

EFFECT OF COOKING TIME ON THE TEXTURE
AND COOKING QUALITY OF SPAGHETTI

*Aldona Sobota, Piotr Zarzycki, Zbigniew Rzedzicki, Emilia Sykut-Domańska,
Anna Wirkijowska*

Engineering and Cereals Technology Department, University of Life Sciences in Lublin
ul. Skromna 8, 20-704 Lublin, Poland
e-mail: aldona.sobota@up.lublin.pl

Abstract. The objective of this study was to determine the effect of cooking time on the cooking quality and texture properties of spaghetti made with different raw materials. As a result of extension in the cooking time, an increase was observed in the amount of water absorbed by the products, with a simultaneous increase in the index of pasta mass gain after cooking. A high significant correlation between weight increase index and moisture of cooked spaghetti was observed ($r = 0.97$, $p < 0.0001$). The dry matter losses, during 4-16 minutes cooking of spaghetti, were positively correlated with the distance for maximum cutting force and with the cutting work. The correlation coefficients were 0.85 and 0.51, respectively. The highest values of the cutting force and the cutting work characterised pasta cooked in the time immediately preceding the minimum cooking time. The application of cooking times longer than the minimum caused a decrease in the firmness of the pasta but the changes were relatively slight. This shows a high resistance to overcooking of all tested spaghetti.

Key words: pasta, cooking time, cooking quality, texture, firmness

INTRODUCTION

Next to bread, pasta is among the most popular cereal products. It is characterised by a great diversity of forms and shapes. It is produced with the use of various cereal materials, but the most valued is pasta produced from materials based on the grinding of durum wheat grain. High content of proteins and gluten with suitable fractional composition, high levels of carotenoids and low enzymatic activity characteristic of those materials cause that pasta produced from them has sunny-yellow colour, is resistant to overcooking and, when cooked, has proper texture and consistency (Oak *et al.* 2006, Abdel-Aal *et al.* 2007, Borrelli *et al.* 1999, Troccoli *et al.* 2000, Oak and Dexter 2006).

The cooking quality of pasta largely depends on the cooking time (Martinez *et al.* 2007, Baiano *et al.* 2008, Sozer *et al.* 2007). The cooking time applied affects, among other things, the mass increase of the products and the loss of dry matter in the course of cooking, as well as the consistency and firmness of spaghetti (Grzybowski and Donnelly 1979, Dziki and Laskowski 2005, Sozer *et al.* 2007). Generally, the consumers put more value on undercooked pasta, with firm and suitably hard texture, referred to as “al dente”. Spaghetti texture depends not only on the cooking time. The specificity of raw materials used in the manufacture or parameters of the technological process of pasta production are of great importance (Grant *et al.* 2004, Martinez *et al.* 2007, Noni and Pagani 2010, Kaur *et al.* 2012).

The instrumental study will allow the analysis of changes in texture as a function of the pasta cooking time and will help to objectively determine the cooking time allowing to obtain cooked products with the greatest firmness. The instrumental methods of pasta texture testing give relatively good results and are recommended by many authors (Sissons *et al.* 2008, Gonzalez *et al.* 2000).

MATERIAL AND METHODS

The experimental material comprised 3 assortments (A, B, C) of spaghetti-type pasta available on the market, designated in the model of the experiment as A, B and C. The products were from three different manufacturers. They were produced with the use of various cereal materials – flour of durum wheat (type A), wheat pasta flour (70% semolina and 30% vulgare wheat flour) (type B) and semolina (type C). Table 1 presents the material composition and characteristics of the pasta products studied. The chemical composition of the spaghetti was determined according to AACC-Approved Methods (AACC 2000). Protein content was determined by method 46-08 (N x 5.7), fat content by method 30-10 and ash content by method 08-01.

The minimum cooking time of spaghetti was determined on the basis of the modified method AACC 16-50 (AACC 2000). For this purpose, 100 g portions of spaghetti were weighed and cooked in 1000 cm³ of distilled water. In accordance with the method, the minimum cooking time was adopted as the time required for total gelatinisation of starch and for the disappearance of the white core inside the pasta. Then, 100 g of the spaghetti was cooked in 1000 cm³ of distilled water applying cooking times of 4, 6, 8, 10, 12, 14 and 16 min. After cooking, the pasta was strained, cooled and weighed. Each time the dry matter losses during the cooking were determined. The level of dry matter losses was determined by assaying the content of dry matter in the water after the cooking. The method applied was the oven-dry method AACC, 44-15A (AACC 2000). The weight in-

crease index was calculated by dividing the weight of the pasta after cooking by the weight on uncooked pasta (Obuchowski 1997).

