Journal of Food Engineering 178 (2016) 31–38

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Study of bread staling by means of vibro-acoustic, tensile and thermal analysis techniques

Lubomír Lapčík [a, b, *], Martin Vašina [c], Barbora Lapčíková [a, b], Tomáš Valenta [b]

[a] Regional Centre of Advanced Technologies and Materials, Department of Physical Chemistry, Faculty of Science, Palacky University, 17. Listopadu 12, 771 46 Olomouc, Czech Republic
[b] Tomas Bata University in Zlin, Faculty of Technology, Inst. Foodstuff Technology, Nam. T.G. Masaryka 275, 760 01 Zlin, Czech Republic
[c] VŠB-Technical University of Ostrava, Department of Hydromechanics and Hydraulic Equipment, Faculty of Mechanical Engineering, 17. Listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic

ARTICLE INFO

Article history:
Received 14 October 2015
Received in revised form
16 December 2015
Accepted 6 January 2016
Available online 8 January 2016

Keywords:
Bread
Staling
Mechanical testing
Sound absorption measurement
Thermal analysis

ABSTRACT

Staling of two commercial breads was studied by mechanical tensile testing, transfer damping function vibrator testing and Kundt's impedance tube sound absorption measurements. The staling process was found to be affected by the porosity as well as the elasticity and rigidity of the cellular structure of the studied breads. Thermal analysis revealed two successive thermal events in the bread during heating, i.e., moisture liberation accompanying gelatinization of starch components and thermal degradation of carbohydrate constituents. A linear or exponential growth increase of the stiffness of the bread matrix with staling time was apparent from the Young's modulus dependences. Concurrently, the transfer damping function dependence indicated higher stiffness, as confirmed by evolution of the first resonance frequency peak after staling. The primary sound absorption peak frequency position shifted from 900 Hz to 1070 Hz. Simultaneously the sound absorption coefficient increased from 0.72 to 1.0 after 336 h of staling.

1. Introduction

Bread, as a basic food constituent, has been associated with humans for centuries (Mondal and Datta, 2008; Revedin et al., 2010). It has functioned not only as a food but also influenced sociological aspects of humans by affecting the formation of early human societies (Katz and Weaver, 2003). From the western half of Asia, where wheat was domesticated, cultivation spread north and west, to Europe and North Africa, enabling humans to become farmers rather than hunters. This in turn spurred the formation of towns and gave rise to more sophisticated forms of societal organization. Similar developments occurred in eastern Asia, centered on rice, and in the Americas with maize. In ancient times, Greek bread was barley bread. The industrialization of bread baking was a formative step in the creation of the modern world. For generations, white bread was preferred over dark (wholegrain) bread. However, in the late 20th century, wholegrain bread gained popularity owing to its superior nutritional value in comparison with white bread. Another major change happened in the 1960s with the development of the intense mechanical working of dough in order to reduce fermentation time. This process, whose high-energy mixing allows for the use of inferior grain, is now widely used around the world in large factories. In contrast, traditional breadmaking is extremely time-consuming, as the dough is mixed with yeast and requires several cycles of kneading and resting prior to baking. More recently, chemical additives have been introduced to speed up the mixing time and reduce the fermentation time necessary. Common additives include L-cysteine, potassium bromate or ascorbic acid. Often these chemicals are added to the dough in the form of a prepackaged base, which also contains most or all of the dough's non-flour ingredients (Cauvain, 2015). In recent years, numerous studies have focused on the use of hydrocolloids as additives to influence the moisture content, texture and starch retrogradation (Armero and Collar, 1998; Davidou et al., 1996; Eugenia Barcenas et al., 2009; Shi et al., 2014). Hydrocolloids improve the bread volume, soften the texture and slow the staling rate. In addition, hydrocolloids decrease physical damage induced by ice crystals in breads obtained from frozen dough (Eugenia

* Corresponding author.Regional Centre of Advanced Technologies and Materials, Department of Physical Chemistry, Faculty of Science, Palacky University, 17. Listopadu 12, 771 46 Olomouc, Czech Republic.
E-mail address: lapcikl@seznam.cz (L. Lapčík).

http://dx.doi.org/10.1016/j.jfoodeng.2016.01.004
0260-8774/

Barcenas et al., 2009). They also interfere with the formation of gluten linkages, affecting to different extent the elastic and viscous moduli of the bread. The effects of other food additives, such as glycerol, linolenic acid, beeswax and hydroxypropylmethylcellulose, on the mechanical, microstructure and permeability properties of model breads have been studied, with special focus on crusty breads production. It was found that crust production acts as a barrier to water migration, thus affecting the final mechanical properties of the bread matrix (Altamirano-Fortoul et al., 2015; Polaki et al., 2010). The degree of structural bread pore damage during storage was evaluated by measuring change in the pore shape and pore distribution. It was found that there was a decrease in pore roundness with time. Simultaneously, a negative correlation of pore roundness to aroma was observed, indicating that less round pores could negatively affect aroma retention (Polaki et al., 2010). Recent paper (Parthasarathi and Anandharamakrishnan, 2014) studied theoretical modeling of shrinkage, rehydration and textural changes for food structural analysis with respect to the limitations of commercial softwares available on the market.

