Impact of baking conditions on bread staling

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ABSTRACT

Bread staling encompasses a combination of physico-chemical, mechanical and sensorial resulting in a decrease of the quality of bread. Bread structure in particular the crust crumb ratio is affected by the baking conditions (temperature, steaming condition, degree of fermentation). Staling can be also controlled by using enzymes which act on starch biopolymers during fermentation and during baking.

This study aims at evaluating the impact of crust presence on the staling rate of pan bread. The kinetics of heating (heating rate during baking) has also been considered with the objective of obtaining different crust crumb ratio. Two matrixes have been considered; a degassed bread crumb baked in a miniaturized baking system and a conventional bread crumb with and without crust. Two heating rates have been considered corresponding to baking at 180°C and 220°C (corresponding to long and short baking). The mechanical properties (Young modulus), melting enthalpy of amylopectin and freezable water have been determined during staling.

First order kinetics models have been used to model the hardening of the crumb and the melting enthalpy of amylopectin during staling. Amylopectin appears before crumb hardening; indeed, recrystallized amylopectin traps the free water resulting in a hardening of the crumb (degassed crumb). In the case of a conventional crumb (bread with crust), water is also trapped by the dry crust resulting in a change in the kinetics of staling (faster staling). The heating rate had an impact on the case of dough without added enzymes. The Young modulus of degassed crumb and conventional crumb have been compared using the Gibson and Ashby model. In conclusion, the presentation permits to better understand the mechanisms linked to moisture diffusion within the bread during staling.

Keywords: bread, staling, texture, baking, α-amylase

INTRODUCTION

One of the major problems of baked products is staling. This phenomenon affects two different parts of the bread: the crust and the crumb. Although, crust staling is associated with the moisture migration from crumb to crust resulting in a soft and leathery texture, crumb staling is somehow more complicated and is the result of physicochemical changes in starch of bread [1, 2]. Moreover, [3] indicates that the staling of the crumb is a complex phenomenon which involved several mechanisms: the most important are starch retrogradation and moisture redistribution between and among components [4]. Crumb firmness is the most important change associated to bread staling and related to the retrogradation of starch. Different solutions have been developed to prevent staling bread such as the addition of α-amylases which reduced the firming rate in bread and the recrystallization of the amylopectin in bread crumb. These enzymes hydrolyze linkages in starch, resulting in short chains which interfere with starch retrogradation and disrupt the continuity of the starch network [4]. Traditional methods of evaluation of bread staling are based on compression tests which provide data describing mechanical changes associated to staling process [5]. Other methods can be used to characterize staling especially the starch retrogradation, such as the determination of the melting enthalpy of retrograded amylopectin and the amount of freezable water [6-8].

Baking process has an impact on bread staling by influencing the starch retrogradation. A relation between baking temperature and retrogradation has been found: the higher the baking temperature is, the more retrogradation will occur [9]. Some researchers reported that low temperature and long time baking induced a decrease of crumb firmness of the final bread. Moreover, baking conditions, in particular the rate of temperature rise and baking time, are likely to affect the action of enzymes and thus the phenomenon of staling.

The objectives of this work are to understand the effects of storage with crust, the influence of α-amylase and baking conditions on staling kinetics. To achieve this aim, an approach based on baking degassed dough in a

miniaturized system was carried out, in addition to baking a conventional dough. For analysing staling process, two different approaches have been performed. Firstly, the retrogradation of amylopectin and the amount of freezable water were determined by differential scanning calorimetry. Secondly, hardness increase during storage was evaluated using dynamic mechanical analysis.