Table 1. Characteristics of the spaghetti

Sample	Declared ingredients	Declared cooking time (min)	Minimal cooking time (min)	Diameter (mm)	Moisture (%)	Nutritional components (% d.m.)			
						Protein	Fat	Ash	CHO ¹⁾
A	durum wheat flour, water	6-10	8±0.29	1.9	7.51 ±0.09*	11.52 ±0.13*	1.16 ±0.03*	0.78 ±0.03*	86.54
B	wheat flour (70% semolina, 30% vulgare wheat flour), water	10-12	13±0.58	1.9	8.41 ±0.06*	14.33 ±0.15*	0.92 ±0.04*	0.68 ±0.05*	84.07
C	semolina, water	6	10±0.29	1.9	8.79 ±0.06*	13.79 ±0.17*	1.28 ±0.04*	0.8 ±0.04*	84.08

¹⁾Carbohydrate (by difference), *Values are mean of 3 replications.

At the same time it was studied how the cooking time of spaghetti affects the texture of the cooked products. The texture determinations were conducted on the basis of the method AACC 16-50, using a TA-XT2 texture analyser (Stable Microsystems, Godalming, England). Five strands of spaghetti were placed on the table of the texture analyser and cut with the tooth moving at the speed of 0.2 mm s⁻¹ (Fig. 1). The maximum cutting force of a single strand of spaghetti was determined, and the cutting work was calculated. The distance over which the maximum cutting force was also determined. The texture parameters analysed are shown in Figure 2.

The measurements were conducted immediately after cooking the pasta, in five replications for each sample. The moisture and dry matter content in the cooked products were determined with the oven-dry method (AACC, 44-15A)

(AACC 2000). The determinations were performed in three replications. The significance of differences among the results was determined using the Duncan test ($p \leq 0.05$). For selected continuous variables the trend lines, regression equations and coefficients of determination were determined. Also the Pearson correlation between the cooking quality and texture properties of spaghetti was performed. The statistical analysis of the results was performed with the use of the program SAS 9.1.3.

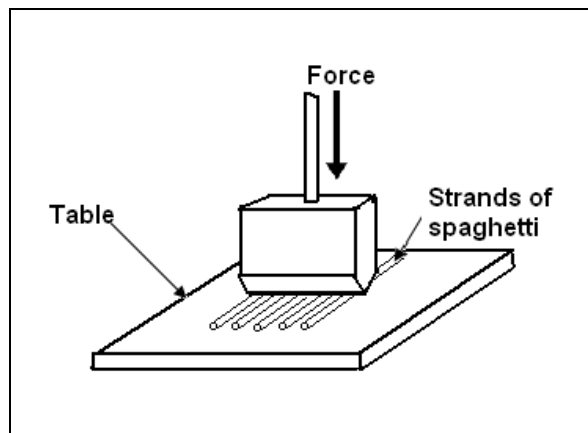


Fig. 1. Scheme of the spaghetti texture analysis

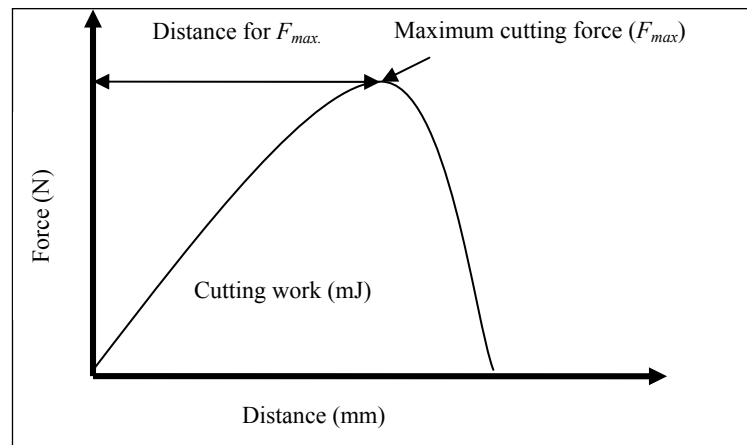


Fig. 2. Deformation curve indicating the studied texture parameters: maximum cutting force (F_{max}), distance for maximum cutting force, and cutting work (area under the curve)