Analysis of acoustic emission also showed that crispiness characterized by means of acoustic indices was strongly affected by water activity for both wheat and rye flat extruded breads (Marzec et al., 2007). The effect of chemical composition on acoustic activity was not as evident as that of water activity. It was found that the moisture content influenced the tensile properties of the breads. The brittle to ductile transition of extruded bread was observed to occur between 9 and 13.7% moisture. This finding was attributed to the glass transition of starch and gluten, which is affected by moisture content (Fontanet et al., 1997). As known from earlier studies (Kimshin et al., 1991), the water migration, the effect of bound and free water on plasticization of bread matrix are strongly affected by staling process.

As mentioned earlier, with such a long history of production and diversity of form, breadmaking will always be an emotive subject. Whenever the subject of quality is raised, there is likely to be a diversity of opinions from consumers and bakers extolling the virtue of different breads, different manufacturing processes, different dough formulae and different ingredients (Cauvain, 2015). However, the staling is remaining still a major problem in the baking industry. Thus the bakers are focusing their scientific interests to increase product shelf life, that is, the time when bread remains fresh with respect to its textural characteristics. Hence, our study was not aimed at quality comparison of the tested breads, but was focused on application of novel vibro-acoustic experimental methods of sound absorption and vibration damping measurements for the characterization of bread staling process suitable for field quality control applications.

2. Materials and methods

2.1. Products

Two different commercial breads were tested in this study. The consumer's bread with cumin (Penam, Inc., Brno, Czech Republic) assigned as sample 1 was of 1200 g weight. Dough components were wheat flour (36 w. %), water (40 w. %), rye flour (19.5 w. %), iodized salt (1.2 w. %), yeasts (1.4 w. %), malt rye flour (1.25 w. %), cumin (0.16 w. %) and other minor ingredients, e.g., vegetable oil, E300 – L-ascorbic acid etc. The baking loss for sample 1 was 11 w. %. The commercial bread Topek large (Topek, Ltd., Topolná, Czech Republic) (sample 2) was of 1400 g weight. Dough components were wheat flour (43 w. %), water (40 w. %), rye flour (14.3 w. %), salt (1.15 w. %), cumin (0.28 w. %), thickener E412 – guar gum (0.57 w. %), yeasts (0.4 w. %) and other ingredients, e.g., wheat gluten, swelling corn flour, E300 - ascorbic acid and enzymes. The baking loss for sample 2 was 14 w. %. The time interval from the end of baking to analysis of the first samples (0 time of staling) was 3 h. Prior to analysis, the tested breads were kept in an air atmosphere at constant laboratory temperature of 25 °C and relative humidity of 43% without packaging.

2.2. Sound absorption properties

The sound absorption properties of the samples were expressed by the sound absorption coefficient α defined by the following ratio (Sgard et al., 2011):

$$\alpha = \frac{P_d}{P_i} \tag{1}$$

where P_d is the dissipated power in the investigated material, and P_i is the incident acoustic power. The sound absorption of materials is influenced by many factors, e.g., excitation frequency, material thickness, structure, density and humidity. The frequency dependence of the sound absorption coefficient of the investigated materials was determined by the transfer function method ISO 10534-2 (Han et al., 2003; International Organization for Standardization, ISO 10534-2, 1998; Lapcik et al., 2015) employing an impedance tube (see schematic in Fig. 1) (Vasina et al., 2006). In this case, α can be expressed by the following equation:

$$\alpha = 1 - |r|^2 = 1 - \left(r_r^2 + r_i^2\right) \tag{2}$$

where r is the normal incidence reflection factor, r_r and r_i are the real and imaginary components of the factor r, which can be described by the equation

$$r = r_r + ir_i = \frac{H_{12} - H_I}{H_R - H_{12}} \cdot e^{2k_0 \cdot x_1 i} \tag{3}$$

where H_{12} is the complex acoustic transfer function, H_I is the transfer function for the incident wave, H_R is the transfer function for the reflection wave, k_0 is the complex wave number, x_1 is the distance between the microphone M_1 and the tested material sample. The transfer functions can be expressed by the formulas

$$H_{12} = \frac{p_2}{p_1} = \frac{e^{k_0 \cdot x_2 i} + r \cdot e^{-k_0 \cdot x_2 i}}{e^{k_0 \cdot x_1 i} + r \cdot e^{-k_0 \cdot x_1 i}} \tag{4}$$

$$H_I = e^{-k_0 \cdot (x_1 - x_2) i} \tag{5}$$

$$H_R = e^{k_0 \cdot (x_1 - x_2) i} \tag{6}$$

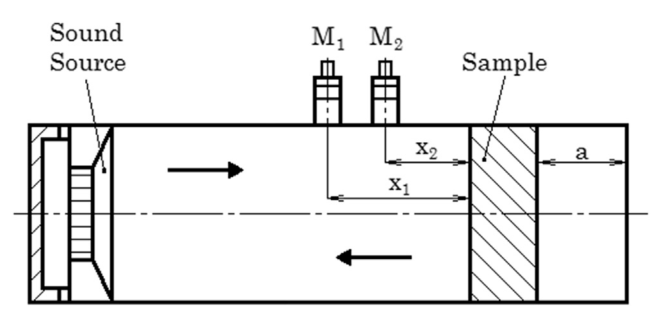

Fig. 1. Schematic of the acoustic impedance measurement tube device. Arrows indicate incident (left to right direction) and reflected acoustic wave directions.