PAPER

CHANGES IN THE TEXTURE OF BUTTERNUT SQUASH FOLLOWING THERMAL TREATMENT

B. ŚLASKA-GRZYWNA[1], A. BLICHARZ-KANIA[1], A. SAGAN[1*], R. NADULSKI[2], Z. HANUSZ[3], D. ANDREJKO[1], M. SZMIGIELSKI[1]
University of Life Sciences in Lublin, Poland
[1] Department of Biological Bases of Food and Feed Technologies
[2] Department of Food Process Engineering and Machines
[3] Department of Applied Mathematics and Computer Science
*Corresponding author: agnieszka.sagan@up.lublin.pl

ABSTRACT

Samples of butternut squash were heated in a convection steam oven at the temperature of 80°C and 100°C without any/or with addition of steam. The most significant changes of texture properties in the pulp were registered regarding its hardness and chewiness, while the alterations of its springiness and cohesiveness occurred within a smaller range. The decisive influence on changing the hardness and chewiness of butternut pulp was observed for the addition of steam, and, to a lower extent, for the time and temperature of treatment; in case of springiness the vital factor was the temperature of the process.

- Keywords: squash, thermal treatment, texture properties, convection steam oven -

INTRODUCTION

Pumpkin belongs to the family of *Cucurbitaceae*. Its edible part is the pulp of the fruit at different stages of ripeness, as well as its seeds (giant pumpkin and summer squash). The nutritional values of pumpkin fruit are high. This is determined primarily by a high content of carotenoids (from 2 to 10 mg·100 g^{-1}), which are characterized by antioxidant and anticancerous properties. Pumpkin fruit provides a good source of vitamins C, A and B, as well as minerals, such as potassium, phosphorus, calcium, magnesium, iron and selenium. They also contain organic acids (citric, malic and fumaric). Studies have revealed that the polysaccharides extracted from pumpkin have hypolipidemic activity. Additionally, pumpkin has low content of calories. Due to the presence of numerous, easily absorbed nutrients, it can be used as a component of slimming diets (CARVALHO *et al.*, 2012; NAWIRSKA-OLSZAŃSKA *et al.*, 2014; RAKACJEVA *et al.*, 2011; WOJDYLA *et al.*, 2007; ZHAO *et al.*, 2014).

Pumpkin pulp may be a healthy and valuable component of many dishes and fruit products. It is used to manufacture juices, baby foods and canned foods. A disadvantage of pumpkin, which may contribute to its low consumption, is its bland flavor and specific cucumber-like smell. This problem may be resolved by mixing pumpkin with other materials (e.g. cornel berries or quinces) in order to obtain food products of better sensory properties and chemical composition (NAWIRSKA-OLSZAŃSKA *et al.*, 2012). Pumpkin seeds are used in bakery, oil manufacturing and in pharmaceutical industry. Oil from pumpkin seeds contains valuable bioactive elements: squalene, unsaturated fatty acids, tocopherols (OBIEDZIŃSKA and WASZKIEWICZ-ROBAK, 2012).

Prior to consumption, pumpkin fruits are subjected to different types of treatment, most often thermal processing, during which their properties undergo changes (MAYOR *et al.*, 2011; ŒELASKA-GRZYWNA *et al.*, 2013), hence the aim of the study was to determine the changes in texture properties caused by thermal treatment in a convection steam oven with different parameters of the processes.

MATERIALS AND METHODS

Raw material

Research material was provided by butternut squash (*Cucurbita moschata* Duch.) originating from Portugal and purchased in London chain supermarkets. Butternut squash is an annual plant belonging to the gourd family (*Cucurbitaceae*), from Latin America. 100 g of butternut squash contains (after cooking): 0.9 g of protein, 7.4 g of carbohydrates, including 3.9 g sugars, 0.1 g of fat, 1.4 g of fiber, trace amounts of salt, 15 mg of (19% of RDA) vitamin C. Its caloric value is 156 kJ/37 kcal in 100 g. In the study we used ripe, healthy fruits, without any mechanical damage.

