Pol. J. Food Nutr. Sci. 2005, Vol. 14/55, No 4, pp. 417–422

INFLUENCE OF SOME FUNCTIONAL COMPONENTS ADDITION ON THE MICROSTRUCTURE OF PRECOOKED PASTA

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Key words: extrusion cooking, precooked pasta, expansion ratio, WAI, starch gelatinization, microstructure

In the present paper the addition of some functional ingredients to common wheat flour and its effect on the quality parameters and the microstructure of the extrusion-cooked precooked pasta products was investigated. The expansion ratio, water absorption index, a cooking degree and the organoleptic assessment were tested with the standard methods for pasta products. The microstructure was characterised by SEM microscopy technique at different magnifications. The processing parameters (like, a screw rpm and a moisture content of raw materials) established some physical properties and the microstructure of the pasta products processed on a modified single screw extrusion-cooker TS-45. The addition of functional components like salt, egg powder, disodium orthophosphate, methylcellulose and ascorbic acid had a strong effect on the surface and the interior structure of products as well as dried precooked pasta quality. The best results associated with the uniform and compact structure of pasta products and excellent quality were obtained at processing a flour mixture enriched with a methylcellulose additive at 80–100 rpm and at 80–95°C temperature range.

INTRODUCTION

The consumption level of pasta in Poland may be considered as variable, mostly it is served twice a week (over 37% of the population) and mainly by the oldest consumer group. The most popular assortment of pasta usually chosen by Polish consumers are: rotoni, vermicelli, shell macaroni, elbow macaroni, spaghetti, o-rings and ribbons [Mościcki *et al.*, 2002]. To extend the domestic markets and win the neighbouring ones, the pasta manufacturers have to intensify the market activity offering new attractive assortment and adopting modern marketing forms. One of the most interesting products of recent years appeared to be precooked and/or instant pasta or noodle products manufactured from natural durum or soft wheat flours and then dried to reduce the moisture level. Also other kinds of starchy products can be used for precooked pasta or instant noodles formulation, *i.e.* bean, potato or rice starch [Pagani, 1986; Kim *et al.*, 1996]. Instant pasta is most suitable for instant soups and snacks making, it can be used in microwave dishes, one-pan meals or cups. Products can be specially formulated to contain eggs, vegetables, bran, flavours, vitamins or fibre. Instant or precooked pasta is a good combination of maximum convenience and excellent organoleptic qualities [Vansevenant, 1996].

The industrial manufacturing stages of precooked or instant pasta are the traditional processes of mixing, kneading, extrusion and cutting [Kim, 1996]. After the material is forced through the die face, it is pre-dried to prevent a product from losing its shape. Then the pasta is cooked at above 90% and successively dried. The final product, which looks like a traditional one, is thus completely natural. The preparation of traditional dried and cooked pasta is determined by the cooking time, temperature and water amount, which are responsible for the final gelatinization of starch and hydration of pasta during cooking. In contrast to cooked pasta, the preparation of the instant pasta involves only the hot water hydration process and complete cooking effect is affected by the hydration time.

When pasta products are made from bread-wheat flour, the quality in terms of texture, colour and cooking behaviour differs substantially from the pasta manufactured from semolina. In this case, functional ingredients addition is necessary. Various types of these additives are mixed with flour, for example monoglycerides, salt, lipase, carbonates, phosphates, eggs or others, to improve the quality of pasta products [Kim, 1996; Kubomura, 1998; Pagani, 1986].

The present study focused on the effect of processing variables and some functional additives to bread-wheat flour on selected quality traits, organoleptic characteristics and the microstructure of extrusion-cooked instant pasta products.

MATERIALS AND METHODS

All experiments were performed with standard flour obtained from an industrial flourmill in Płońsk, Poland. Three types of flour were used at different extraction rates: type 450, type 500 and type 550. The chemical composition of the wheat flour is shown in Table 1.

The raw materials of the same moisture content (m.c.), stored under the same conditions were supplemented with

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TABLE 1. Chemical composition of various types of wheat flour used in pasta in experiment.

Chemical components	Contents (%)		
	450	500	550
Water[b]	14.1	14.1	14.1
Proteins[b]	11.0	12.0	11.8
Fat[a]	1.2	1.2	1.2
Carbohydrates[a]	75.2	75.2	75.2
Ash[a]	0.45	0.50	0.55
Wet Gluten[b]	33.8	36.6	35.4

a – producer's data, b – experimental data.

water ingredient and as a consequence the prepared dough had 28%, 30% and 32% moisture content, respectively. All components were mixed, left for rest for 0.5 h and then used in the extrusion-cooking process.

