dough. 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) when dough has elastic properties. Also, because fermented dough is typical example as viscoelastic material, 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% α-amylase. 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 dough quality. During fermentation, dough probes were taken. Using a cork borer (20 mm diameter) specimens with height of about 20 mm were cut, at 0, 25, 50, 70, 90, 110 and 130 minutes of fermentation. To determinate Young modulus, by using a compression apparatus JTL Janz, the dough specimens were uniaxial compressed between parallel-lubricated plates at $6\ mm \cdot min^{-1}$. 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. 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 dough with 0.15% α-amylase after 70 minutes of fermentation 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 initial compression modulus or Young modulus (E).

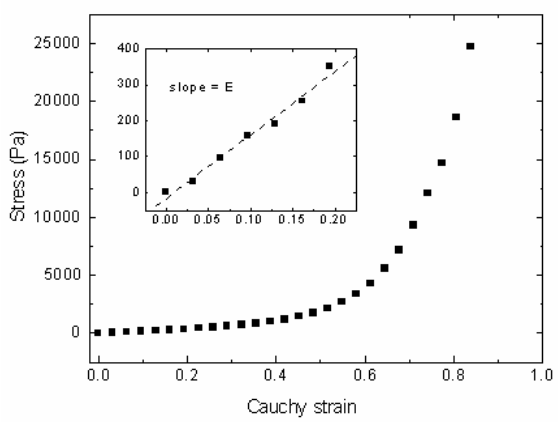

Fig. 1. Compression curve for dough with 0.15% α-amylase after 70 minutes of fermentation

The values of Young modulus for dough with different α-amylase content and different fermentation times are presented in table 1.

Table 1. Influence of α-amylase content on dough Young modulus ($Pa \cdot m^{-2}$)

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	3810	1727	1449	1338	1653	2328	2202
25	3202	1827	1648	1651	1389	1682	2101
50	2933	1661	1612	1803	1549	1779	2259
70	2805	1789	1423	1481	1755	2107	1810
90	2318	1743	1853	1175	1697	1880	1594
110	2377	1743	1700	1176	1903	2022	1214
130	2577	1820	1400	1605	1688	1560	1312
Med*	2860	1758	1583	1461	1662	1908	1784
SD	522	58	168	242	161	264	425
SE	197	22	63	91	61	100	161
R**	0.89874	0.23648	0.10686	0.22635	0.6037	0.45636	0.91247

*Medium values for a studied content of α-amylase
**Pearson linear regression coefficients of dependence: Young modulus – fermentation time

Could be observed that for the same duration of fermentation, the minimum values of Young modulus are attaining to a content of 0.10 – 0.15% α-amylase. For the same content of α-amylase generally there are not linear dependence, R < 0.23 for a content of 0.05-0.15. This suggests that fermentation phase does not depend on duration for a content of 0.05 – 0.15% α-amylase. Both for the maximum content in α-amylase (0.3%) and for none content, there is a good linear dependence ($R > 0.898$) suggesting that duration of fermentation phase influences the rheological characteristics of dough.

The relaxation test is a static procedure used to characterization viscolelastic properties of studied 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 tables 2 – 4. The greater values for equilibrium force suggest more elastic properties of dough, and the smaller suggests more viscous properties.

Table 2. Influence of α-amylase content on dough relaxation equilibrium force (%)

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	32.5	30.1	31.5	27.1	26.0	27.3	26.6
25	32.3	37.2	35.3	30.5	36.8	27.5	26.9
50	30.1	35.2	35.6	38.3	30.7	35.5	29.9
70	29.1	39.7	37.8	34.9	32.4	35.8	32.3
90	41.8	36.8	38.1	36.4	33.8	38.3	29.2
110	32.5	39.0	37.7	33.5	31.6	30.8	22.2
130	29.7	35.3	34.1	35.0	28.3	30.7	21.5
Med*	32.6	36.2	35.7	33.7	31.4	32.3	26.9
SD	4.3	3.1	2.4	3.8	3.5	4.3	4.0
SE	1.6	1.2	0.9	1.4	1.3	1.6	1.5
R**	0.0634	0.53432	0.51918	0.60756	0.01886	0.03886	0.45626

*Medium values for a studied content of α-amylase

**Pearson linear regression coefficients of dependence: relaxation equilibrium force – fermentation time

A α-amylase content of 0.05-0.15% assure the best elastic properties of dough ($F_e = 36.2$-33.7%), but the fermentation is medium influenced on duration ($R = 0.52 – 0.61$). Greater contents of α-amylase decrease the elastic properties and increase viscous properties of dough; the duration of fermentation does not influence these properties (R<0.05).

