sciendo
DOI: 10.1515/agriceng-2018-0031
ISNN 2083-1587; e-ISNN 2449-5999
2018,Vol. 22,No.4, pp.5-13
Agricultural Engineering
www.wir.ptir.org

EFFECT OF SONICATION ON THE MECHANICAL PROPERTIES OF ORGANIC MIXED GRAIN BREAD

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ARTICLE INFO

Article history:
Received: October 2018
Received in the revised form: November 2018
Accepted: November 2018

Key words:
ultrasonic technique,
bread,
mechanical properties,
TPA

ABSTRACT

The aim of this study was to determine the effect of ultrasound waves on mechanical properties of organic bread. Mixed grain bread baked at a local bakery according to its original recipe was the material subjected to testing. Prior to baking, the dough was sonicated at frequencies of 20 kHz and 40 kHz for 3 minutes, and at a frequency of 100 kHz for 3 minutes and 6 minutes. The mechanical properties of the bread (compression test, penetration test and TPA) were examined after 24 h, 48 h and 72 h following the baking process. The maximum work obtained in the compression test after 24 h following the baking ranged from 616 N to 668 N. On the next day following the baking, the maximum work value ranged from 750 N to 898 N, while after 72 hours, it ranged from 988 N to 1135 N. In the penetration test, the following results were obtained: after 24 hours, the force value ranged from 2.71 N to 3.17 N; after 48 hours following the baking, it ranged from 4.90 N to 6.35 N; and after 72 hours following the baking, from 3.98 N to 6.88 N. As regards elasticity, the obtained results fell within the following ranges: after 24 hours following the baking, from 0.53 to 0.58; after 48 hours following the baking, from 0.43 to 0.55; and after 72 hours following the baking, from 0.40 to 0.45. Gumminess measured after 24 hours following the baking ranged from 8.75 N to 18.71 N; after 48 hours, from 10.83 N to 15.48 N; and after 72 hours, the gumminess values ranged from 15.57 N to 19.06 N. As regards chewiness, the following results were obtained: after 24 hours following the baking, from 8.00 N to 17.59 N; after 48 hours following the baking, from 9.77 N to 13.87 N; and after 72 hours following the baking, from 12.56 N to 16.85 N. The frequencies and durations of sonication applied changed no mechanical properties of the tested bread.

Introduction

Bread is one of the basic food products in the daily diet of the inhabitants of many countries worldwide, including Poland. For a few decades, a steadily decreasing consumption of bread in Poland has been observed. Borowska and Kowrygo (2013) believe that the reasons for the decrease in the consumption of bakery products include both deterioration in their quality and a change in consumer preferences with regard to this group of products. The quality of bakery products is affected by many factors, including the properties of flour, the type of additives used and the baking technology applied (Jędrzejczyk & Hoffman, 2009; Dziki et al., 2011). The acceptance of a food product is determined by its sensory characteristics, i.e. taste, smell, appearance and texture (Heenan et al., 2008; Arvola et al., 2007). Studies conducted on the consumers' perception of cereal products, particularly bread, indicate that the most desirable characteristics of these foods include freshness, taste, colour and texture. Gray and Bemiller (2003) found that hardness is one of the key features of texture that is assessed and recognised by the consumer.

The current situation in the bakery product market encourages producers of this group of products to apply new technologies to modify the sensory characteristics of bakery products to satisfy the expectations of increasingly demanding consumers.

This paper proposes the use of ultrasounds to modify the properties of bread.

Ultrasound waves are mechanical vibrations with a frequency of over 16 kHz, the range of which is higher than the upper audible limit of human hearing (Leighton, 2007). They were used to modify the properties of materials and substances. Modifications of the properties of food products may both enable creation of new articles and contribute to an increase in the acceptability or attractiveness of products available on the market (Maksymiec et al., 2016).

Even though, the ultrasonic technology has been applied in the food industry only for a short time, a number of studies have been published which indicate broad possibilities and a great potential for the application of ultrasound to support food production and processing (Cárcel et al., 2012; Charoux et al., 2017; Kaczmarski & Lewicki, 2005; Konopacka et al., 2015; Nowak et al., 2015; Patist & Bates, 2008; Stadler et al., 2016; Wesołowski et al., 2016a and b). It was demonstrated, *inter alia*, that ultrasound can contribute to changes in the texture of food products. In 2006, Jayasooriya et al. conducted a study which demonstrated that ultrasound may reduce the hardness of beef without adversely affecting the colour and pH value of the meat (Jayasooriya et al., 2006). In 2012, ultrasound was used to decrease the hardness of chicken breast meat (Xiong et al., 2012).

