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Research Article

Comparison of Conventional and Microwave Baked Bread Concerning Recrystallization of Starch Molecules

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Abstract: Bread is one of the most important foods in industrial countries and it is at its best when consumed fresh. One of the major problems during storage of baked products is staling. Bread staling incorporates a combination of physical and chemical changes resulting in a decrease of bread quality. The predominant mechanism of staling is the time-dependent recrystallization of starch molecules. Avoiding this recrystallization is one of the most desired topics in science of bread technology but still not solved. Therefore, this study investigates a new possibility by trying to influence the recrystallization of starch with microwave heating. For this, the differences between microwave and conventional baked rye-wheat bread were examined concerning the difference of water activity and firmness of the bread during time. As result, a faster water loss during storage period could be observed in microwave heated bread, which probably implies an even more rapid recrystallization instead the desired avoiding of recrystallization of starch.

Keywords: Bread, crystallization, firmness value, moisture migration, staling

INTRODUCTION

The bread underlies physical and biochemical changes during the baking process such as volume expansion, denaturation of proteins, gelatinization of starch, crust formation and redistribution as well as evaporation of water (Sablani *et al*., 1998).

After baking special attention is given to the starch, because it is the reason for the typical rearrangement of bread characteristics during storage time of bread. The main transformation of starch during storage is the retrogradation, where the polysaccharide chains of starch (amylose and amylopectin) aggregate and form crystal phases inside and outside the contours of native starch granules. During this process, water is forced out of the amorphous forms of amylose and amylopectin. Without the water, the close bound of the crystalline starch structures results in firmness and hardness of the crumb (Schiraldi and Fessas, 2001).

In this investigation the recrystallizing behaviour of starch in brown bread (rye-wheat bread) was researched under different heating mechanisms. Those were microwave heating and convective heating in a conventional baking oven. The main measured quality parameters for recrystallization were free humidity and firmness development during the time of 7 days.

Through the microwave radiation, a rapid rise in temperature was achieved. The generation of the fast increasing temperature is caused by the interaction of microwaves and polar water molecules. Molecules rearrange towards the oscillating microwave field, which leads to a rotating friction between the water molecules. Palav and Seetharaman (2007) hypothesized that the microwaves vibrate the water molecules present in the crystalline regions of the starch, thereby the lamellar arrangements of amylopectin crystals are destroyed. This occurs before the system reaches gelatinization temperature and probably fragments the granule at higher temperatures. Slower heating rates, as within convection heating oven, provide enough time for starch gelatinization to pass through its different phases, like starch swelling, loss of birefringence, amylose leaching and granule folding (Palav and Seetharaman, 2007).

MATERIALS AND METHODS

Baking trials described below were performed as triplicate. A single baking test consisted of two microwave and two oven baked breads. The recipe for a kilogram of dough is shown in Table 1.

Dough preparation: Ingredients were kneaded with the dough kneader (DIOSNA, Osnabrück) initially for six min at Level 1 (60 strokes/min) and further six minutes at Level 2 (120 strokes/min). Dough resting followed at a temperature of 22°C for 30 min. Dough was covered with a damp cloth. Subsequently 800 g dough was weighed and transferred into the baking pan. Silicone molds (Mallaredo di Pianigo, Italy) were used for microwave bread and metal molds were used for conventional heating. Subsequently, the raw dough was

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Table 1: Recipe for a kilogram of dough

Ingredients	(g)
Rye flour type 997[1]	347.7
Wheat flour type 550[1]	100.4
Breadcrumbs	9.7
Dry auer (diamalt)[1]	13.9
Yeast (*S. cerevisiae*)[2]	6.5
Salt	9.7
Water [3]	512.2

[1]: Provided by bakery storch, fulda; [2]: Stored at 4°C; [3]: Pre-warmed (36°C)

incubated for 1 h at 35°C and 80% humidity in the proofing cabinet for rising process.

Conventional and microwave heating process: For bakery process in microwave (Sharp R-26 ST) two silicone molds were directed towards each other and fixed with a rubber. The bread was baked for 14 min at 400 watts and ended up with a core temperature of 95°C. The oven (Winkler Wachtel) was heated up to 200°C and bakery process took place for 40 min until bread had the same core temperature of 95°C.

Product-evaluation: For the following measurement, the bread was cut with a bread cutting machine (Greaf, Fehrmann, Fulda) into 1.5 cm thick slices. For storage at 4°C bread was sealed in plastic bags. One slice was sealed at 700 mbar and two slices at 600 mbar.

Measurement of crumb-firmness: From the center of each bread a sample was cut out using a quadratic template with a side length and an edge length of x = 5.0 cm.

The texture analysis of the microwave-and conventional oven bread was carried out using a Texture Analyzer Type-TA.XT plus by Winopal. The firmness of the bread samples was determined with an aluminum cylinder (diameter 35 mm), a test speed of 2 mm/sec and to a path of 7 mm in a time of 3 sec with the method "texture profile analyses". The firmness-force was plotted over time.