Treatment

The pumpkin was subjected to preliminary treatment: washing, peeling, removing the seeds. Such material was used to cut out samples for analyses. The pumpkin was sliced into 1-centimeter-thick slices. Next, cylinders of 2-centimeter diameter were cut out from the central part of the slices with the use of a calibrator. In this way cylinders were obtained of 1-centimeter height (h) and the diameter Φ = 2 cm. Six representative samples (cylinders) were selected for tests from each measurement series. Treatment was conducted in a convection steam oven (HOUNÖ CombiSlim CPE 2306 model, Randers, Denmark) at the temperature of 80 °C and 100 °C; 0, 20, 40, 60, 80 and 100% of steam added in relation to the initial humidity in the oven chamber; treatment time: 5, 10, 15, 20, 25 and 30 min.

For the temperature of 100 °C only the 0, 20, 40, 60% of steam addition were conducted. In case of steam addition of 80 and 100% resulted in structural changes going too far (overcooking), which made it impossible to carry out strength tests.

Strength tests

Immediately after thermal treatment warm samples were subjected to strength tests. Compression strength measurement for pumpkin samples was performed in the strength test machine, Zwick/Roell Z.5. (Zwick Roell Polska, Łódź, Poland). The material was subjected to double compression at the speed of head movement equal to 50 mm·min^{-1}. The process of compression was carried out at a stable deformation of the plates equal to 50% of their height, while the interval between the series was 5 s. The measurements were performed in 6 replications. On the basis of the measurements obtained in the form of texturegrams in the arrangement of two coordinates of strength and time, the following texture parameters were determined: hardness, springiness, chewiness and cohesiveness. After the tests, the results of the measurement were subjected to a statistical analysis. Namely, a double variance analysis was performed with the interaction for each of the analyzed properties with six variations for the temperature of 80°C and four variations for the temperature of 100°C.

Statistical analysis

Detailed comparisons of the mean values in pairs were performed on the basis of Tukey's multiple confidence intervals. Also, a combined analysis of the four variations was performed for the temperatures of 80°C and 100°C, with the use of triple cross classification with interactions. Calculations were done in the SAS Enterprise Guide 5.1 software, adopting the significance level of 0.05 in all the statistical analyses.

RESULTS

The results regarding changes in the hardness of pumpkin pulp resulting from thermal treatment at the temperature of 80°C and 100°C during the time from 5 to 30 min at different levels of steam addition [%] are presented in Fig. 1(a,b). A significant impact of heating time and the amount of steam on the hardness of pumpkin hardness was observed.

In case of pumpkin heated at the temperature of 80°C, the hardness of the pulp was decreasing along with increasing the amount of steam added for all the analyzed heating time spans (Fig. 1a). On the other hand, the hardness of pumpkin pulp heated at the temperature of 100°C was decreasing along with the amount of steam added for all time spans adopted in the research program, except for the shortest period of 5 min (Fig. 1b). With this particular heating time and steam addition, an increase in pulp hardness was noted from 40 to 60%. Regardless of the adopted heating temperature, the lowest hardness was recorded for pumpkin pulp after heating it for 30 min. To analyze the effect of heating time and the amount of steam added during heating we used double cross classification with interaction. The analysis conducted suggests that heating time, the amount of steam added and the interaction between the heating time and the amount of steam added significantly differentiate pumpkin hardness. The results of a detailed comparative analysis of mean pumpkin hardness, based on Tukey›s multiple comparisons are presented in Table 1 for butternut squash heated at the temperature of 80°C, and 100°C.

The data in Table 1 suggest that the average hardness of pumpkin pulp heated at the temperature of 80°C for 5, 10 and 15 min does not differ significantly, and it is significantly higher than the hardness of pumpkin pulp heated for 20, 25 and 30 min. Analyzing the amount of steam added, the significantly highest value was recorded when no steam was added, while the significantly lowest value was with a 100% addition of steam. The analysis of Table 1 demonstrates that the average hardness of pumpkin pulp heated at the temperature of 100 °C for 5 min was significantly higher than the hardness of squash heated for a longer time. The significantly lowest hardness of pumpkin pulp was obtained for the heating periods of 20, 25 and 30 min. The significantly highest hardness of squash was noted when no steam was added. No significant differences in the mean hardness of pumpkin pulp were observed with adding 20, 40 and 60% of steam.

The results of studies on the springiness of pumpkin pulp heated at the temperature of 80 °C and 100°C depending on the amount of steam added [%] and the time of heating [min] are presented in Fig. 1(c,d).