Table 3. Influence of α-amylase content on dough relaxation time (λ_1) (s)

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	6.00	3.47	5.29	3.11	2.37	3.03	3.52
25	6.44	8.98	4.92	2.17	4.22	3.30	4.84
50	4.87	3.88	5.03	4.10	3.66	3.88	4.17
70	4.16	5.49	7.65	3.68	3.84	4.91	4.94
90	6.00	5.71	5.21	4.19	3.62	3.83	5.50
110	8.01	7.44	5.90	4.20	4.53	3.24	2.29
130	4.21	4.67	5.85	5.39	5.20	6.74	3.64
Med*	5.67	5.66	5.69	3.83	3.92	4.13	4.13
SD	1.37	1.96	0.94	1.00	0.88	1.31	1.08
SE	0.52	0.74	0.35	0.38	0.33	0.49	0.41
R**	0.07624	0.09577	0.32155	0.84138	0.79658	0.64434	0.21803

*Medium values for a studied content of α-amylase

**Pearson linear regression coefficients of dependence: λ_1 – fermentation time

Table 4. Influence of α-amylase content on dough relaxation time (λ_2) (s)

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	87.7	49.8	57.3	50.7	36.4	41.9	65.5
25	89.0	91.8	56.4	55.6	53.4	55.1	76.0
50	57.2	59.2	52.6	63.6	56.3	64.3	78.0
70	73.8	54.6	74.9	63.0	58.0	53.6	76.4
90	62.0	64.6	59.4	53.4	50.4	49.7	69.3
110	79.7	65.1	60.3	64.6	52.5	45.9	77.1
130	66.4	67.8	49.8	73.3	52.7	89.6	70.1
Med*	73.7	64.7	58.7	60.6	51.4	57.2	73.2
SD	12.4	13.5	8.0	7.8	7.1	16.0	4.8
SE	4.7	5.1	3.0	3.0	2.7	6.0	1.8
R**	0.51177	0.03547	0.05934	0.7522	0.48967	0.53149	0.15532

*Medium values for a studied content of α-amylase

**Pearson linear regression coefficients of dependence: λ_2 – fermentation time

The smaller values of first relaxation time λ_1, 3.83 and 3.92 s, suggest greater values for initial stress decay, namely more pronounced dough viscoelastic properties, for a α-amylase content of 0.15-0.20% (table 3) and the duration of fermentation increase these values (R = 0.80 – 0.84). The second Maxwell relaxation time λ_2, corresponding to the curve stabilization zone, represents the rate of relaxation of the main gluten dough structure. A α-amylase content of 0.05-0.15% (table 4) assure the best values for these times.

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):

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

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 k_1 and k_2 are presented in tables 5 and 6.

In figure 2 there is experimental stress relaxation curve obtained for specimens from dough with 0.15% α-amylase after 70 minutes of fermentation. Also is presented normalized stress relaxation curve.

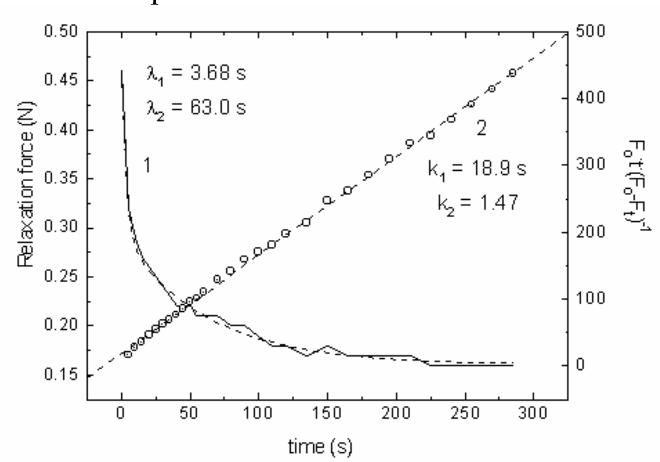

Fig. 2. Stress relaxation curves (1) and normalized stress relaxation curve (2) for dough with 0.15% α-amylase after 70 minutes of fermentation (dot line – calculated curve)

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. The smallest values for Peleg parameter k_1 (table 5) are attained at a α-amylase content of 0.15-0.20%, when are obtained the greatest values for initial stress decay (table 3). Probably, α-amylase induces a weakening effect of dough gluten structure.

