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IMPACT OF SPOUTED-MICROWAVE DRYING ON THE SELECTED MECHANICAL AND RHEOLOGICAL PROPERTIES OF ZUCCHINI

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ABSTRACT

Mechanical and rheological properties of zucchini dried with spouted microwave - assisted heating was analysed. During spouted drying two levels of microwave power were applied: 100W and 250W. Tests were carried out for the raw material blanched in the temperature of 60ºC for 10 minutes and not subjected to a pretreatment. Compression resistance, cutting resistance and stresses relaxation ratios *a* and *b* were determined. A significant impact of drying conditions on the product quality within the scope of mechanical and rheological properties was reported. Raw zucchini has 5 to 7 times higher compression resistance, several times lowered cutting resistance and almost two times higher elasticity in comparison to dried material. Low-temperature blanching significantly affected the values of all investigated properties of dried zucchini. Change in microwave powers during spouted drying significantly influenced the increase of the compression work value.

Introduction

Dietary changes of a greater part of society draw attention of consumers to vegetables which have appropriate biological, taste properties and low calorific value. Zucchini contains higher protein and vitamin C content in comparison to other cucurbitales. It is recommended in low-calories diets on account of a low content of carbohydrates and fats. Zucchini is perceived as a vegetable with a high utility value for direct consumption as well as for processing (Lintas, 1992).

Vegetables and fruit play more and more significant role in the diet of a conscious consumer. However, they are obtained seasonally and their shell life is short. Storing of these raw materials in cool storages or modern storages does not give a desired effect because considerable quantity and quality losses occur. Their nutritive and consumption value decreases at high costs of storing of raw materials (Krzysztofik and Łapczyńska-Kordon, 2008).

Many methods which aim at reduction of losses or creation of conditions for long storing of raw materials are used; cooling, freezing, smoking, pasteurization, pickling or finally drying. Each of the mentioned method of preserving food has its drawbacks and ad-

vantages. It seems that drying has a prevailing position due to possibilities of lowering the water activity in dry material, as a result of which a product may be led to the condition in which micro-organisms' development is impossible and enzymatic and non-enzymatic changes may be limited (Feng et al., 2012; Lewicki, 1999). Food products in the form of dried material have properties which facilitate transport, storing and processing.

A convective method is still the most frequently used drying method. It allows obtaining a cheap product, mainly due to relatively low costs of installation but characterized with unfavourable changes concerning smell, taste, content of nutritive substances and unfavourable reconstitution properties (Lin et al., 1998). Putting the dehydrated material in motion with complex trajectory allows elimination or limitation of a great number of faults of classical convective drying. During spouted drying material heating is more regular, conditions of heat and mass transport are improved. As a result duration of the process shortens and dry material with the raised quality is obtained (Bezera et al., 2013; Kahyaoglu et al., 2012).

The use of microwaves as a source of heat for the dehydrated material is the next step of researchers towards obtaining dried material with the quality expected by consumers. It is then possible to shorten the duration of the process, reduce energy consumption and improve the product quality (Wang et al., 2004; Yan et al., 2010). In the search for drying techniques, which will allow obtaining products with the highest quality a big group of combined drying methods has developed. Most often microwave heating is used during convective drying (Lentas et al., 2011), sublimation drying (Cohen and Young, 1995) and spouted drying (Feng et al., 2012; Kahyaoglu et al., 2012). Drying with combined methods allows shortening the process duration by several times and dried materials have minimal biochemical changes, smaller drying shrinkage and hardness and hygroscopicity of the product increases.

Blanching fruit and vegetables is the most often used initial treatment before further technological treatment e.g. before drying. It influences enzymes activity and loosening of tissue. As a result of high temperature blanching results the mechanical properties and texture of dried tissue and the level of sugars which are soluble in raw material worsen. (Saldivar et al., 2010). Many researchers indicate the favourable impact of high temperature blanching on the texture and mechanical properties, which is related to obtaining a firming effect (Neri et al., 2011; Ni et al., 2005; Lentas and Witrowa-Rajchert 2009).

Objective, scope and methods of research

The objective of the research was to determine the dried zucchini properties, obtained with a spouted-microwave method from the point of view of the selected mechanical properties (compression work and cutting work) and rheological (ratios *a* and *b* which determine the course of the stresses relaxation process).