The springiness of pumpkin pulp heated at the temperature of 80°C decreased when the amount of steam added increased from 0 to 40%, while a further increase in the amount of steam from 40% to 100% resulted in an increased value of springiness for the majority of heating periods. A different course of changes in springiness of squash heated during the shortest time of 5 min may be observed. The springiness of squash heated at the temperature of 100 °C increased along with the amount of steam added for the analyzed heating periods, except for the time of 15 min (Fig. 1d). For this particular period springiness decreased with increasing the

Table 1 - The results of Tukey's studentized range test for mean hardness values of pumpkin pulp heated at the temperature of 80°C and 100°C depending on heating time and the amount of steam added.

Temperature							
80ºC	Time [min]	5	10	15	20	25	30
	Mean values	205.92A	187.79A	185.51A	150.30B	129.10B	133.80B
	SD	27.07	25.19	26.02	24.20	19.01	25.58
	Steam [%]	0	20	40	60	80	100
	Mean values	442.17a	230.78b	118.33c	107.69c	68.39d	25.06e
	SD	12.05	14.06	7.38	8.82	3.82	1.09
100ºC	Time [min]	5	10	15	20	25	30
	Mean values	126.96A	86.85B	49.08BC	32.67CD	33.11D	67.10D
	SD	24.96	20.78	11.60	6.26	6.32	20.99
	Steam [%]	0	20	40	60	-	-
	Mean values	184.38a	33.74b	21.72b	23.99b	-	-
	SD	17.43	1.58	1.70	5.40	-	-

Means with the same letter are not significantly different at 0.05 significance level.