Various additives were employed in the experiment, including: salt, egg powder, disodium orthophosphate, methylcellulose, and ascorbic acid, that were applied at doses recommended in literature [Kim, 1996; Kubomura, 1998; Thorvaldsson *et al.*, 1999; Vansevenant, 1996].

Extrusion-cooking was carried out at the Department of Food Process Engineering with a TS-45 single screw extrusion-cooker (ZMCh Gliwice, Poland) with a modified last barrel section before the die to reduce a product's temperature and prevent its stickiness [Wójtowicz, 2003]. For the pasta making, L:D=16:1 was utilised. Products were extruded through the die with 12 outlets 0.8 mm in diameter. Pasta products were made under the following conditions: a barrel temperature ranged from 80°C to 95°C and an extruder screw speed 60–120 rpm. After the extrusion-cooking and conditioning for 4 h at 40°C, all the pasta products were stored in plastic bags at room temperature.

The expansion ratio of the dried pasta products was established dividing the diameter of a product by the die-opening diameter of an extruder, manufacturing the products under varied conditions. The data were obtained for all extrusion conditions. The expansion ratio proves to be a vital factor for instant products due to a short hydration time for thin-walled products.

The water absorption index (WAI) was tested according to the method described by Harper [1981] with some modifications. The pasta (10 g) was hydrated in 500 mL of hot water for 10 min, then the samples were drained for 10 min and weighed. The WAI was calculated as the product weights increase and expressed as a percentage of sample weight (mentioned above) before hydration.

A starch gelatinization degree was tested after the PN--A-79011-11 [Polish Norm, 1998] for food mixes. The method was based on the enzymatic hydrolysis of starch with β-amylase. The starch gelatinization degree was expressed as a percentage amount of reducing sugars measured in the processed material in the presence of iodine.

The organoleptic assessment of the uncooked products was performed using a 5-point scale according to PN-A-74131 [Polish Norm, 1999], which includes the appearance, colour, and aroma of uncooked products. The sensory panel consisted of 15 members, trained in the use of the rating method, terminology and the sensory characteristics of pasta products.

SEM pictures were taken at the Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences in Olsztyn, Poland. The samples of pasta products were cut into 0.5 cm pieces, frozen in liquid nitrogen and lyophilized. The specimens 2–3 mm in length were applied on the carbon discs using silver tape and sprayed with gold in a vacuum sublimator JEOL JEE 400. The obtained specimens were characterised by a JEOL JSM 5200 scanning electron microscope (SEM) at accelerating voltage of 10 kV. The surface and cross-section of specimens were observed at different magnifications. The series of photographs were analysed in the context of the influence the processing parameters and additives have on the interior structure of precooked pasta products.

RESULTS AND DISCUSSION

The expansion ratio established for the pasta products was highly affected by the extruder operating conditions. This parameter was mostly influenced by the speed of extruder screw and increased with the screw speed growth for all the products, irrespective of a flour type and an additive applied. The expansion ratio values lowered with a moisture content rise of the processed dough and varied from almost 1.9 for 28% m.c. of dough processed at 120 rpm to 1.4 for 32% m.c. processed at 60 rpm. These results are presented in Figure 1. The addition of disodium orthophosphate at a dose of 1% w/w yielded the highest values of the expansion ratio, the results ranged between 1.5 at 60 rpm to almost 3.0 at 120 rpm. The consistency of the products obtained with the highest expansion ratio was poor with multiple air bubbles outside and inside the pasta strains.

The expansion ratio of pasta products processed with the addition of salt or egg powder (2% w/w) was like in the products without any addition and varied from 1.2 at the lowest screw rotational speed to 2.1 at the highest rpm. More distinct differences were noted when an emulsifier was added. While determining the expansion ratio for the pasta with a methylcellulose supplement there was observed an upward tendency of this parameter as a methylcellulose content was elevated in the mixture with flour. The lowest values of the expansion ratio were recorded for this pasta mentioned above produced at 60 rpm with 0.08% and 0.1% methylcellulose addition.

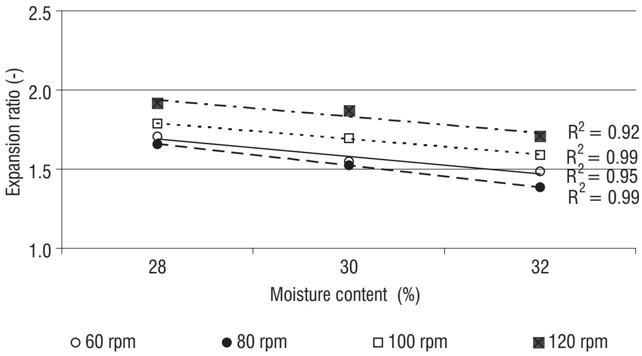

FIGURE 1. The expansion ratio of pasta processed with different moisture content of dough from a flour type 450 and 2% of salt under various extrusion screw speed.