MATERIALS & METHODS

Dough preparation

The basic dough recipe of pan bread contained 2000 g of wheat flour, 1200 g of water, 40 g of salt, 80 g of milk powder, 40 g of sugar, 40 g of sunflower oil, 80 g of wet yeast, 0.02g of ascorbic acid, 10 g of calcium propionate and 4 g of potassium Sorbate. Bacterial α-amylase was added at the level of 0.00011 g/100g of flour. All ingredients were mixed in a spiral mixer (VMI SP10, Montaigu, France) for 4 min at 100 rpm, followed by 8 min at 200 rpm. Salt was added after 3 min mixing at high speed. After mixing, dough temperature was between 22°C and 25°C. Dough pieces of 770g each were rested for 20 min before being molded manually. Each piece of dough was placed in greased metallic moulds (10 cm x 10 cm x 30 cm), without cover. Proofing was carried out in a fermentation cabinet (Panimatic, France) at 35°C, 95% relative humidity until obtaining an expansion ratio of 3.

Conventional and degassed crumb

Baking was done for the “conventional” bread (in pan) in a ventilated oven using two conditions (180 °C/28.7 min and 220 °C/21.3 min). The end of baking was arbitrarily chosen as the time for which the temperature of 98 °C was reached at the centre of bread during baking. After 40 min of chilling, fresh pan breads were cut into slices and packaged in hermetical boxes. Samples were stored either with the crust or without the crust. In parallel to the conventional bread, degassed dough samples were baked using a miniaturized baking system made of two parallel Peltier elements, as described by [7] using two programs “180 °C” condition and the “220 °C” condition. All samples were stored in a controlled temperature cabinet (20 °C ± 1 °C) for 10 to 15 days.

Mechanical properties of the crumb

Compression tests were performed on conventional bread with a rate of 2% per minute until 10% strain. However, for the degassed crumb, the sample was first contacted by the two trays with a 0.01 N force. Then a rapid "pre compression" with a strain of 12 % was done followed by a second compression with a strain of 20 %. Young modulus (quoted as Es) was recorded and determined from the linear section of the force-deformation plot obtained by compression tests.

DSC analysis

A thermal cycle was conducted with DSC: a sample was firstly equilibrated at 20 °C for 5 min and then cooled from 20 °C to -60 °C at 3 °C/min. After a 10 min waiting period at -60 °C, the sample was heated at 3 °C/min from -60 °C to 100 °C. This program was carried out twice using two different samples to determine the amount of freezable water (FW) and the enthalpy of melting of amylopectin.

RESULTS & DISCUSSION

Effects of baking conditions and storage with or without crust on mechanical properties of bread during storage were studied. Figure 1 shows the changes of Young modulus of bread crumb during storage at 20 °C. An increase in the crumb hardness was observed during storage for all samples. However, some differences occurred depending on the baking conditions and the presence or the absence of crust. It was found that during a storage with crust, the Young modulus of bread baked at 180 °C (long baking) was higher at the end of staling than that of bread baked at 220 °C (short baking). Storage without crust seems to increase the Young modulus in comparison with storage with crust.

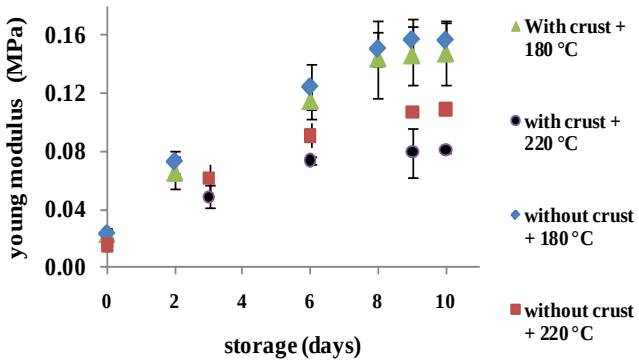

Figure 1. Evolution of the Young modulus of conventional bread for samples baked with conditions “180 °C” and conditions “220 °C” and stored with crust and without crust

Also, some differences existed between samples of degassed crumb depending on baking conditions and the presence of α-amylase. Figure 2 showed that the Young modulus obtained at the end of staling for α-amylase treated samples was significantly lower than that of samples without α-amylase whatever baking conditions were. With respect to baking conditions, samples baked at low heating rate (6.88 °C/min at 180 °C) have the higher young modulus. Finally, the phenomenon of staling seems to be independent on the kinetic of baking when α -amylase was added.