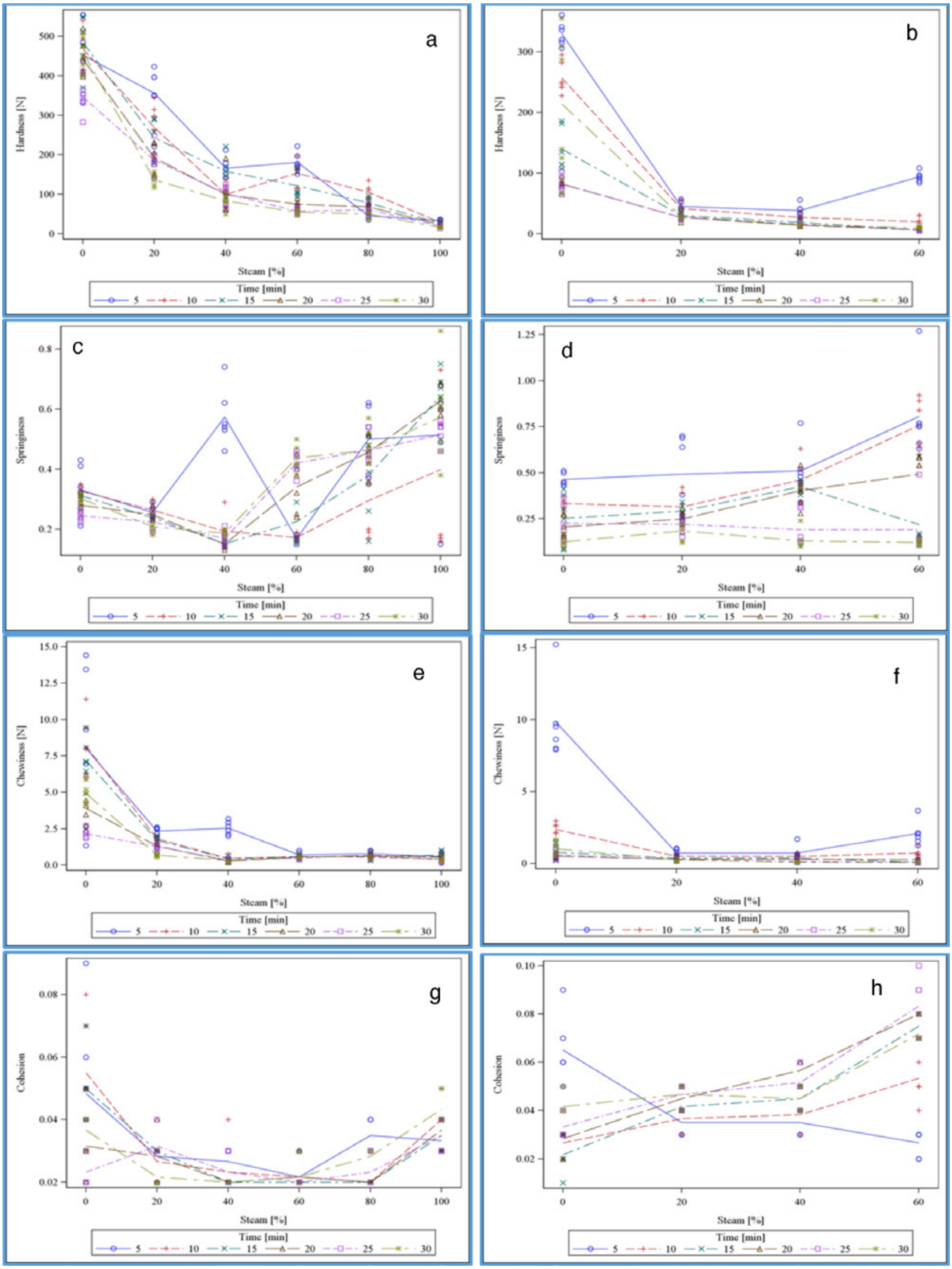

Fig. 1 - Analyzed properties of pumpkin pulp depending on amount of steam added and heating time: hardness of pumpkin pulp heated at the temperature of 80°C (a) and 100°C (b); springiness of pumpkin pulp heated at the temperature of 80°C (c) and 100°C (d); chewiness of pumpkin pulp heated at the temperature of 80°C (e) and 100°C (f); cohesiveness of pumpkin pulp heated at the temperature of 80°C (g) and 100°C (h).

Table 2 - The results of Tukey's studentized range test for mean springiness values of pumpkin pulp heated at the temperature of 80°C and 100°C depending on heating time and the amount of steam added.

Temperature							
80ºC	Time [min]	5	10	15	20	25	30
	Mean values	0.390A	0.275C	0.325BC	0.350AB	0.339AB	0.362AB
	SD	0.030	0.023	0.030	0.027	0.023	0.027
	Steam [%]	0	20	40	60	80	100
	Mean values	0.299c	0.239d	0.237d	0.294cd	0.426b	0.545a
	SD	0.008	0.005	0.027	0.021	0.020	0.028
100ºC	Time [min]	5	10	15	20	25	30
	Mean values	0.568A	0.467B	0.297CD	0.338C	0.207DE	0.140E
	SD	0.044	0.041	0.028	0.031	0.020	0.009
	Steam [%]	0	20	40	60	-	-
	Mean values	0.268c	0.292bc	0.353b	0.431a	-	-
	SD	0.022	0.022	0.028	0.053	-	-

Means with the same letter are not significantly different at 0.05 significance level.

amount of steam from 40 to 60%. The highest springiness of pulp was recorded for squash heated for the shortest time.

On the basis of double cross classification with interaction it can be concluded that the heating time, the amount of steam added and the interaction of heating time and the amount of steam added significantly differentiate the springiness of pumpkin pulp subjected to thermal treatment both at the temperature of 80°C and 100°C. The results of a detailed comparative analysis of mean springiness of pumpkin pulp on the basis of Tukey's studentized range test are presented in Table 2.

Analyzing the results presented in Table 2, it should be noted that the average springiness of pumpkin pulp heated at the temperature of 80°C for 5 min was the highest, yet it was not significantly higher than the mean springiness of squash for the heating time of 20, 25 and 30 min. The lowest mean springiness was obtained for the heating time of 10 min. On the other hand, the highest mean springiness of pumpkin pulp was obtained after adding 100% of steam, while the significantly lowest mean values of springiness were recorded in the situation when 20, 40 and 60% of steam was added.

Table 2 suggests that the mean springiness of squash heated at the temperature of 100°C for the time of 5 min was significantly highest at the level of significance of 0.05. The significantly lowest springiness of squash was obtained for the heating periods of 25 and 30 min. Analyzing the amount of steam added, the significantly highest springiness of squash was recorded with adding 60% of steam. No significant differences of mean squash springiness were noted when there was no steam addition or when 20% of steam was added.