RESULTS AND DISCUSSION

The uncooked spaghetti-type pasta products were characterised by moisture content at the level of 7.51-8.79% (Tab. 1). During cooking the products absorbed water. The gradual extension of the pasta cooking time caused an increase in the content of water in the cooked products. Spaghetti cooked for 4 minutes was characterised by moisture content at the level of 51.19-55.21%, while that cooked for 16 min had moisture in the range of 64.69-67.97% (Fig. 3). Therefore, longer time of cooking permitted the absorption of greater amounts of water with simultaneous changes the texture.

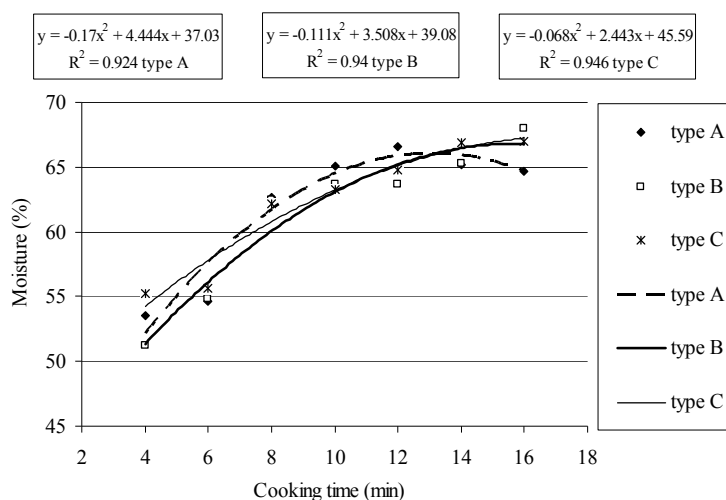


Fig. 3. Influence of cooking time on moisture of spaghetti

The capacity of pasta to absorb water during cooking determined the value of the weight increase index of the products after the cooking. Based on the study it was found that the value of the weight increase index largely depended on the cooking time of the pasta. The values of the index varied from 1.9 for the shortest cooking time (4 min) to 2.7-2.8 for the longest – 16-minute time of cooking (Fig. 4). A similar tendency was noted by, among others, Grzybowski and Donnelly (1979), Sozer *et al.* (2007), and by Dziki *et al.* (2010). It should be emphasised that the value of the parameter in addition to the cooking time, can also be affected by many different factors such as the type or raw materials used in production, the form and shape of the pasta, the content and fractional composition of gluten proteins, and also by the process parameters applied in the production (Grant *et al.* 2004, Sobota and Skwira 2009, Dziki and Laskowski 2005, Dziki *et al.* 2010, Sozer *et al.* 2007).

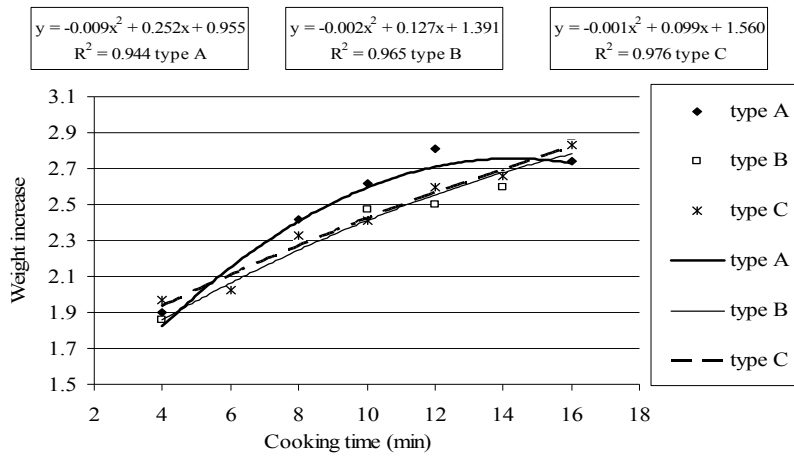


Fig. 4. Influence of cooking time on weight increase of spaghetti

The level of dry matter losses during cooking of the spaghetti increased with the cooking time. In the case of the shortest cooking time of 4 minutes, the level of dry matter losses was low at ca. 2-3% (Fig. 5).