In bread processing ultrasonic techniques were used to investigate the cellular structure of bread crumb (Elmehdi et al., 2003; Lagrain et al., 2006). In addition Pa et al., (2014) investigate ultrasound power and time influence on bread physical properties.

At the Department of Foundations of Safety at the Faculty of Technical Sciences of the University of Warmia and Mazury in Olsztyn, studies are being carried out into the application of the sonication technique in the production and processing of organic articles without impairing their quality or decreasing their nutritional value while maintaining health-promoting properties and appropriated storage parameters and, at the same time, expanding their durability.

The aim of the study was to determine the effect of ultrasound applied at various frequencies and durations of action on the mechanical properties of organic mixed grain bread. In this research as opposed to the research already published, dough was treated by ultrasounds.

Material and methods

Regular mixed grain bread baked at Paweł Bednarczyk's Bakery in Dobre Miasto was the study material. Mixed grain bread consist of 70% wheat flour, 9% of rye leaven, 8% wheat leaven and 2% rye flour (flours certificate number Agro BIO test PL-EKO-07-90001). The dough for the bread was prepared according to the bakery's original recipe. After the pieces of dough were rounded, twenty wads intended for testing were removed from the dough processing line. Of these, four pieces of dough were non-sonicated control samples. The other pieces of dough were sonicated in an ultrasonic device (Ultron, Poland). Pieces of dough were subjected to 6-minute sonication at frequencies of 20 kHz, 40 kHz and 100 kHz, and to 3-minute sonication at the frequency of 100 kHz. After baking, the bread was left to cool down. After 24 hours the loaves were cut into 20 mm thick slices from the centre of which cylindrical samples with a diameter of 52 mm were cut out.

Penetration, compression and TPA test were proceeded to determine mechanical properties of the bread texture. The testing was conducted using a Multitest-1 tensile and compression testing system (the United Kingdom). The penetration test was conducted using a cylindrical tip with a diameter of 5 mm; the penetration force of the tip moving with a speed of 10 mm/min was measured, and the maximum force of the test (N) was determined. The compression test was conducted using a cylindrical tip with a diameter of 74 mm, with the measuring head travelling speed of 10 mm/min; the assumed deformation of crumb samples was 10%. In the compression test the maximum compression work – hardness was determined.

The mechanical parameters of texture (cohesiveness, gumminess, and chewiness) were determined using a double compression test TPA (Multitest-1, UK). Cohesiveness defined as the ratio of work compression in the second TPA cycle to the first one gumminess defined as multiplication of hardness and cohesiveness value, chewiness defined as multiplication of gumminess and elasticity.

TPA testing was conducted using a cylindrical tip with a diameter of 74 mm. The measurement was carried out at a constant travelling speed of 60 mm/min, to the depth of 12 mm. The penetration, compression and TPA test were performed according to the Multitest-1 software. The same tests were conducted 48 and 72 hours after the bread had been baked.

A statistical analysis was conducted using Statistica 13.1 software (Statsoft, Poland). The results presented in the paper are an arithmetical mean of five independent repetitions. In the absence of normal distribution, to compare mean values with the reference group, i.e. non-sonicated bread, a non-parametric Mann-Whitney U test was applied. The frequency of ultrasound in relation to the variable of time following the baking was adopted as the grouping variable.

Results and discussion

The maximum penetration force was determined in penetration test and results are presented in Figure 1.

After 24 hours following the baking, the values of the maximum penetration force for the tested samples ranged from 2.71 N to 3.17 N. After 48 hours following baking, the highest value of penetration force (6.35 N) was obtained for a 6-minute ultrasonic action at the frequency of 40 kHz, while the lowest value (4.90 N) was obtained for a non-sonicated sample. For sonication at the frequency of 100 kHz, regardless of its duration (3 minutes, 6 minutes), the obtained values of the maximum penetration force were the same and amounted to 5.05 N. After 72 hours following the baking, the value of maximum penetration force ranged from 3.97 N to 6.88 N. No statistically significant changes were noted between the control sample and the sonicated sample for the maximum penetration force. Neither the duration of ultrasonic action nor the frequencies applied caused changes in the mechanical properties of the tested bread.