The results of studies on the chewiness of squash heated at the temperature of 80°C and at 100°C depending on heating time and the amount of steam added are presented in Fig. 1(e,f). The chewiness of squash heated at the temperature of 80°C was decreasing when the amount of steam added increased from 0 to 20 and 40%, and when the addition of steam continued increasing no drop in chewiness was observed. The course of curves presented in Fig. 1f suggests that the chewiness of squash heated at 100°C for 5 min differed from the chewiness of squash heated for longer periods included in the research program. In case of the periods of 10, 15, 20, 25 and 30 min the chewiness of squash altered only slightly.

Double cross classification with interaction used to analyze the effect of heating time and the amount of steam added during heating on changing chewiness of butternut squash revealed that the heating time, the amount of steam added and the interaction of the heating time and the amount of steam added do not differentiate significantly the chewiness of squash. The results of a detailed comparative analysis of average chewiness of pumpkin pulp based on Tukey's multiple comparisons are presented in Table 3.

While analyzing the results presented in Table 3, it should be noted that the mean chewiness of squash heated at the temperature of 80°C for 5, 10 and 15 min was the highest and it was significantly higher than the mean chewiness of squash for the heating time of 20, 25 and 30 min. On the other hand, the significantly highest chewiness of squash was obtained when there was no steam addition. No significant differentiation in the chewiness of squash was observed when 15, 20, 25 and 30% of steam was added. The analysis of Table 3 demonstrates that the mean chewiness of squash heated at the temperature of 100°C for 5 min was significantly highest at the significance level of 0.05. The significantly lowest chewiness of squash was observed for the periods of 15, 20, 25 and 30 min. Analyzing the amount of steam, the significantly highest chewiness of squash was obtained when no steam

Table 3 - The results of Tukey's studentized range test for mean chewiness values of pumpkin pulp heated at the temperature of 80°C and 100°C depending on heating time and the amount of steam added.

Temperature							
80ºC	Time [min]	5	10	15	20	25	30
	Mean values	2.499A	2.005A	1.863AB	1.211BC	0.879C	1.249BC
	SD	0.557	0.492	0.420	0.228	0.114	0.281
	Steam [%]	0	20	40	60	80	100
	Mean values	5.7231a	1.5236b	0.7317c	0.5767c	0.6447c	0.5058c
	SD	0.5429	0.0946	0.1416	0.0233	0.0295	0.0372
100ºC	Time [min]	5	10	15	20	25	30
	Mean values	3.349A	1.023B	0.411C	0.356C	0.282C	0.363C
	SD	0.836	0.172	0.071	0.030	0.051	0.093
	Steam [%]	0	20	40	60	-	-
	Mean values	2.523a	0.408b	0.356b	0.569b	-	-
	SD	0.591	0.035	0.049	0.134		

Means with the same letter are not significantly different at 0.05 significance level.

was added. No significant differences of mean values of chewiness were noted when adding 20, 40 and 60% of steam.

The results of studies on the cohesiveness of squash heated at the temperature of 80 °C and at 100°C depending on heating time [min] and the amount of steam added [%] are presented in Fig. 1(g,h).

The cohesiveness of squash heated at the temperature of 80°C was changing depending on the amount of steam added and the course varied depending on the heating time (Fig. 1g). The highest cohesiveness was observed for squash to which no steam was added and when 100% of steam was supplied. In case of treatment at the temperature of 100°C for the heating periods of 10, 15, 20, 25 and 30 min the cohesiveness of squash generally increased along with the amount of steam added and it reached its highest values for 30% of steam (Fig. 1h). After heating for 5 min the cohesiveness of squash decreased along with increasing the amount of steam added.

The results of double cross classification with interaction used to analyze the effect of heating time and the amount of steam added during heating on changing cohesiveness of butternut squash revealed that the heating time, the amount of steam added and the interaction of the heating time and the amount of steam added significantly differentiate the cohesiveness of squash. A detailed comparative analysis of mean values of squash cohesiveness on the basis of Tukey's multiple comparisons revealed that the average cohesiveness of squash heated at the temperature of 80°C for 5 and 10 min was significantly higher, as compared with the mean cohesiveness of squash heated for 20 and 25 min (Table 4). The significantly highest cohesiveness of pumpkin pulp was recorded after heating with no steam addition and after adding 100% of steam. No significant differentiation of squash cohesiveness was observed after adding 15, 20, 25 and 30% of steam.