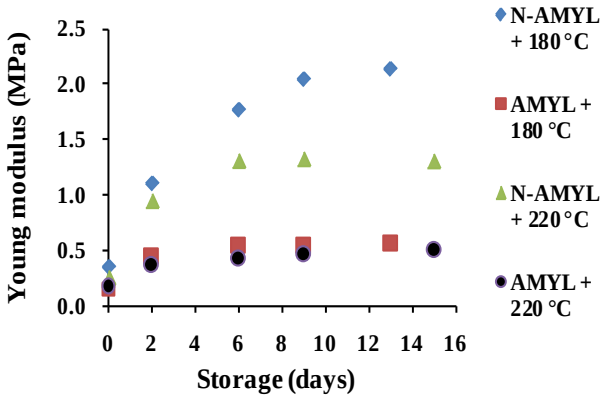

Figure 2. Evolution of the Young modulus of degassed crumb for samples containing α-amylase (AMY), and without α-amylase (N-AMY), baked with conditions “180 °C” and conditions “220 °C”

A comparison between conventional crumb and degassed crumb has been carried out, based on the different parameters of a first kinetic model (Equation 1) used to describe the hardening of samples during storage.

$$E(t) = E_{\infty} + (E_0 - E_{\infty}).\exp\left(-t/\tau\right) \quad (1)$$

with E_0 (MPa) and E_{∞} (MPa) the Young modulus at initial time (beginning of staling) and at the end of staling respectively, τ (days) a time constant.

Table 1 shows that the Young modulus (initial and at t_{∞}) of degassed dough was significantly higher than the Young modulus of conventional crumb ($P<0.05\%$) for each case. Comparing values of time constant from this table, it appears that the staling was much slower (high value of τ) for the conventional crumb than for the degassed crumb, whatever baking conditions were and in the presence of enzymes or not. A low temperature baking conducts to a slower staling rate than baking at high temperature. Moreover, α-amylases promoted an improvement of the initial crumb texture (which was softer) but resulted in an increase of the firming rate in the case of baking at low temperature.

Table 1. Effect of baking conditions and addition of α-amylase parameters of the mechanical model describing kinetics of staling and comparison between conventional crumb and degassed crumb[a]

Baking conditions	Formulation	Matrix	E_0 (MPa)	E_∞ (MPa)	τ (days)
T = 180 °C	Without	Conventional crumb	0.022 ± 0.004a	0.189 ± 0.002a	6.77± 0.4b
Heating rate	α-amylase	Degassed crumb	0.355± 0.03a	2.217 ± 0.17a	4.02± 0.05c
10.27 °C/min	With α-amylase	Conventional crumb	0.018 ± 0.001b	0.124± 0.001c	3.82± 0.1d
		Degassed crumb	0.150 ± 0.02d	0.577± 0.02f	1.50± 0.04h
T = 220 °C	Without	Conventional crumb	0.0157 ± 0.002c	0.090 ± 0.002e	3.43± 0.2e
Heating rate	α-amylase	Degassed crumb	0.251 ± 0.04b	1.362 ± 0.06b	2.14± 0.03g
6.88 °C/min	With α-amylase	Conventional crumb	0.012 ± 0.001d	0.085 ± 0.004g	3.22± 0.3g
		Degassed crumb	0.193 ± 0.01c	0.482 ± 0.03g	2.18± 0.02f

[a] Mean ± standard deviation, n=3, means within columns followed by the same letter are not significantly different (P<0.05)

According to [10], a mechanical model exists to describe the proportionality between effective mechanical properties of a cellular solid, the mechanical properties of the material constituting the cellular system and the structure of the cellular system (density).

$$\frac{Es}{E} = \left(\frac{\rho s}{\rho}\right)^2 \qquad (2)$$

where *Es* and *ρs* correspond to the Young modulus and the density of the conventional crumb respectively and *E* and *ρ* are the Young modulus and the density of the degassed crumb (material constituting the conventional crumb). Figure 3 showed that the relative Young modulus predicted by the model of [10] was relatively underestimated in all cases, except samples baked at 180°C and treated with α-amylase. But, in general, the Gibson's model was well adapted to our conditions and matches quite well with our experimental data.