Samples were cut off the zucchini pulp in the form of cubes with the side length of 10 mm. One half of the samples were subjected to low temperature water blanching in the temperature of 60ºC for 10 minutes. The second part of material was treated as a test sample and was not subjected to pretreatment. Moisture of raw material was 96.2%±0.2. Spouted-microwave drying was carried out with the use of a prototype drying installation designed and constructed for the Laboratory of Plant Materials Processing of the Institute of

Agricultural Engineering of Wroclaw University of Life Sciences. The literature shows that the microwave power significantly influences the changes in hardness, colour and content of volatile substances in dried material (Calin-Sanchez et al., 2011; Marzec iand Zadrożna, 2008). Thus, extreme microwave powers from the scope which can be obtained in the installation i.e. 100 W and 250 W were applied. Temperature of the drying agent was 70ºC. The necessity to obtain the spouting effect of the bed required regulation of the velocity of the drying agent flow within 4-10 $m \cdot s^{-1}$.

Strength and rheological tests were carried out on the testing machine Instron 5566 equipped with a tensometric head class 0.5 with an admissible load of 100 N. Compression tests were carried out with a plate. A single sample was deformed by 20% of its initial height. The velocity of the head move was 1.8 $mm \cdot min^{-1}$, which was the highest speed from the recommended scope for research carried out in quasistatic conditions (ASAE Standard, 1986). Compression work values were calculated for 10 iterations (*Pś*). Also single samples were subjected to cutting with the modified attachment by Instron company with a knife whose blade angle and cutter tip angle was 60º each. Cutting speed was 10 $mm \cdot min^{-1}$ which is the lowest speed which allows absolute cutting of material. Values of appropriate cutting work were calculated for 10 iterations (*Pp*) i.e. work calculated per 1 cm^2 of the cut surface. For stresses relaxation tests, an attachment for compression tests was used and 5 iterations of measurements were carried out. The course of standard function of stresses relaxation was determined with the equation:

$$Y(\tau)=\frac{a \cdot b \cdot \tau}{1+b \cdot \tau} \tag{1}$$

where:

$Y(\tau)$ – standard function of stresses relaxation, (-)
a, b – stresses relaxation process ratios (-),
τ – duration of the stresses relaxation process, (s)

Values of ratios *a* and *b* were determined, which describe respectively the level and speed of stresses removal during the test. Details of mechanical and rheological properties research methodologies and calculations were presented in the publication (Stępień, 2009).

Program *Statistica 10.5* was used for assessment of the low-temperature blanching impact and microwaves power on mechanical and rheological properties by multi-factor analysis of variance at the level of significance which is $\alpha=0.05$.

Analysis of results

All variants of dried zucchini obtained with the spouted - microwave method had the average moisture of 8%±0.3. Slight differences in the moisture allowed an assumption that dry material moisture did not have a significant impact on the investigated properties which was proved in previous publications (Stępień, 2009; Stępień et al., 2013). Calculations of compression work values and values of appropriate cutting work were carried out with a trapezoid method (Stępień, 2008) which allowed including sudden changes of the course

of compression curves and cutting curves. Results of multi-factor analysis of variance for all tests were presented in table 1.

Table 1.
Results of statistical analysis of the impact of blanching and microwaves power on mechanical and rheological properties presenting p values of p-probability of hypothesis rejection 0)

	Mechanical and rheological properties			
Factors	*Pś*	*Pp*	*a*	*b*
Microwaves power	0.002782	0.166766	0.669892	0.089336
Blanching	0.030217	0.000810	0.472961	0.000345

Figure 1 presents results of microwaves power impact during spouted-microwave drying and blanching on the compression work values.

