



**BADANIE PROCESU CZERSTWIENIA PIECZYWA Z ZASTOSOWANIEM  
METOD TEKSTUROMETRYCZNEJ I AKUSTYCZNEJ**

**Investigation of staling of bread using mechanical and acoustic methods**

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**STRESZCZENIE**

Badanie procesu czerstwienia pieczywa przeprowadzono na próbkach pieczywa pszenno-żytniego, wypiekanego metodą tradycyjną. Celem badań było określenie wpływu zmian wilgotności strukturalnej badanego materiału na twardość wierzchniej warstwy pieczywa. Autorzy zastosowali następujące metody diagnostyczne: mechaniczny test penetrometryczny połączony z pomiarem emisji akustycznej, wykonywany za pomocą akcelerometru połączonego z penetrometrem. Testy mechaniczny i akustyczny, wykonane na materiale przechowywanym w warunkach stałej wilgotności i temperatury wykazały, że twardość wierzchniej warstwy pieczywa rośnie w okresie pierwszych 24 - 48 godzin po wypieku. Po tym czasie rozpoczyna się proces odzyskiwania przez warstwę wierzchnią twardości na poziomie wyjściowym w wyniku przebudowy struktury matrycy skrobiowo-białkowej produktu i migracji wody. Otrzymane wyniki mogą być wykorzystane do kontroli procesu czerstwienia pieczywa będącego w obrocie handlowym.

**1. INTRODUCTION**

Bread can be considered as a partly elastic and partly crispy solid foam composed of starch and gluten molecules with multiple minor and low molecular weight components (pentosans, yeast cells, sugars, inorganic salts, etc.). During baking the ingredients are transformed into a starch polymer structure mixed with partially gelatinized inclusions. The mechanical properties of this structure highly depend on the amount of adsorbed water. Bread staling is a complex and not fully understood process [1]. Generally, it is evident that the moisture transfer undergoes from crumb to the crust and, later on some water can evaporate from the crust to the environment. The gradual changes in the starch components leading from amorphous to crystalline forms is called retrogradation and is by many researches treated as an important part of bread staling process [2].

## 2. EXPERIMENTAL

The following investigation was undertaken on a mixed wheat-rye bread baked by traditional method. Its aim was to determine the effect of moisture transfer from crumb to the crust on mechanical and acoustic properties of the crust. The most commonly used method to measure bread physical texture is penetration test. This was made by application of a standard penetrating tool with a ¼ inch ball tip. The tool was moving with a speed of 0.5 mm/s., powered by a silent Zwick 1445 loading machine. After each experiment a work of penetration was calculated. An accelerometer sensor, Brüel & Kjaer 4381V was mounted near the lower end of the upper head of the loading machine to achieve an acoustic contact with the bread sample. The AE sensor was capable to register the acoustic signal at a frequency range from 0.1Hz to 14 kHz. The AE signal was transmitted from the sensor to a 20 dB low – noise amplifier and finally registered using a 44.1 kHz sampling sound card placed in a PC computer.

Sets of ten measurements were made in the following order: right after baking and after 1, 2 3, 4 and (for storage temperature 25°C) – after 5 days of storage. The penetration test lasted 60 seconds, however only precisely defined 20 seconds period next to the region of greatest acoustic activity was analyzed in each case. This was made to avoid the influence of the initial movement of the penetration tool to the process of collecting the acoustic signal. An automatic computer procedure was designed to calculate Acoustic Emission (AE) signal energy what was done in the following way. The procedure was capable to detect AE signal bursts, called AE events within the recognized 20 seconds of the most vital AE activity and then the amplitude and energy of AE events was determined. After the review of the collected data it was concluded that *average AE event energy* calculated according to the software procedure described above is a process *descriptor* characterized by the lowest level of dispersion within the population of the same product and also this parameter is sensitive to the changes of the product firmness what will be shown in the next paragraph.

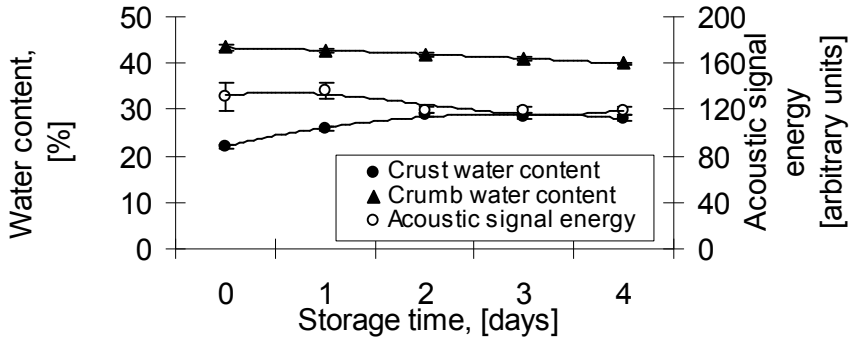
Moisture content of the bread specimens was measured before and after the storage period according to Polish Standard PN-84/A-86361 .