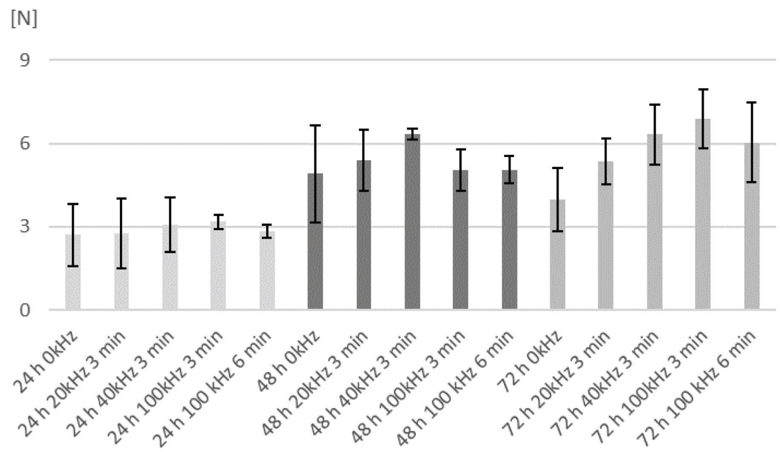

Figure 1. Maximum penetration force

Hardness was determined based on the maximum work obtained in the compression test (Fig. 2). 24 hours after the bread had been baked, the compression work ranged from 616 N to 668 N. 48 hours following the baking, the compression work value ranged from 750 N to 898 N, while after 72 hours, values were noted ranging from 988 N to 1135 N.

Nevertheless, no statistically significant differences were demonstrated between the hardness of the control bread and bread baked from sonicated dough, regardless of the ultrasound frequency applied, and the duration of ultrasonic action. In the research presented by (Janve et al., 2015) power ultrasound was used to corn (Zea Mays) Tortilla Chips quality evaluation. In this study, power ultrasound reduces the traditional corn stripping during tortilla chips dough processing.

The TPA test mimics the biting action of the human mouth on a particular product (Bourne, 2002). It provides information on the primary distinguishing features of the texture, including hardness, cohesiveness, and elasticity, as well as secondary ones, such as e.g. chewiness (Breene, 1975). After the performance of the TPA test, the following mechanical parameters characterising texture of the bread under study were determined: elasticity, gumminess and chewiness.