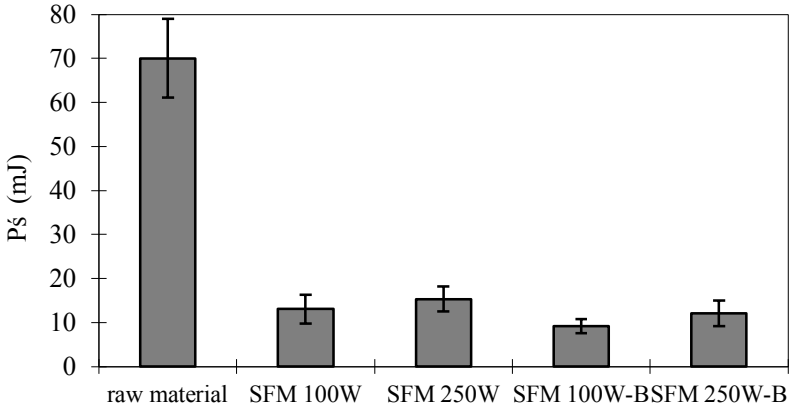

Figure 1. Values of compression work of zucchini

Dried material obtained with the spouted-microwave method have 5-7 times lowered compression resistance in comparison to raw zucchini. The increase of microwave power from 100 W to 250 W causes significant increase of the work values needed for deformation of dried zucchini. These observations are compliant with applications from Lentas et. al., (2011) and Marzec and Zadrożna (2008). Low-temperature blanching before spouted-microwave drying allows obtaining dried material with compression resistance in comparison to dried material obtained from zucchini which was not subjected to initial treatment (Table 1). The obtained results of tests conform to previously obtained results of Niedziółka and Szymanek (2004) and Stępień (2008).

Values of cutting work of zucchini dried with the spouted-microwave method were presented in figure 2. Previous tests proved justification for calculation of total cutting work values into the unit of the cut surface area for products obtained through drying (Stępień, 2008). It is related to differences in the drying shrinkage of dried materials obtained in particular versions of an experiment.

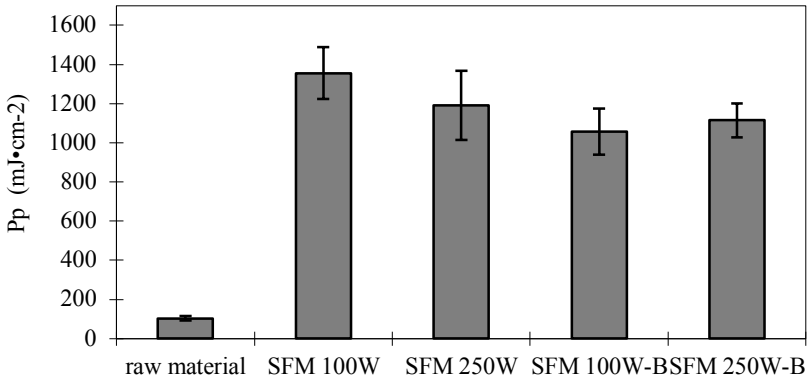

Figure 2. Values of appropriate cutting work of zucchini

Zucchini dried with spouted microwave – assisted method has a double raised cutting resistance in comparison to raw material. It is related to the destructive impact of removing moisture from biological material which is reflected in numerous changes within cell walls visible in microscopic images (Stępień, 2009). Statistical analysis proved that only blanching has a significant impact on the values of work which is necessary to cut dried zucchini (Table 1). A pretreatment in the form of low-temperature blanching causes decrease in the value of cutting work of dried material in comparison to the product obtained from raw material which was not subjected to pretreatment. Research carried out by other Authors confirm a decisive impact of thermal treatment on forces which occur during cutting of various types of agricultural products (Śląska-Grzywna, 2008), which is confirmed by the presented research results and statistical analysis (Table 1).

Product elasticity is one of the basic indexes which define texture which considerably decides on the acceptance of a given food product by a consumer. The assumed method of analysis of the course of the stresses relaxation process allows comparison of the process courses for various materials. Moreover, it enables clear determination of the drying method impact, conditions of the process or using initial treatments on elasticity of the final product. Values of ratios *a* and *b*, which describe respectively the level and speed of stresses disappearance during the test were calculated. Both sudden nature of stresses drop and the level to which the drop takes place prove the destruction degree of the cell structure of the dried biological material. Physical interpretation of ratios *a* and *b* is very explicit: the higher the values of ratios the higher the elasticity of material. Figure 3 presents the values of ratios *a* and *b* for zucchini dried with spouted-microwave method.