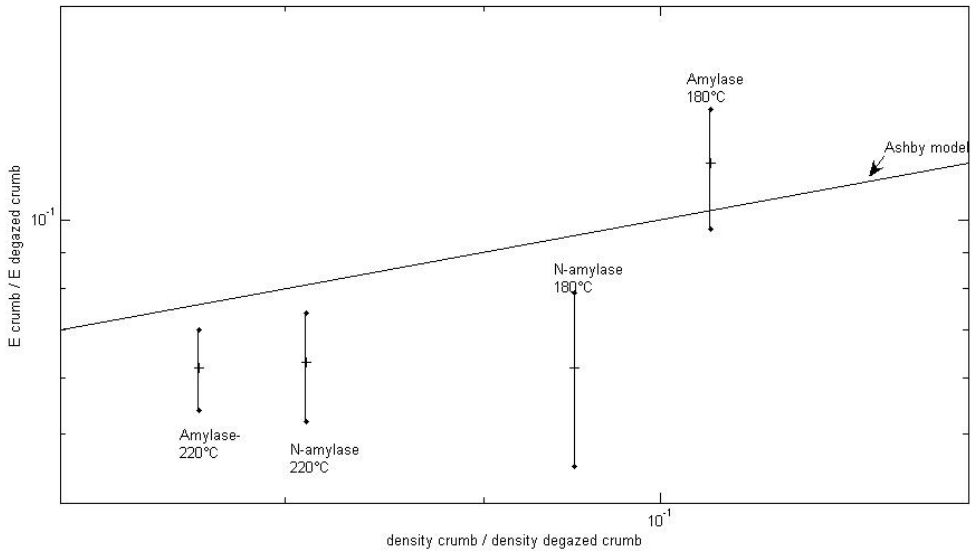

Figure 3. Evolution of the relative Young modulus in function of the relative crumb density as described by the model of [10]

The melting enthalpy of retrograded amylopectin (ΔH) and the amount of freezable water (FW) were also assessed. Figure 4 presents the evolution of the amount of FW during storage of samples treated with or without α-amylase and baked with the both conditions.. Results showed that FW decreased and the melting enthalpy of retrograded amylopectin increased during storage. With respect to α-amylase treatment, samples with α -amylase contain a significant amount of freezable water, contrarily to those without α -amylase,

whatever the baking conditions were. Concerning the effect of baking conditions on the amount of FW, the FW of samples baked with low heating rate (6.88 °C/min at 180 °C) was higher than that of samples baked with high heating rate (10.27 °C/min at 220 °C). To resume, baking at low temperature resulted in a higher value of the Young modulus which in turn contained also more of 'free' water.

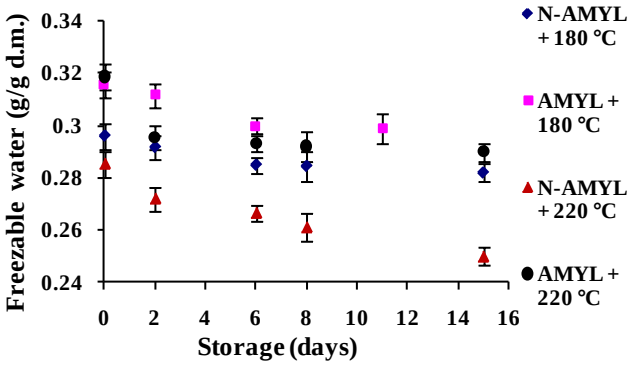

Figure 4. Evolution of the amount of freezable water during storage of samples treated with α-amylase (AMY), without α-amylase (N-AMY) and baked with conditions "180 °C" and "220 °C"

Figure 5 shows the evolution of enthalpy of melting of amylopectin during storage of samples treated with or without α-amylase and baked with both conditions. Results show that the melting enthalpy of retrograded amylopectin increases during storage. Samples baked at high heating rate have a higher amount of retrograded amylopectin at the end of staling than the samples baked at low heating rate, in the presence of enzymes or not. However, it seems that the adding of α -amylase had no significant impact on the melting enthalpy of amylopectin whatever the baking conditions were.