An analysis of Table 4 shows that the mean cohesiveness of squash heated at the temperature of 100°C for 20, 25 and 30 min was significantly

Table 4 - The results of Tukey's studentized range test for mean cohesiveness values of pumpkin pulp heated at the temperature of 80°C and 100°C depending on heating time and the amount of steam added.

Temperature							
80ºC	Time [min]	5	10	15	20	25	30
	Mean values	0.0322A	0.0311A	0.0286AB	0.0264B	0.0261B	0.0292AB
	SD	0.0022	0.0025	0.0020	0.0014	0.0011	0.0016
	Steam [%]	0	20	40	60	80	100
	Mean values	0.0408a	0.0278b	0.0222c	0.0211c	0.0244bc	0.0372a
	SD	0.0029	0.0009	0.0008	0.0005	0.0011	0.0010
100ºC	Time [min]	5	10	15	20	25	30
	Mean values	0.0404C	0.0388C	0.0458B	0.0525A	0.0538A	0.0513A
	SD	0.0034	0.0023	0.0041	0.0040	0.0041	0.0026
	Steam [%]	0	20	40	60	-	-
	Mean values	0.0361c	0.0419b	0.0453b	0.0650a	-	-
	SD	0.0027	0.0011	0.0015	0.0035	-	-

Means with the same letter are not significantly different at 0.05 significance level.

Table 5 - The results of Tukey's studentized range test for pairs of mean values for the three agents and analyzed properties.

Analyzed agent	Level of agent	Analyzed property			
		Hardness	Springiness	Chewiness	Cohesiveness
Temperature	80	224.74A	0.2674B	2.139A	0.0280B
	100	65.96B	0.3360A	0.964B	0.0471A
Steam	0	313.27A	0.2833B	4.123A	0.0385B
	20	132.26B	0.2657B	0.966B	0.0349C
	40	70.03C	0.2953B	0.544B	0.0338C
	60	65.84C	0.3625A	0.573B	0.0431A
Time	5	207.96A	0.4498A	3.3754A	0.035833A
	10	167.42B	0.3527B	1.8921B	0.035208A
	15	150.48B	0.2642CD	1.4421BC	0.037917A
	20	117.53CD	0.2960C	0.9350CD	0.038958A
	25	103.19D	0.2356DE	0.6769D	0.039167A
	30	125.53C	0.2119E	0.9869CD	0.038125A

Means with the same letter are not significantly different at 0.05 significance level.

highest at the significance level of 0.05. The significantly lowest mean cohesiveness of butternut squash was observed after 5 and 10 min of heating. Analyzing the amount of steam added, the significantly highest mean cohesiveness of squash was recorded after treatment with the addition of 100% of steam, while the significantly lowest values were noted when no steam was used.

The results of three-agent variance analyses for the studied properties, namely hardness, springiness, chewiness and cohesiveness provide a basis for claiming that all the agents analyzed in the present work, namely temperature, the amount of steam added, heating time and the interactions occurring between these agents significantly differentiate the studied qualities of butternut squash. The results of Tukey's multiple comparisons in pairs for the analyzed agents and for all the properties are presented in Table 5. These results show that there were significant differences concerning the analyzed properties of squash at the temperature of 80°C and 100°C. For hardness and chewiness the mean values of the properties at the temperature of 80°C were significantly higher, as compared with the mean values of the properties at the temperature of 100°C. In case of springiness and cohesiveness, it may be claimed that the mean value at the temperature of 100°C is significantly higher than the mean value at 80°C. Analyzing the comparisons of mean values for the properties with the use of different amounts of steam, it may be noted that the significantly highest mean hardness and chewiness were observed when no steam was added. On the other hand, the significantly highest springiness and cohesiveness were observed for the biggest amount of steam added, amounting to 60%. The most varied mean values of the studied properties were observed for the periods of treatment studied in the work. Only in case of the mean cohesiveness there were no significant differences for the pairs of mean values compared. The highest values of mean hardness, springiness and chewiness were noted for the shortest treatment time.