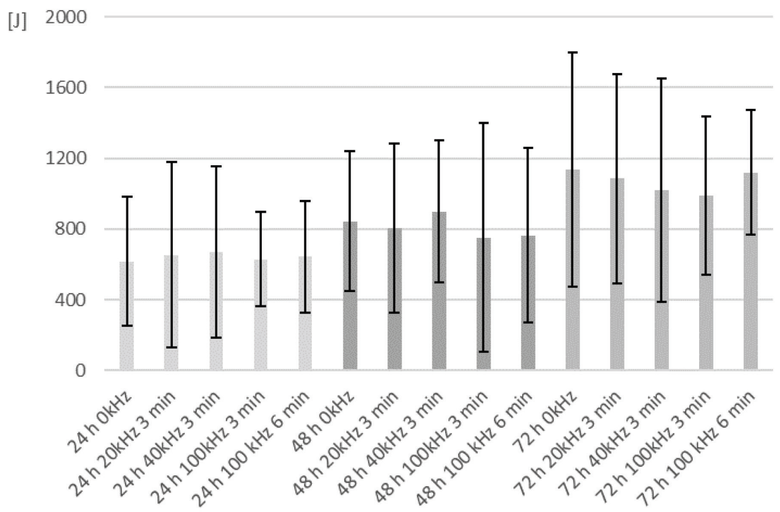

Figure 2. Maximum work obtained in the compression test

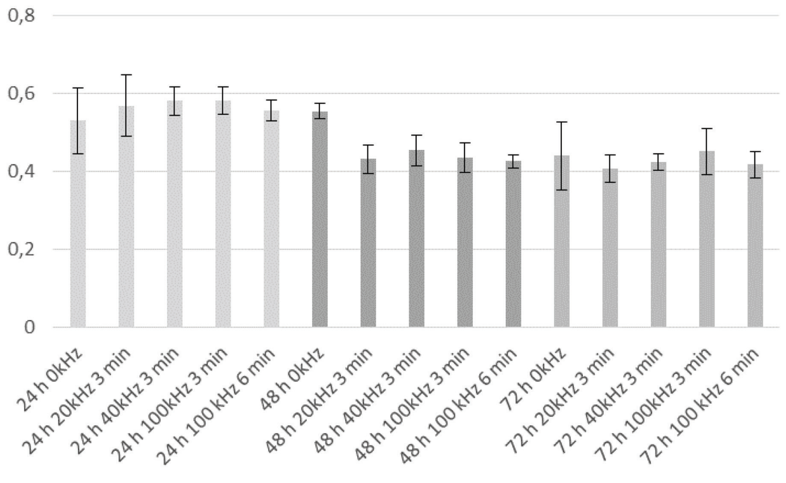

Figure 3. Bread cohesiveness obtained in the TPA test

Figure 3 presents cohesiveness values obtained for the tested bread. On the first day following the baking, the value of the parameter ranged from 0.53 to 0.58. The lowest value of 0.53 was obtained for the non-sonicated sample. The highest values were noted for bread samples subjected to sonication for 6 minutes at the frequencies of both 40 kHz and 100 kHz. On the second day following the baking, bread cohesiveness ranged from 0.43 to

0.56. The highest value (0.56) was obtained for the control sample, while the lowest one was obtained in two cases: following 6-minute sonication at the frequency of 20 kHz, and following 3-minute sonication at the frequency of 100 kHz. Cohesiveness of the bread after 72 hours following the baking ranged from 0.41 to 0.45. The lowest cohesiveness value was noted for the bread baked from dough subjected to 6-minute sonication at the frequency of 20 kHz, while the highest cohesiveness value was obtained for the bread baked from dough subjected to 6-minute sonication at the frequency of 100 kHz.

Gumminess values for the tested bread are presented in Figure 4. Gumminess of the tested bread after 24 hours following the baking ranged from 8.75 N to 18.71 N. The lowest gumminess value was noted for the bread baked from dough sonicated for 6 minutes at the frequency of 100 kHz. The highest gumminess value was obtained for a 6-minute ultrasonic action at the frequency of 20 kHz. On the next day following the baking, the gumminess values for the tested bread ranged from 10.83 N to 15.48 N. The lowest gumminess value was noted for the bread sonicated for 3 minutes at the frequency of 100 kHz. On the third day following the baking, the value of the tested parameter ranged from 15.57 N (control sample) to 19.06 N (sample sonicated at the frequency of 20 kHz).

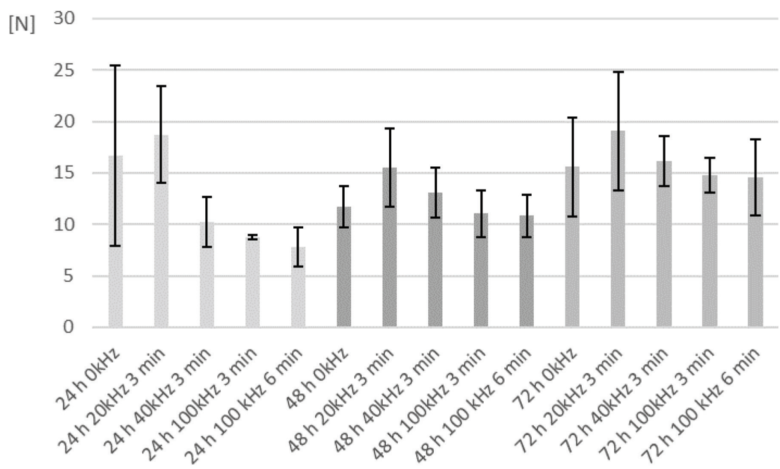

Figure 4. Bread gumminess obtained in the test

Figure 5 presents the chewiness results obtained for the tested bread. On the first day following the baking, the highest chewiness value of 17.59 N was reported for the sample subjected to 3-minute sonication at the frequency of 20 kHz, while the lowest value of 8.60 N was noted for sonication at the frequency of 40 kHz. 48 hours after the bread had been baked, similar to its condition after 24 hours, the highest chewiness value was noted for the bread sonicated at the frequency of 20 kHz (13.87 N), while the lowest value was obtained for 3-minute sonication at the frequency of 100 kHz (9.77 N). On the third day following baking, similar to the two previous days, the highest chewiness value was reported for sonication at the frequency of 20 kHz (16.85 N).