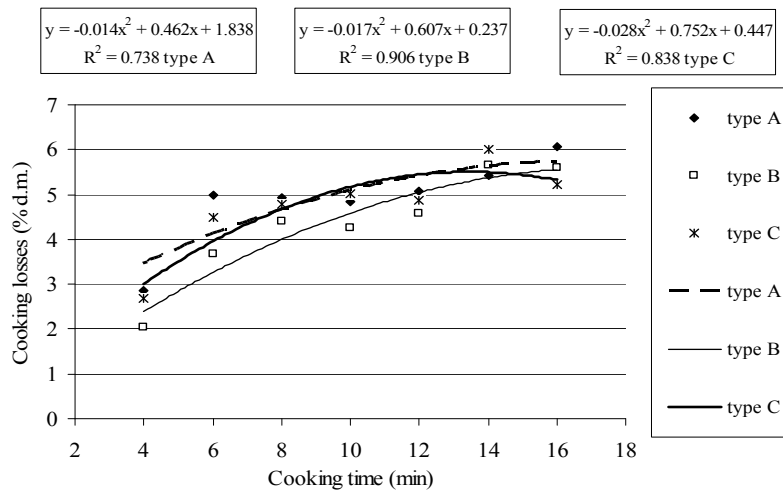


Fig. 5. Influence of cooking time on cooking losses of spaghetti

Cooking time extension to 16 minutes caused an increase in dry matter losses to the level of about 5-6%. The values of this parameter were similar for all the pasta products studied. When the cooking times recommended by the manufac-

turers were applied, the levels of dry matter losses were, respectively, 5% for pasta A, 4.3-4.6% for pasta B and 4.5% for pasta C. Notably greater dry matter losses in spaghetti-type pasta were observed by Dziki and Laskowski (2005). Those authors report that in the case of products of semolina, depending on the cooking time applied, dry matter losses oscillated at the level from 4.9 to 9.2%, while in the case of common wheat pasta the losses were even higher, within the range from 6.4 to 13.7%. Malcolmson and Matsuo (1993) reported that good quality pasta should not lose more than 10% of dry matter during cooking. Numerous authors emphasise that the level of dry matter losses is related to the content of proteins in the products (Sobota and Dobosz 2010, Malcolmson and Matsuo 1993, Samaan *et al.* 2006). Oak and Dexter (2006) maintain that the level of dry matter losses depends not only on protein content but also on the fractional composition of gluten proteins. In the opinion of Brunori *et al.* (1994), especially desirable is a high content of glutenins which, after hydration, have the form a strongly elastic mass. Those authors found a positive correlation between the glutenin/gliadin ratio and pasta quality. According to Oak and Dexter (2006) and Malcolmson and Matsuo (1993), in the case of gliadin fractions, particularly important is the presence of subunits γ -45 which, as opposed to gliadins γ -42, produce strong gluten and determine high cooking quality of pasta products, including low dry matter losses during cooking.

Good quality pasta should be characterised by high resistance to overcooking, and after cooking it should be firm. The application of a short cooking time (4 min), did not permit full hydration of pasta. Non-hydrated, hard and brittle pasta core cracked during the cutting test, giving relatively low values of the cutting force and work (Tab. 2).

With extension of the cooking time, the pasta core became gradually hydrated, which was evident in the extending distance for the maximum cutting force (F_{max}) (Tab. 2). The maximum cutting force and cutting work for pasta cooked in the time immediately preceding the minimal cooking time was observed. After reaching the minimal cooking time that distance for maximum cutting force did not change significantly ($p \leq 0.05$), which is evidence that we have now pasta that is fully cooked. Noteworthy is the fact that in the course of cooking the products studied were characterised by varied dynamics of hydration. The rate of hydration was notably slower in the case of spaghetti – sample B. Each time, in the case of that product, with cooking times in the range from 4 to 10 min, the distance of the maximum cutting force was shorter as compared to the other two pasta products. At the same time, the minimal cooking time determined for that product was considerably longer (Tab. 1). The differences observed may result both from the specifics of the raw materials used in production and from the parameters of the extrusion process of the spaghetti. With increase in the cooking