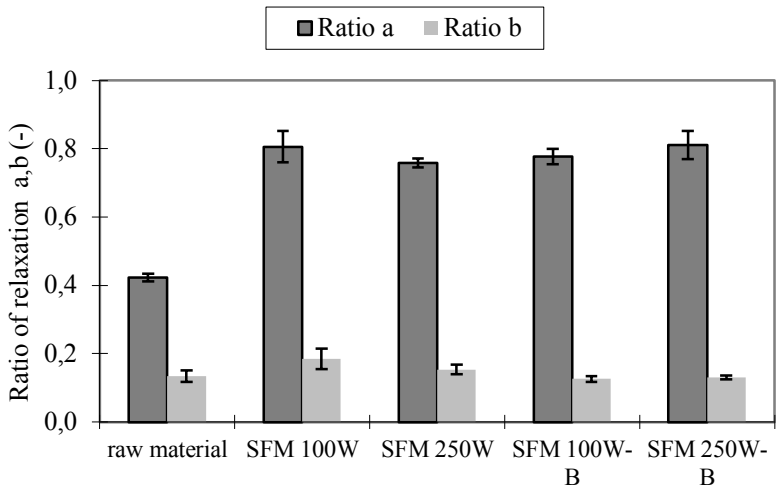

Figure 3. Values of stresses relaxation ratios

Elasticity of zucchini dried with spouted method with microwave heating is reduced in comparison to the raw material elasticity. It is not a favourable phenomenon from the point of view of acceptable nature of the product. Dried materials have lower elasticity in comparison to the elasticity of raw materials. they are poorely assessed during sensory analysis (Stępień et al., 2013). Statistical analysis (Table 1) proved that within the scope of elasticity only low temperature blanching had a significant impact on the value of ratio *b*.The applied initial treatment caused that dried material with a reduced value of ratio *b* in comparison to the value of the ratio for dried zuchini not subjected to initial treatment was obtained. It means that dried material from zucchini subjected to the initial treatment is more elastic because the speed of stresses disappearance during relaxation test is lower. It proves at the same time that low-temperature blanching applied as an initial treatment allows partial protection of the structure of dried biological material against destructive activity of the moisture removal process.

Conclusions

1. Spouted-microwave drying of zucchini causes significant changes within the scope of analysed mechanical and rheological properties of the product.
2. Spouted drying with microwave heating allows obtaining a product which has a reduced compression resistance in comparison to raw material, raised cutting resistance and lower elasticity.
3. Low temperature blanching used before drying of zucchini significantly affects the decrease of the compression work value and cutting work and the increase of dried material elasticity.

4. The increase of microwave power during spouted -microwave drying from 100 to 250 W causes only a significant increase of the compression work value, but it has no significant impact on the cutting work value and elasticity of dried zucchini.

References

ASAE Standard. (1986). 1, 361.

Bezerra, C.V., Amante, E.A., Cardoso de Oliveira, D., Rodrigues, A.M.C., Meller da Silva L.H. (2013). Green banana (*Musa cavendishii)* flour obtained in spouted bed – Effect of drying on physico-chemical, functional and morphological characteristics of the starch. *Industrial Crops and Products*, 41, 241-249.

Calin–Sanchez, A., Szumny, A., Figiel, A., Jałoszyński, K., Adamski, M., Carbonell–Barrachina, A. (2011). Effects of vacuum level and microwave power on rosemary volatile composition during vacuum-microwave drying. *Journal of Food Engineering*, *103*, 219-227.

Cohen, J.S., Yang T.C.S. (1995). Progress in food dehydration. *Trends in Food Science & Technology*, *6*, 20-25.

Feng, Y.F., Zhang, M., Jiang, H., Sun, J.C. (2012). Microwave-assisted spouted bed drying of lettuce cubes. *Drying Technology*, *30*, 1482-1490.

Kahyaoglu, L.N., Sahin, S., Sumnu, G. (2012). Spouted bed and microwave-assisted spouted bed drying of parboiled wheat. *Food and Bioproducts Processing, 90*, 301-308.

Krzysztofik, B., Łapczyńska-Kordon, B. (2008). Wpływ sposobów i czasu przechowywania na wybrane cechy sensoryczne jabłek. *Inżynieria Rolnicza*, *2*(100), 121-128.

Lentas, K., Witrowa-Rajchert, D. (2009). Wpływ parametrów blanszowania na właściwości mechaniczne i barwę suszu korzenia selera. *Acta Agrophysica*, *13*(1), 165-174.

Lentas, K., Witrowa-Rajchert, D., Hanku,s M. (2011). Wpływ parametrów blanszowania oraz metod suszenia na właściwości mechaniczne suszonych pieczarek. *Acta Agrophysica*, 17(2), 359-368

Lewicki, P.P. (1999). Właściwości wody w produktach spożywczych. *Inżynieria Chemiczna i Procesowa*, *24*, 29-46.