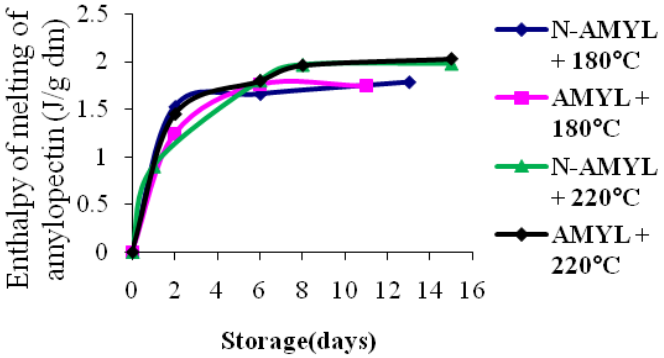

Figure 5. Evolution of enthalpy of melting of amylopectin during storage of samples treated with α-amylase (AMY), without α-amylase (N-AMY) and baked with conditions "180 °C" and "220 °C"

CONCLUSION

This work aims at studying the influence of baking conditions and the addition of bacterial α-amylase on the mechanical properties of degassed crumb and conventional crumb during storage and on staling kinetics. Results showed that a rapid baking resulted in a rapid staling. In addition, compression tests indicated that the hardening of the crumb increased during storage and samples baked with "220 °C" baking conditions staled faster than those baked with "180 °C" baking conditions. The adding of α -amylase led to a significant decrease of the initial firmness and the firmness at the end of staling. So that, the anti-staling effect of α-amylase was due essentially to the retardation in the starch retrogradation. However, α-amylases didn't prevent firmness during storage.

REFERENCES

[1] Bhatt C.M. & Nagaraju J. 2009. Studies on glass transition and starch re-crystallization in wheat bread during staling using electrical impedance spectroscopy. Innovative Food Science and Emerging Technologies, 10: 241-245.

[2] Stear A.C. 1990. Moisture movements during the cooling and maturation of bread. England Elsevier science.

[3] Fessas D. & Schiraldi A. 2001. Water properties in wheat flour dough I: classical thermogravimetry approach. Food Chemistry, 72: 237-244.

[4] Gray J.A. & Bemiller J.N. 2003. Bread Staling : Molecular basis and control. Comprehensive Reviews in Food Science and Food Safety 2: 1-21.

[5] Angioloni A. & Collar C. 2009. Bread crumb quality assessment : a plural physical approach. European Food Research Technology 229: 21-30.

[6] Baik M.Y. & Chinachoti P. 2000. Moisture redistribution and phase transitions during bread staling. Cereal Chemistry 77: 484-488.

[7] Le Bail A., Boumali K., Jury V., Ben-Aissa F. & Zuniga R. 2009. Impact of baking kinetics on staling rate and mechanical properties of bread crumb and degazed bread crumb. Journal of Cereal Science 50: 235-240.

[8] Ribotta P.D. & Le Bail A. 2007. Thermo-physical assessment of bread during staling. Lebensmittel-Wissenschaft und-Technologie, 40: 879-884.

[9] Giovanelli G., Peri C. & Borri V. 1997. Effects of baking temperature on crumb staling kinetics. . Cereal Chemistry, 74: 710-714.

[10] Gibson L.J. & Ashby M.F. 1997. Cellular solids- structure and properties. Cambridge: Cambridge University Press.