Structural and rheological properties determine behavior of the squash pulp under compression (SHIRMOHAMMADI *et al.*, 2014). Recognizing the mechanical properties of squash enables improvement of processing its pulp (SOSIŃSKA *et al.*, 2012). The texture of the squash pulp exhibits characteristics of chewiness and springiness, which can be modified by thermal treatment. Earlier studies concerning thermal treatment of pumpkin pulp in a convection steam oven revealed significant modifications in its texture properties (ŚLASKA-GRZYWNA *et al.*, 2013). It was noted that the most significant effect on changing hardness, springiness and chewiness of squash resulted from the amount of steam added, and to a lower degree from the time and temperature of treatment. Similarly, works by GONÇALVES *et al.* (2007) suggest a significant decrease in the firmness of squash during thermal treatment at the temperature of 75-95°C for 50 min. Prior to thermal treatment the firmness of squash was ca. 60 N, while after the treatment it did not exceed 10 N. Changes in the texture of pumpkin pulp following thermal treatment during its storage were studied by RATNAYAAKE *et al.* (2004). In their studies with the help of double-compression test they observed the most significant changes in the texture of pumpkin pulp in case of measuring its hardness and chewiness, while the changes were only slight in case of springiness and cohesiveness. The key factor affecting rheological qualities of vegetables is turgor (LIN TA-TE and PITT, 1986). Softening of tissues is related to the loss of turgor cells and their easier separation (GREVE *et al.*, 1994). Plant tissue is built of cells mutually linked by middle lamella. The cell wall is kept rigid due to hydrostatic pressure inside the cell, which normally amounts to 1-8 bar (0.1 - 0.8 MPa) (AGUILLERA *et al.* 1998). Cellulose present in the cell wall affects the rigidity and strength of the plant tissue, while pectins and hemicellulose present in middle lamella are responsible for its plasticity (LEWICKI and PAWLAK, 2003). Thermal treatment of vegetables results in structure alterations, tissue disintegration, enzyme inactivation, washing out soluble components, loss of firmness and, consequently, their softening (CRUZ *et al.* 2011; GALINDO *et al.*, 2005). According to researchers, both raw and cooked squash pulp provides numerous health benefits and can be used in prevention and treatment of certain diseases (CAILI *et al.*; 2006, NIEWCZAS *et al.*; 2005, STIRG, 1997). Studies suggest a possibility of selecting adequate parameters of thermal treatment helping to maintain the texture most required by consumers. Moreover, the research results will be useful for food producers, allowing them to select the optimal parameters of thermal treatment of squash pulp.

CONCLUSIONS

Thermal treatment in a convection steam oven results in statistically significant changes of all the studied parameters of squash texture, namely its hardness, springiness, chewiness and cohesiveness.

The range and dynamics of texture properties of butternut squash depends on the parameters of thermal treatment, such as temperature, amount of steam added and time.

The most significant range of modifications concerning texture qualities of squash were registered for its hardness and chewiness, while changes in its springiness and cohesiveness occurred to a smaller extent.

The decisive influence on changing the hardness and chewiness of squash was exerted by the addition of steam, while treatment time and temperature were less significant. In case of springiness the key agent was treatment time, while with cohesiveness it was the temperature of treatment.

Conducted studies will allow food producers to select the optimal parameters of thermal treatment of squash pulp for consumption purposes.

REFERENCES

Aguilera J. M., Cuadros, T. R. and Del Valle J. M. 1998. Differential scanning calorimetry of low-moisture apple products. Carbohydrate Polymers 37: 79.

Astorg P. 1997. Food carotenoids and cancer prevention: An overview of current research. Trends in Food Science & Technology 8(120): 406.

Caili F., Huan S. and Quanhong L. 2006. A review on pharmacological activites and utilizacion technologies of pumpkin. Plant Foods for Human Nutrition 61: 73.

Carvalho L.M.J., Gomes P.B., Oliveira Godoy R.L., Pacheco S., Monte P.H.F., Carvalho J.L.V., Nutti M.R., Neves A.C.L., Rodrigues Alves Vieira A.C. and Ramos S.R.R. 2012. Total carotenoid content, α-carotene and β-carotene, of landrace pumpkins (*Cucurbita moschata* Duch): A preliminary study. Food Research International 47: 337.