time and the gradual hydration of deeper and deeper layers of the product, there was a change in the properties of the pasta. During the cutting test, incompletely cooked pastas were cutting only partially. Therefore, initially the extension of the cooking time from 4 to 6, 8 and 12 minutes, respectively for samples A, C and B, caused an increase in the cutting force of the pasta products and of their cutting work (Tab. 2). Only as a result of application of cooking times longer than those above a decrease in the firmness of the products was observed, with a corresponding decrease in the values of the cutting force and work. A significant negative correlation between the cooking time of spaghetti and its firmness was observed by Grzybowski and Donnelly (1979) and by Samaan *et al.* (2006). Many authors

Table 2. Texture properties of cooked spaghetti

Sample	Cooking time (min)	Distance for F_{max} (mm)	F_{max} (N)	Cutting work (mJ)
A	4	1.44 ⁱ	1.17 ^h	0.87 ^h
	6	1.78 ^g	1.45 ^{de}	1.39 ^{ab}
	8	1.92 ^{ef}	1.43 ^{de}	1.21 ^{def}
	10	2.04 ^{abcd}	1.36 ^{efg}	1.17 ^{defg}
	12	2.01 ^{abcde}	1.36 ^{efg}	1.11 ^{fg}
	14	1.99 ^{bode}	1.36 ^{efg}	1.11 ^{fg}
	16	2.06 ^{abcd}	1.30 ^{fg}	1.05 ^g
B	4	1.22 ^j	1.28 ^g	0.77 ^h
	6	1.44 ⁱ	1.43 ^{de}	1.10 ^g
	8	1.61 ^h	1.44 ^{de}	1.19 ^{defg}
	10	1.97 ^{de}	1.54 ^{cd}	1.25 ^{cde}
	12	1.98 ^{cde}	1.73 ^a	1.46 ^a
	14	2.08 ^{abc}	1.71 ^{ab}	1.44 ^a
	16	2.09 ^{ab}	1.61 ^{bc}	1.29 ^{bcd}
C	4	1.61 ^h	1.41 ^{efg}	1.12 ^{fg}
	6	1.79 ^g	1.38 ^{efg}	1.26 ^{cde}
	8	1.86 ^{fg}	1.53 ^{cd}	1.36 ^{abc}
	10	1.97 ^{de}	1.44 ^{de}	1.21 ^{def}
	12	1.99 ^{bode}	1.42 ^{def}	1.12 ^{efg}
	14	2.01 ^{abcde}	1.42 ^{def}	1.11 ^{fg}
	16	2.10 ^a	1.39 ^{efg}	1.11 ^{fg}

Mean values in the same column denoted by a different letter are significantly different ($P \leq 0.05$). Results were expressed as the mean of 5 replications \pm SD (standard deviation).

emphasise that products of raw materials originating from the grinding of durum wheat grain, characterised generally by a higher content of proteins and a stronger gluten, are less susceptible to overcooking and changes in consistency as a result of extended cooking times (Grzybowski and Donnelly 1979, Oak *et al.* 2006, Samaan *et al.* 2006). The results showed that a large impact on the texture of spaghetti is exerted not only by the type of raw material but also by the parameters of the production process. Spaghetti made from semolina with added vulgare wheat flour (sample B) was characterised by the highest resistance to overcooking and by the greatest firmness.

The selected results of texture parameters correlated well with cooking properties of spaghetti (Tab. 3). A positive correlation was observed between distance for F_{max} and cooking losses ($r = 0.85$), weight increase ($r = 0.88$), spaghetti moisture ($r = 0.89$). But there was no linear correlation between firmness of spaghetti (F_{max}) and cooking properties such as cooking losses, weight increase or spaghetti moisture.