Measurement of free humidity (water activity): The measurement of free humidity (a_w-value) measured by Sartorius, Moisture Analyzer MA40 was carried out at a temperature of 25°C and lasted until remained constant for 15 min. For determination, a circular sample was punched out with the help of a round shape below the crust, in the upper center of the crumb.

Before analysis, round sample was halved in height (0.75 cm) with a knife and this half was then measured.

Statistical analysis: To determine significant differences between samples the statistical analysis were performed with application of the t-test. The test conditions were two-tailed, independent samples and heterogeneous at a significance level of 0.5%.

Regressions line calculation: For calculating the regression line following formula was used:

$$b = \bar{y} - m\bar{x}$$

For the calculation of the line of best fit, the slope m is required and is described by the following formula:

$$m = \frac{\Sigma(x-\bar{x})(y-\bar{y})}{\Sigma(x-\bar{x})^2}$$

m is in this case the slope of the regression line, x/y the measured values and $\bar{x}/\bar{y}$ the mean values of the measurements.

RESULTS

Due to the storage of bread (staling of bread) the starch structure changed. These transformations (e.g., gelatinization and retrogradation of starch) are often measured by changes in crumb firmness (Bloksma and Bushuk, 1988; Gray and Bemiller, 2003). The crumb firmness is measured by Texture Analyzer.

Figure 1 shows the changes in crumb firmness of microwave and conventionally baked rye-wheat bread during a storage period of 7 days.

Figure 1 indicates that firmness of microwave and conventional baked bread rises during a storage period of 7 days in parallel. At storage day 1 both had the lowest hardness. At day 7 the highest firmness of the slices was observed. The statistical analysis with application of the t-test showed a value of 1.23 with a probability of 0.1% at a significance level of 0.5%. Based on this test, there was no significant difference between the measured values of the microwave-baked bread in comparison to the conventional bread. In contrast, other authors established firmer crumb texture of microwave baked bread than conventionally baked bread (Demirekler *et al*., 2004; Keskin *et al*., 2004; Ozkoc *et al*., 2009).

Free humidity (water activity): Water in food, which is not bound to food molecules can be described by the term free humidity (a_w-value). This refers to the unbound water in the sample. It is expressed as the quotient of water vapour partial pressure in the sample environment to the saturation vapour pressure over pure water (Ternes, 2011).

Figure 2 demonstrates that the crumb of conventionally baked bread had initially and over the time a higher free humidity in comparison to microwave-heated bread. It can be observed, that in both cases the water activity rises and concludes to an increased release of unbound water during storage period. Between storage day 1 and 7 the activity enhances with a value of 0.7% in conventional bread and a value of 1.1% in microwave bread. A steeper slope in water activity can be observed in microwave-heated bread with a value of 0.182 compared to conventional bread with a value of 0.122. This implies that microwave bread, despite lower water activity,

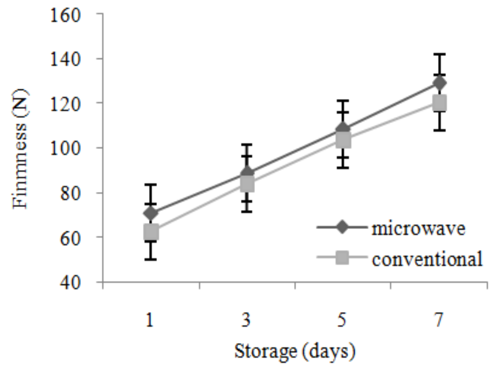

Fig. 1: Changing in crumb firmness of microwave and conventional baked breads during storage period of 7 days

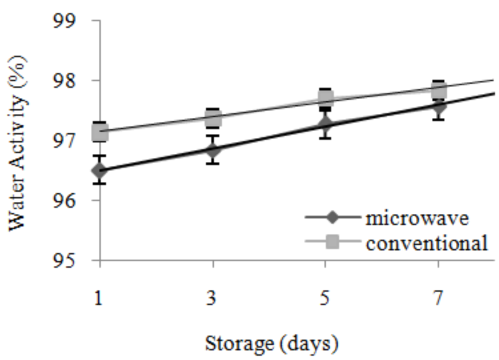

Fig. 2: Changes in water activity of microwave and conventional baked bread during storage of 7 days

showed an accelerated development and release of unbound water. At day 7 the a_w-value of both bread types corresponds approximately.