An ascorbic acid supplementation also exerted an impact on the expansion ratio of the precooked pasta. Studying the pasta manufactured from a flour type 550, this ratio's decline was reported only for the product made at 60 rpm when an ascorbic acid content increased. For a flour type 500 there was noted the smallest scatter of results between particular values of the ratio and there was observed a reduction in its value with ascorbic acid content growth for pasta made at 60 and 80 rpm. The evident growth of expansion ratio was recorded for a flour type 450 along with an increase in an ascorbic acid content. In this case, the highest value of the expansion ratio (1.75) was obtained at 0.1% addition of ascorbic acid and 120 rpm.

While determining the water absorption index for pasta products, functional additives were observed to affect this parameter's values. The WAI of the pasta manufactured from a wheat flour type 450 showed the highest water absorption of all the samples, which can be explained with a weak wet gluten quality compared to others. The addition of both disodium orthophosphate and egg powder yielded some lower results of the pasta WAI measurements of these samples due to a higher expansion for disodium orthophosphate addition and a low starch gelatinization degree for the pasta enriched with egg powder. In these cases, the WAI values varied from 127% to 294%.

A growing content of ascorbic acid was observed to significantly affect an increase in WAI values in the case of products made from a flour type 500, whereas any explicit effect was confirmed of the operating screw rotation speed on water absorption. In addition, the products made of flour type 500 showed the lowest WAI values, *i.e.* from 290% to 335%. While establishing WAI for the pasta products made from a flour type 550, water absorption was observed to decline with ascorbic acid increase (Figure 2). These products were characterised by the highest water absorption, even up to 360% of pasta weight. A similar tendency for water absorption decrease at an increasing content of the additive was reported for the pasta products obtained from a flour type 450, yet a slight discrepancy between the results implies insignificant effect of ascorbic acid on water absorption of the products. The highest results of water absorption index for all the products processed with an ascorbic acid ingredient are likely to be caused by the improvement of a protein network of wheat flour dough and more efficient water binding inside the products, which has been confirmed by Larsson *et al.* [1996].

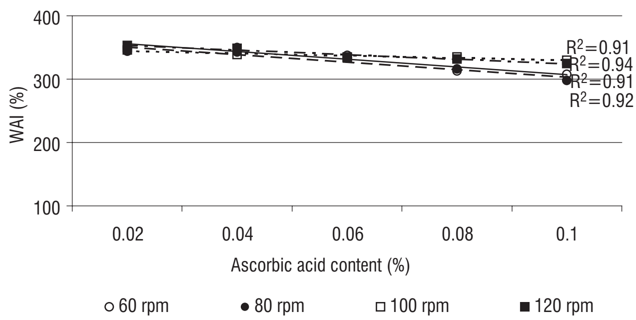

FIGURE 2. Water absorption index for pasta products processed from a flour type 550 with ascorbic acid addition (30% m.c.) at various extrusion screw speed.

The WAI for the pasta made with a methylcellulose addition ranged from 265% to 315% and it was lower than the index for the pasta supplemented with ascorbic acid. The most considerable divergence between the results of measurements was reported for the products manufactured from a flour type 500. The minimal WAI upward tendency noted for the products made at 60 rpm was opposite to a downward tendency of water absorption of the products processed at other screw rotations with a growing methylcellulose content. However, correlation coefficients for this portion of products exhibited a slight effect of the additive on their WAI. In contrast, for both products manufactured from flour types 450 and 500, a significant impact of an increasing methylcellulose content on their water absorption was confirmed. In both cases, the WAI ratio value was observed to increase along with a growing methylcellulose content in pasta. The pastas processed at 60 and 80 rpm demonstrated the highest water absorption.