Lin, T.M., Durance, T.D., Scaman, C.H. (1998). Characterization of vacuum microwave, air and freeze dried carrot slices. *Food Research International*, *31*(2), 111-117.

Lintas, C. (1992). Nutritional aspects of fruit and vegetable consumption. *CIHEAM-Options Méditerranéennes. Ser. A. 19,* 79-87.

Marzec, A., Zadrożna, M. (2008). Wpływ mocy mikrofal na jakość suszu jabłkowego. *Acta Agrophysica*, *12*(2), 457-467.

Neri, L., Hernando, H., Perez-Munuera, I., Sacchetti, G., Pittia, P. (2011). Effect of blanching in water and sugar solutions on texture and microstructure of sliced carrots. *Journal of Food Science*, *1*(79), 23-30.

Ni, L., Lin, D., Barrett, D.M. (2005). Pectin methylesterase catalyzed firming effects on low temperature blanched vegetables. *Journal of Food Engineering*, *70*, 546-56.

Niedziółka, I., Szymanek, M. (2004). Wpływ blanszowania na wybrane właściwości mechaniczne ziarna kukurydzy cukrowej. *Acta Agrophysica*, *4*(2), 449-457.

Saldivar, X., Wang, Y.J., Chen, P., Maurornoustakos, A. (2010). Effect of blanching and storage conditions on soluble sugar contents in vegetable soybean. *Food Science and Technology*, *43*, 1368-1372.

Stępień, B. (2008). Impact of vacuum-microwave drying on selected mechanical and rheological features of carrot. *Biosystems Engineering*, *99*, 234-238.

Stępień, B. (2009). Modyfikacja cech mechanicznych i reologicznych wybranych warzyw pod wpływem różnych metod suszenia. *Monografia LXXIX. Wydawnictwo Uniwersytetu Przyrodniczego we Wrocławiu*, Wrocław.

Stępień, B., Jaźwiec, B., Pasławska, M., Jałoszyński, K., Surma, M. (2013). Wpływ suszenia fontannowo-mikrofalowego na jakość suszonej dyni. *Inżynieria Rolnicza, 3*(146), 371-380.
Śląska-Grzywna, B. (2008). Wpływ parametrów obróbki cieplnej selera na siłę cięcia. *Inżynieria Rolnicza*, 6(104), 175-180.
Wang, J., Xi, Y.S., Yu, Y. (2004). Microwave drying characteristics of potato and the effect of different microwave power on the dried quality of potato. *European Food research and Technology*, *219*, 500-506.
Yan, W.Q., Zhang, M., Huang, L.L., Tang, J., Mujumdar, A.S., Sun, J.C. (2010). Studies on different combined microwave drying of carrot pieces. *International Journal of Food Science and Technology*, *45*, 2141-2148.

WPŁYW SUSZENIA FONTANNOWO-MIKROFALOWEGO NA WYBRANE WŁAŚCIWOŚCI MECHANICZNE I REOLOGICZNE CUKINII

Streszczenie. Analizie poddano właściwości mechaniczne i reologiczne cukinii suszonej fontannowo z nagrzewaniem mikrofalowym (SFM). W trakcie suszenia fontannowego wykorzystano dwa poziomy mocy mikrofal: 100W i 250W. Badania wykonano dla surowca blanszowanego w temperaturze 60ºC przez 10 minut oraz nie poddanego obróbce wstępnej. Określono wytrzymałość na ściskanie, wytrzymałość na przecinanie oraz wskaźniki relaksacji naprężeń *a* i *b*. Stwierdzono istotny wpływ warunków suszenia na jakość produktu w zakresie zarówno cech mechanicznych, jak i reologicznych. Surowa cukinia charakteryzuje się od 5 do 7 razy wyższą odpornością na ściskanie, kilkunastokrotnie obniżoną odpornością na przecinanie oraz około dwukrotnie wyższą sprężystością w stosunku suszu. Niskotemperaturowe blanszowanie istotnie wpłynęło na wartości wszystkich badanych cech suszonej cukinii. Zmiana mocy mikrofal w trakcie suszenia fontannowego wpłynęła istotnie jedynie na wzrost wartości pracy ściskania.

Słowa kluczowe: suszenie, blanszowanie, cukinia, cechy wytrzymałościowe, reologia