## 3. EXPERIMENTAL RESULTS

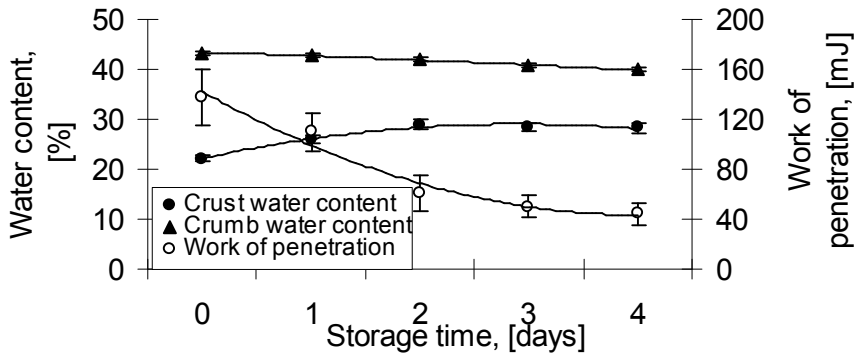
Storage of investigated bread under environment conditions is accompanied by mass transfer processes. Crumb water content is much higher than that of crust and the water concentration gradient causes movement of water from interior to the surface of bread. Just after baking the difference between the crust and crumb water content was 21.18% absolute, while after 4 days of storage the difference decreased to 11.68% absolute. At the same time the crust is losing water to the surrounding air, but the desorption process is slow and the flux of water is small. In consequence the stream of water from crumb to crust is larger than that from the surface to the surroundings and increasing water content in the crust is observed. The mass transfer processes and wetting of crust result in decreased acoustic signal energy (Fig. 3.1). During the first day of storage acoustic activity of bread is almost constant, thereafter acoustic signal energy decreases and after 4 days of storage the difference reaches some 9.5%.

Changes in crust water content are also reflected by the changes in work of penetration (Fig. 3.2). Increasing water content in the bread crust causes pronounced decrease of its resistance to penetration. Increase of the crust water content by 6.08%

absolute, decreases almost 3-fold work of penetration.



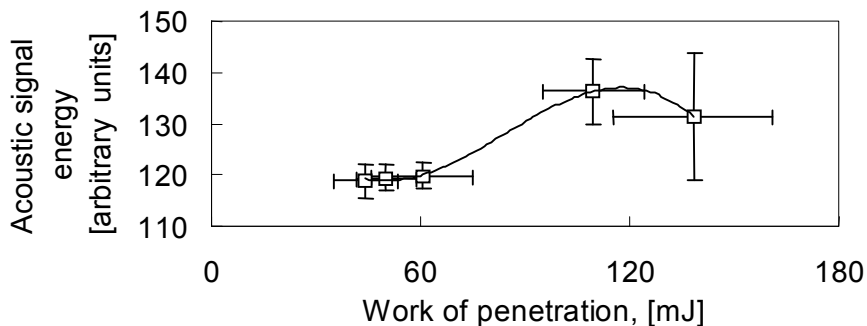
3.1. Changes in water content of crust and crumb of bread during storage and their influence on acoustic signal energy.



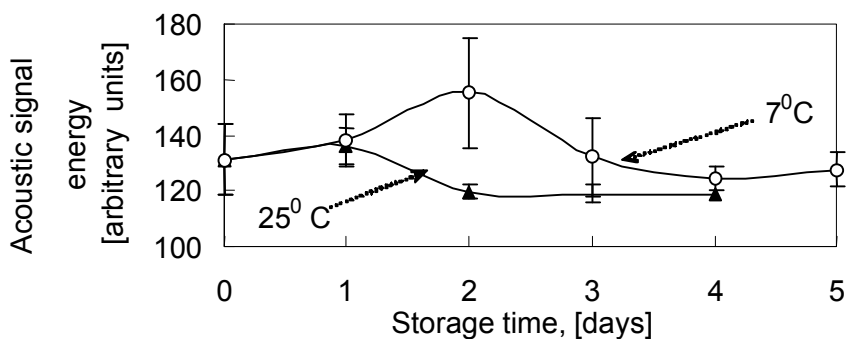
3.2 Changes in water content of crust and crumb of bread during storage and their influence on work of penetration of the crust.

Plotting acoustic signal energy in respect to work of penetration of bread crust, at the same water content, a logistic type of relationship is obtained (Fig. 3.3). It shows that mechanical test not necessarily follow changes in acoustic properties of the material. Resistance to penetration decreases continuously with increasing water content in the crust, while acoustic signal energy changes abruptly within the narrow range of water contents. Hence, acoustic measurements are more sensitive to changes in the quality of the bread crust than the penetration test.

Storage of bread at temperature lower than the ambient one slows down changes in the crust. Maximum acoustic signal energy occurs after two days of storage (Fig. 3.4), hence changes in the crust responsible for its acoustic properties are temperature dependent.



3.3. Relationship between acoustic signal energy and work of penetration of bread crust.



3.4. Influence of storage time and temperature on acoustic signal energy of bread crust.

#### 4. CONCLUSIONS

1. Increasing water content in bread crust causes continuous decrease of its resistance to penetration, while acoustic activity changes within the narrow range of water contents.

2. Changes in the bread crust responsible for its acoustic properties are temperature dependent.

#### REFERENCES

1. M.G. Scanlon, M.C. Zghal, Bread properties and crumb structure, *Food Research International* **34**, 841 – 864 (2001)
2. J. A. Gray, J. N. Bemiller, Bread Staling: Molecular Basis and Control, *Comprehensive Reviews in Food Science and Food Safety*, **2**, 1 – 8, (2003)

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