Table 5. Influence of α-amylase content on dough parameter k_1 (s)

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	23.9	15.2	18.0	13.9	9.6	11.8	16.1
25	24.0	29.6	21.5	13.7	17.5	13.8	17.6
50	15.3	17.4	18.7	22.0	13.7	21.0	18.9
70	19.2	26.2	22.0	18.9	17.2	17.7	18.8
90	39.4	19.4	21.4	15.4	16.2	20.2	18.9
110	27.4	27.7	22.6	17.5	19.6	15.7	14.7
130	19.6	20.7	20.7	19.9	16.7	27.1	13.8
Med*	24.1	22.3	20.7	17.3	15.8	18.2	17.0
SD	7.8	5.5	1.7	3.1	3.2	5.1	2.1
SE	3.0	2.1	0.6	1.2	1.2	1.9	0.8
R**	0.16681	0.21397	0.59208	0.49341	0.04757	0.74564	0.41986

*Medium values for a studied content of α-amylase

**Pearson linear regression coefficients of dependence: k_1 – fermentation time

Table 6. Influence of α-amylase content on dough parameter k_2

Fermentation time (min)	α-Amylase concentration (%)						
	0	0.05	0.10	0.15	0.20	0.25	0.30
0	1.43	1.36	1.40	1.32	1.29	1.32	1.31
25	1.43	1.54	1.47	1.39	1.56	1.33	1.32
50	1.39	1.49	1.48	1.55	1.40	1.49	1.38
70	1.36	1.55	1.56	1.47	1.42	1.49	1.43
90	1.58	1.52	1.55	1.51	1.44	1.54	1.34
110	1.41	1.55	1.53	1.45	1.38	1.46	1.25
130	1.36	1.49	1.43	1.48	1.33	1.38	1.23
Med*	1.42	1.50	1.49	1.45	1.40	1.43	1.32
SD	0.07	0.06	0.06	0.07	0.08	0.08	0.07
SE	0.03	0.02	0.02	0.03	0.03	0.03	0.02
R**	0.06248	0.53797	0.3881	0.60164	0.15193	0.47434	0.42598

*Medium values for a studied content of α-amylase

**Pearson linear regression coefficients of dependence: k_2 – fermentation time

The proportion of relaxed initial force is represented by k_2. The greatest values of k_2 which show the highest "solidity" of dough are observed (table 6) at a α-amylase content of 0.05-0.15% similar with the best elastic properties of dough (F_e = 36.2-33.7%) (table 2).

For all studied rheological parameters of dough were calculated the Pearson coefficients for linear correlations (table 7). The best linear fitting was obtained for dependence k_2 – F_e (R = 0.996) and for dependence k_1 - λ_1 (R = 0.923). This suggests that the both mathematical treatment of relaxation data, by equations 1 and 2 are strong means for interpretation stress relaxation tests.

Table 7. Pearson coefficients for linear correlations between studied rheological parameters

	E	λ_1	λ_2	k_1	k_2	F_e
E	-	0.44508	0.60173	0.66759	-0.16266	-0.11663
λ_1	0.44508	-	0.36621	**0.92330**	0.56788	0.59200
λ_2	0.60173	0.36621	-	0.51459	-0.35408	-0.33774
k_1	0.66759	**0.92330**	0.51459	-	0.50482	0.53852
k_2	-0.16266	0.56788	-0.35408	0.50482	-	**0.99632**
F_e	-0.11663	0.59200	-0.33774	0.53852	**0.99632**	-

Conclusions

Taking into consideration all experimental data presented in tables 1 – 6, results that a α-amylase content of 0.10-0.15% assure the best quality for flour dough, from rheological point of view. For this α-amylase content the duration of fermentation does not influence significantly the rheological properties of dough.

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