Cruz R.M.S., Vieira M.C., Fonsec, S.C., and Silva C.L.M. 2011. Impact of thermal blanching and thermosonication treatments on watercress (*Nasturtium officinale*) quality: Thermosonication process optimization and microstructure evaluation. Food Bioprocess Technology 4: 1197.

Galindo F. G., Toledo R. T. and Sjöholm, I. 2005. Tissue damage in heated carrot slices. Comparing mild hot water blanching and infrared heating. Journal of Food Engineering 67(4): 381.

Gonçalves E.M., Pinheiro J., Abreu M., Brandão T.R.S. and Silva C.L.M. 2007. Modelling the kinetics of peroxidase inactivation, colour and texture changes of pumpkin (*Cucurbita Maxima* L.) during blanching. Journal of Food Engineering 81: 693.

Greve L.C., Shakel K.A., Ahmadi H., McArdle R.N., Gohlke J.R. and Labavitch J.M. 1994. Impact of heating on carrot firmness: contribution of cellular turgor. Journal of Agricultural and Food Chemistry 42: 2896.

Lewicki P. P. and Pawlak G. 2003. Effect of drying on microstructure of plant tissue. Drying Technology 21(4): 657.

Lin Ta-Te and Pitt R.E. 1986. Rheology of apple and potato tissue as affected by cell turgor pressure. Journal of Texture Studies 1: 291.

Mayor L., Moreira R., and Sereno A.M. 2011. Shrinkage, density, porosity and shape changes during dehydration of pumpkin (*Cucurbita pepo* L.) fruits. Journal of Food Engineering 103: 29.

Nawirska-Olszańska A., Biesiada A., Kucharska A.Z. and Sokół-Łętowska A. 2012. Effect of production method and storage conditions of Pumpkin preserves enriched with Japanese quince and cornelian cherry on their physical-chemical properties. Food Science Technology Quality 3(82): 168.

Nawirska-Olszańska A., Biesiada A., Sokół-Łętowska A. and Kucharska A.Z. 2014. Characteristics of organic acids in the fruit of different pumpkin species. Food Chemistry 148: 415.

Niewczas J., Szweda D. and Mitek M. 2005. The content of selected pro-healthful components in Winter Squash (*Cucurbita Maxima*) fruits. Food Science Technology Quality 2(43) Suplement:147.

Obiedzińska A. and Waszkiewicz-Robak B. 2012. Cold pressed oils as functional food. Food Science Technology Quality 1(80): 27.

Rakcejeva T., Galoburda R., Cude L. and Strautniece S. 2011. Use of dried pumpkins in wheat bread production. Procedia Food Science 1: 441.

Ratnayake R.M.S., Hurst P.L. and Melton L.D. 2004. Influence of cultivar, storage and cooking on the mechanical properties of winter squash (*Cucurbita Maxima*). Journal of the Science of Food and Agriculture 8: 433.

Shirmohammadi M., Yarlagadda P.K.D.V and Gu Y.T. 2014 A constitutive model for mechanical response characterization of pumpkin peel and flesh tissues under tensile and compressive loadings. Journal of Food Science Technology. DOI 10.1007/s13197-014-1605-2

Sosińska E., Panasiewicz M., Nadulski R., Rudy S. and Krzykowski A. 2012. Analysis of the impact of the angle of the knife blade on the value of the forces and work of cutting Pumpkin pulp. Motrol. Commission of Motorization and Energetics in Agriculture 14(5): 125.

Ślaska-Grzywna B., Andrejko B., Kuna-Broniowska I., Sagan A., and Blicharz-Kania A. 2013. Shaping some selected textural properties of Pumpkin (*Cucurbita Maxima Duch.*) by optimized heat treatment. Food Science Technology Quality 4(89): 195.

Wojdyła T., Wichrowska D., Rolbiecki R., Rolbiecki S. and Weltrowska-Miedzińska B. 2007. Content of chosen of chemical components in fresh macaroni Summer Squash after harvest and after storage as well as stabilized in dependence from irrigation and cultivar. Food Science Technology Quality 3(52): 82.

Zhao X.H., Qianb Li, Yina D.L. and Zhoua Y. 2014. Hypolipidemic effect of the polysaccharides extracted from pumpkin by cellulase-assisted method on mice. International Journal of Biological Macromolecules 64: 137.

Paper Received December, 1, 2014 Accepted February 5, 2015