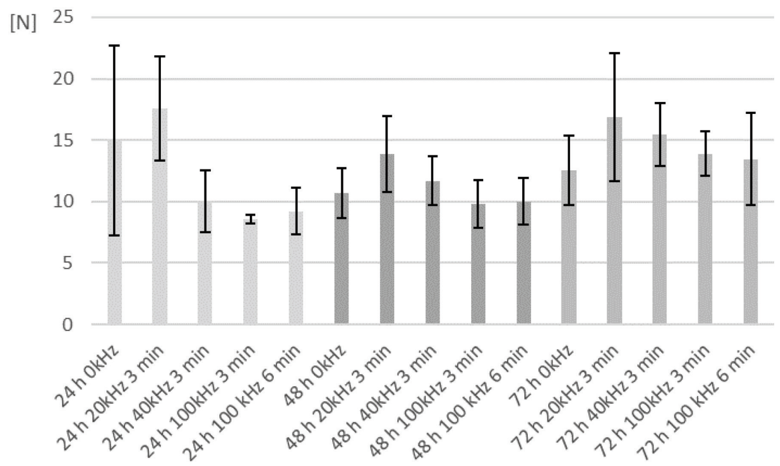

Figure 5. Bread chewiness obtained in a TPA test

The conducted testing demonstrated changes in certain mechanical properties of the bread subjected to sonication compared to the non-sonicated material. These changes, however, are statistically insignificant. This may be due to the fact that the power of ultrasound waves generated oscillated between sonication disrupting and non-disrupting cell structures. The obtained results provide a basis for further research into the effect of ultrasound waves on mechanical properties. It is advisable to apply different frequencies and durations of the ultrasonic action in further studies.

Conclusions

It was found that the application of 3-minute sonication at the frequencies of 20 kHz, 40 kHz and 100 kHz, and of 6-minute sonication at the frequency of 100 kHz resulted in no changes in the tested mechanical properties of the mixed grain bread, which was proven by the results obtained in the TPA test.

Acknowledgements: *We would like to express our gratitude to Paweł Bednarczyk's Bakery in Dobre Miasto for the opportunity of baking bread for the study described in this paper, and for their comprehensive assistance and consultations.*

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WPŁYW SONIKACJI NA WŁAŚCIWOŚCI MECHANICZNE EKOLOGICZNEGO CHLEBA MIESZANEGO

Streszczenie. Celem pracy było określenie wpływu ultradźwięków na właściwości mechaniczne chleba ekologicznego. Badaniom poddano chleb mieszany wypieczony w lokalnej piekarni zgodnie jej recepturą. Przed wypiekiem ciasto zostało poddane sonikacji o częstotliwości 20 kHz i 40 kHz przez 3 minuty oraz częstotliwości 100 kHz przez 3 min i 6 minut. Właściwości mechaniczne chleba (test ściskania, test penetracji oraz TPA) zbadano po 24 h, 48 h i 72 h od wypieku. Maksymalna praca uzyskana w teście ściskania po 24 h od wypieku mieściła się w granicy od 616 N do 668 N. W kolejnej dobie po wypieku wartość pracy maksymalnej wyniosła od 750 N do 898 N, natomiast po 72 h wynosiła od 988 N do 1135 N. W teście penetracji uzyskano następujące wyniki po 24 h wartość siły mieściła się w granicach 2,71÷3,17 N, 48 godzin po wypieku 4,90÷6,35 N oraz 3,98÷6,88 N po 72 godzinach od wypieku. W przypadku sprężystości otrzymano wyniki mieszczące się w następujących granicach 24 h po wypieku 0,53÷0,58, 48 h po wypieku 0,43÷0,55, 72 h po wypieku 0,40÷0,45. Gumiastość mierzona 24 h po wypieku mieściła się w granicach od 8,75 N do 18,71 N, po 48 h od 10,83 N do 15,48 N, a po 72 h wartości gumiastości mieściły się w przedziale od 15,57 N do 19,06 N. W przypadku żujności otrzymano następujące wyniki 24 h po wypieku 8,00÷17,59 N, 48 h po wypieku 9,77÷13,87 N, 72 h po wypieku 12,56÷16,85 N. Zastosowane częstotliwości oraz czas sonikacji nie wpłynęły na zmianę właściwości mechanicznych badanego chleba.

Słowa kluczowe: technika ultradźwiękowa, chleb, właściwości mechaniczne, TPA

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