DISCUSSION

Referring to the measured firmness, it can be summarized, that during storage period over 7 days the firmness of the crumb of microwave and conventionally baked rye-wheat-bread rises in both cases, which was in agreement with early studies (Gray and Bemiller, 2003; Ozkoc *et al*., 2009). Hellmann and Fairchild (1954) investigated that the rate of development of crystallinity in starch gels is similar to the degree of bread firming. Gray and Bemiller's theory (2003) reveal that hydrogen bond between gluten network and gelatinized starch granules caused a firmer bread texture. Also Ozkoc *et al*. (2009) hypothesized that bread firming is reasoned by decreasing hydrogen bonds between gluten network and starch due to the water loss of starch during recrystallizing. In this case, water acts as a plasticizer (He and Hoseney, 1990). During the recrystallization water is forced out of the structure of amylopectin and amylose. This leads to a relationship between decreasing water content and increasing firmness (Ozkoc *et al*., 2009).

On reflection of free humidity (water activity) the slope of the regression line has to be considered, as shown in Fig. 2. The increasing slope is an indication for a faster release and therefore faster development of unbound water. The predominant mechanism for the higher water release is that the starch converts from amorphous to crystalline phase (Katz, 1928) and the former immobilized water is displaced.

It is noticeable that the microwave baked bread had a steeper increase of unbound water loss of the starch molecules. This effect can be concluded by a stronger recrystallization of amylopectin.

This may be due to the different swelling processes of the starch in the two heating modes. In the conventional process the starch granules pass through all its stages, which means swelling, loss of birefringence and amylose leaching. Thus, the granules are not completely destroyed. Therefore, the amylopectin releases the water slow because the granules form a protective cover and allows a better water holding capacity.

In contrast, the swelling process in microwave is faster. This also noted by Zhang and Datta (2006). As former described, microwave heating leads to a vibration of the water molecules in the amorphous phase of starch (Palav and Seetharaman, 2007). This results probably in a rupture of the granules. Amylose and amylopectin are present in free form and are not longer surrounded by the protective cover of the granules. Therefore, they can release water faster than amylopectin in conventionally baked bread. By this observation it can be assumed that the swelling behaviour of starch during baking process with microwaves affects the velocity of recrystallization of starch and speeds up by this way the retro-gradation of those baked bread.

CONCLUSION

In comparison of the two different heating conditions, determination of free humidity (water activity) delivered the most relevant data for the recrystallization process of starch heated by microwaves or in standard bakery ovens. The data indicate an increased recrystallization rate of microwave heated starch compared with standard heated starch in rye-wheat-bread.

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REFERENCES

Bloksma, A.H. and W. Bushuk, 1988. Rheology and Chemistry of Dough. In: Pomeranz, Y. (Ed.), Wheat: Chemistry and Technology. Vol. 2, AACC, St. Paul, pp: 335.

Demirekler, P., G. Sumnu and S. Sahin, 2004. Optimization of bread baking in halogen lamp-microwave combination oven by response surface methodology. Eur. Food Res. Technol., 219: 341-347.

Gray, J.A. and J.N. Bemiller, 2003. Bread staling: Molecular basis and control. Compr. Rev. Food Sci. F., 2: 1-21.

He, H. and R.C. Hoseney, 1990. Changes in bread firmness and moisture during long-term storage. Cereal Chem., 67: 603-605.

Hellmann, N.N. and B. Fairchild, 1954. The bread staling problem. Molecular organization of starch upon aging of concentrated starch gels at various moisture levels. Cereal Chem., 31: 495.

Katz, J.R., 1928. Gelatinization and Retro Gradation of Starch in Relation to the Problem of Bread Staling. In: Walton, R.P. (Ed.), Comprehensive Survey of Starch Chemistry. Chemical Catalog Co., New York, pp: 100-117.

Keskin, S.O., G. Sumnu and S. Sahin, 2004. Bread baking in halogen lamp-microwave combination oven. Food Res. Int., 37(5): 489-495.

Ozkoc, S.O., G. Sumnu, S. Sahin and E. Turabi, 2009. Investigation of physicochemical properties of breads baked in microwave and infrared-microwave combination ovens during storage. Eur. Food Res. Technol., 228: 883-893.

Palav, T. and K. Seetharaman, 2007. Impact of microwave heating on the physico-chemical properties of a starch-water model system. Carbohyd. Polym., 67: 596-604.

Sablani, S.S., M. Marcotte, O.D. Baik and F. Castaigne, 1998. Modeling of simultaneous heat and water transport in the baking process. Lebensm. Wiss. Technol., 31: 201-209.

Schiraldi, A. and D. Fessas, 2001. Mechanism of Staling: An Overview. In: Chinachoti, P. and Y. Vodovotz (Eds.), Bread Staling. CRC Press, Boca Raton, FL, pp: 1-17.

Ternes, W., 2011. Naturwissenschaftliche Grundlagen der Lebensmittelzubereitung. Vol. 3, Behr's Verlag, Hamburg, pp: 11.

Zhang, J. and A.K. Datta, 2006. Mathematical modeling of bread baking process. J. Food Eng., 75: 78-89.