Table 3. Correlation coefficients between the cooking properties and instrumental parameters of cooked spaghetti texture

	Distance for F_{max}	F_{max}	Cutting work	Cooking losses	Weight increase
Force max.	0.33 p = 0.139	–			
Cutting work	0.57 p = 0.007	0.76 p < 0.0001	–		
Cooking losses	0.85 p < 0.0001	0.25 p < 0.268	0.51 p = 0.017	–	
Weight increase	0.88 p < 0.0001	0.21 p = 0.364	0.24 p = 0.286	0.79 p < 0.0001	–
Spaghetti moisture	0.89 p < 0.0001	0.31 p = 0.1690	0.36 p = 0.112	0.79 p < 0.0001	0.97 p < 0.0001

CONCLUSIONS

1. Extension of the cooking time of the pasta products led to a greater weight increase index of the products after cooking.
2. With increase in the cooking time of the pasta products there was an increase in the content of water in 100 g of product, which resulted in changes in the distance for maximum force.

3. Longer cooking time of the pasta products caused greater dry matter losses in the course of cooking. However, even in the case of 16-minute cooking of the spaghetti-type pasta products dry matter losses did not exceed 7%. This indicates high resistance of the pasta products studied to overcooking.

4. Cooking time determined also the firmness of the spaghetti. The highest firmness was characteristic of products cooked for a time permitting the hydration of the pasta core to such a degree that it behaved like a plastic body during cutting. Further extension of cooking time of the spaghetti caused a lowering of its firmness.

5. The dry matter losses, during 4-16 minutes cooking of the spaghetti, were positively correlated with the distance for maximum cutting force and with the cutting work.

REFERENCES

- AACC, Approved Methods of the American Association of Cereal Chemists, 2000. Ed. AACC Inc, St. Paul, USA.
- Abdel-Aal E.-S.M., Young J.Ch., Rabalski I., Hucl P., Fregeau-Reid J., 2007. Identification and quantification of seed carotenoids in selected wheat species. *J. Agric. Food Chem.*, 55, 787-794.
- Baiano A., Fares C., Peri G., Romaniello R., Taurino A.M., Siciliano P., Gambacorta G., Lamacchia C., Pati S., La Notte E. 2008. Use of toasted durum whole meal in the production of a traditional Italian pasta: chemical, mechanical, sensory and image analyses. *Int. J. Food Sci. Technol.*, 43, 1610-1618.
- Borrelli G.M., Troccoli A., Di Fonzo N., Fares C., 1999. Durum wheat lipoxygenase activity and other quality parameters that affect pasta color. *Cereal Chem.*, 76(3), 335-340.
- Brunori A., Galerio G., Mariani G., 1994. Relationship between gluten components in durum wheat and pasta quality. In: *Gluten Proteins* (Eds. W. Bushuk, R. Tkachuk). AACC Inc, St. Paul, USA, 253-260.
- Dziki D., Laskowski J., 2005. Evaluation of the cooking quality of spaghetti. *Pol. J. Food Nutr. Sci.*, 14(55), 153-158.
- Dziki D., Różyło R., Biernacka B., 2010. Effect of cooking time on the physical properties of spaghetti-type pasta (in Polish). *Acta Agrophysica*, 16(1), 35-48.
- Gonzalez J.J., Mccarthy K.L., Mccarthy M.J., 2000. Textural and structural changes in lasagna after cooking. *Journal of Texture Studies*, 31, 93-108.
- Grant L.A., Dick J.W., Shelton D.R., 1993. Effects of drying temperature, starch damage, sprouting and additives on spaghetti quality characteristics. *Cereal Chem.*, 70(6), 676-684.
- Grant L.A., Doehlert D.C., McMullen M.S., Vignaux N., 2004. Spaghetti cooking quality of waxy and non-waxy durum wheats and blends. *J. Sci. Food Agric.*, 84, 190-196.
- Grzybowski R.A., Donnelly B.J., 1979. Cooking properties of spaghetti: factors affecting cooking quality. *J. Agric. Food Chem.*, 27(2), 380-384.
- Kaur G., Sharma S., Nagi H.P.S., Dar B.N. 2012. Functional properties of pasta enriched with variable cereal brans. *J. Food Sci. Technol.*, 49(4), 467-474.
- Malcolmson L.J., Matsuo R.R., 1993. Effects of cooking water composition on stickiness and cooking loss of spaghetti. *Cereal Chem.*, 70(3), 272-275.
- Martinez C.S., Ribotta P.D., Leon A.L., Añón M.C., 2007. Physical, sensory and chemical evaluation of cooked spaghetti. *Journal of Texture Studies*, 38, 666- 683.

- Noni I., Pagani M.A., 2010. Cooking properties and heat damage of dried pasta as influenced by raw material characteristics and processing conditions. *Critical Reviews in Food Science and Nutrition*, 50(5), 465-472.
- Oak M.D., Dexter J.E., 2006. Chemistry, genetics and prediction of dough strength and end-use quality in durum wheat. In: *Gliadin and glutenin the unique balance of wheat quality*, Ed. by C. Wrigley, F. Bekes, W. Bushuk, AACC, St. Paul, USA, , 281-305.
- Oak M.D., Sissons M., Egan N., Tamhankar S.A., Rao V. S., Bhosale S.B., 2006. Relationship between gluten strength and pasta firmness in Indian durum wheats. *Int. J. Food Sci. and Technol.*, 41, 538-544.
- Obuchowski W. 1997. *Industrial Technology of Pasta Production* (in Polish). AR Poznań, Poland.
- Samaan J., El-Khayat G.H., Manthey F.A., Fuller M.P., Brennan Ch.S., 2006. Durum wheat quality: II The relationship of kernel physicochemical composition to semolina quality and end product utilization. *Int. J. Food. Sci. and Technol.*, 41 (Supplement 2), 47-55.
- Sissons M., Ames N., Egan N., Rhymer C., 2008. A comparison of two instrumental techniques used to discriminate the cooking quality of spaghetti. *Int. J. Food Sci. Technol.*, 43, 1323-1329.
- Sobota A., Dobosz M., 2010. Quality of whole meal and whole grain pasta available in market (in Polish). *Food Sci. Technol. Quality*, 6(73), 83-99.
- Sobota A., Skwira A., 2009. Physical properties and chemical composition of extruded pasta (in Polish). *Acta Agrophysica*, 13(1), 245-260.
- Sozer N., Dalgic A.C., Kaya A., 2007. Thermal, textural and cooking properties of spaghetti enriched with resistant starch. *J. Food Eng.*, 81(2), 476-484.
- Troccoli A., Borrelli G.M., De Vita P., Fares C., Di Fonzo N. 2000. Durum wheat quality: a multi-disciplinary concept. *J. Cereal Sci.*, 32, 99-113.

WPLÝW CZASU GOTOWANIA NA TEKSTURĘ I CECHY KULINARNE MAKARONU SPAGHETTI

*Aldona Sobota, Piotr Zarzycki, Zbigniew Rzedzicki, Emilia Sykut-Domańska,
Anna Wirkijowska*

Katedra Inżynierii i Technologii Zbóż, Uniwersytet Przyrodniczy w Lublinie
ul. Skromna 8, 20-704 Lublin
e-mail: aldona.sobota@up.lublin.pl

Streszczenie. Celem badań było określenie wpływu czasu gotowania na jakość kulinarną i teksturę makaronów spaghetti, wytwarzanych z różnych surowców makaronowych. W wyniku wydłużenia czasu gotowania, odnotowano wzrost ilości wody zabsorbowanej przez makaron i jednocześnie wzrost współczynnika przyrostu masy makaronu po ugotowaniu. Wykazano istotną korelację pomiędzy przyrostem masy makaronu w trakcie gotowania, a jego wilgotnością ($r = 0,97$, $p < 0,0001$). Straty suchej masy makaronu w czasie 4-16 minutowego gotowania, były dodatnio skorelowane z dystansem odnotowanym dla maksymalnej siły cięcia i pracą cięcia. Współczynniki korelacji wynosiły odpowiednio 0,85 i 0,51. Największą siłą cięcia i pracą cięcia cechował się makaron gotowany w czasie bezpośrednio poprzedzającym minimalny czas gotowania. Zastosowanie czasu gotowania dłuższego od minimalnego, powodowało obniżenie jędrności makaronu, lecz odnotowane zmiany były stosunkowo małe. Świadczy to o dużej odporności na rozgotowanie wszystkich badanych makaronów spaghetti.

Słowa kluczowe: makaron, czas gotowania, jakość kulinarna, tekstura, jędrność