A temperature of the common wheat gelatinization is *ca.* 59–64°C, thus temperature-shearing interactions inside the extruder can generate the gelatinization of a great amount of starch present in flour. In addition, the moisture content and additives determine the degree of starch gelatinization. The starch gelatinization degree is likely to vary depending on the extrusion-cooking conditions, *e.g.* for corn starch extrudates tested by Lee *et al.* [2000] a gelatinization degree ranged from 44% to 74%. It is a common knowledge that traditional pastas are processed at temperatures below 65°C, hence their starch gelatinization degree reaches *ca.* 50%, depending on the drying conditions [Kruger *et al.*, 1996]. In the experiments, the starch gelatinization degrees of the precooked products processed under the presented conditions were very high and varied from above 70% for the products manufactured at 60 rpm to even 91% for the pasta made at 120 rpm from dough with 32% m.c. More intensive starch gelatinization was observed upon increasing the rotational speed of the screw during the processing, irrespectively of the additive employed. Relatively different behaviour of the processed starch was observed in pasta in respect of the additive used. Pasta enriched with egg powder was characterised by the lowest value of a starch gelatinization degree (below 75%) and manifested low WAI and poor organoleptic characteristics. The higher protein content due to the addition of eggs resulting in the lowering of gelatinization intensity in these products under the experimental extrusion cooking conditions. The highest values of this parameter were recorded for the pasta made with a disodium orthophosphate additive, but other quality characteristics were insufficient and caused the product's disqualification. In the case of a methylcellulose addition to the pasta products, a higher level of additive used improved the starch gelatinization degree from 79% to 90% at the highest dose of the additive. An opposite tendency was reported for an ascorbic acid additive: its higher content generated a lower gelatinization degree, because of functional characteristics of ascorbic acid that improves wheat gluten structure and promotes forming the protein-carbohydrates complexes during the thermal treatment [Liu *et al.*, 1996; Every *et al.*, 1999]. Therefore, a high starch gelatinization degree level enables treating these products as precooked and preparing them for consumption without any traditional cooking process, just short-time hydration in hot water.

The organoleptic characteristics of the uncooked pastas were almost alike for all the products examined with scores ranging from 4 or 5 in the 5-point scale. The pasta products made at a low screw rotational speed (60 rpm) manifested less transparency, glassy and more floury fracture with the lowest scores below 3 or 2 for the appearance. No significant differences were recorded between different types of flours used. The additives used affected the pastas obtained at the subsequent screw rotations. The addition of disodium orthophosphate caused high expansion of products and the lowest scores for the appearance and shape. Similarly low scores of the organoleptic assessment gained the pasta products processed with an egg powder ingredient as the reduced transparency of pasta strain, floury appearance and taste brought about an insufficient level of gelatinised starch. A methylcellulose content resulted in shape improvement of these pastas and at 0.06–0.1% addition the surface was smooth and the pasta was transparent. When ascorbic acid was added the pasta twistability was recorded at its extrusion out of the die, the highest at 80 rpm. The organoleptic assessments of these products were poor (below 3). At the higher rotations, this tendency disappeared and the pasta earned even 4 to 5 scores. At the highest rotations – 120 rpm, the pasta surface became uneven and corrugated. Besides, there was reported an influence of an ascorbic acid additive on a product colour and taste, similarly to the results reported by Every *et al.* [1999]. The higher its percentage was, the more yellow colour and more acid taste appeared, hence the scores were the lowest.

The microstructure of dried precooked pasta products differs depending on the processing conditions, especially a moisture content and screw speed. The combination of a temperature, moisture and shearing inside the extrusion-cooker makes it possible to obtain a coherent precooked structure. On the basis of the cross-section pictures of the dried pasta products, the impact of a moisture content and screw speed on the inside structure changes was investigated. The samples from a flour type 500 with 28% moisture content and processed at 60 rpm (Figure 3a) showed unarranged structure without clearly marked starch fraction. These conditions were unsuitable to complete the starch gelatinization process. Higher water content during the pasta making caused the formation of the network of bonded swollen starch granules (Figure 3b). The samples processed with 32% moisture content and at 120 rpm were characterised by almost homogenous compact gelatinized inside structure shown in Figure 3c. Regarding the inside structure, a flour type conditioned by a protein level and gluten characteristic proved to be important. Flour type 450 showed the lowest protein level and swollen ungelatinized starch granules (Figure 3d). This type of flour was characterised with an oval shape of starch granules. The products manufactured from flour type 500 and type 550 with a low moisture content were similar regarding the marked starch fraction granularity (Figure 3e). Cunin *et al.* [1995] presented the analog SEM pictures for the semolina pasta extruded on a single screw extruder (L:D=35:5) at 40°C with a Teflon die 1.9 mm in diameter. The investigations of Thorvaldsson *et al.* [1999] revealed the influence of the temperature changes 20–85°C on the inside structure of the pasta made from common wheat flour at a high moisture content (39.5–41%). More consolidated structure was observed at a higher processing temperature and the completely gelatinized

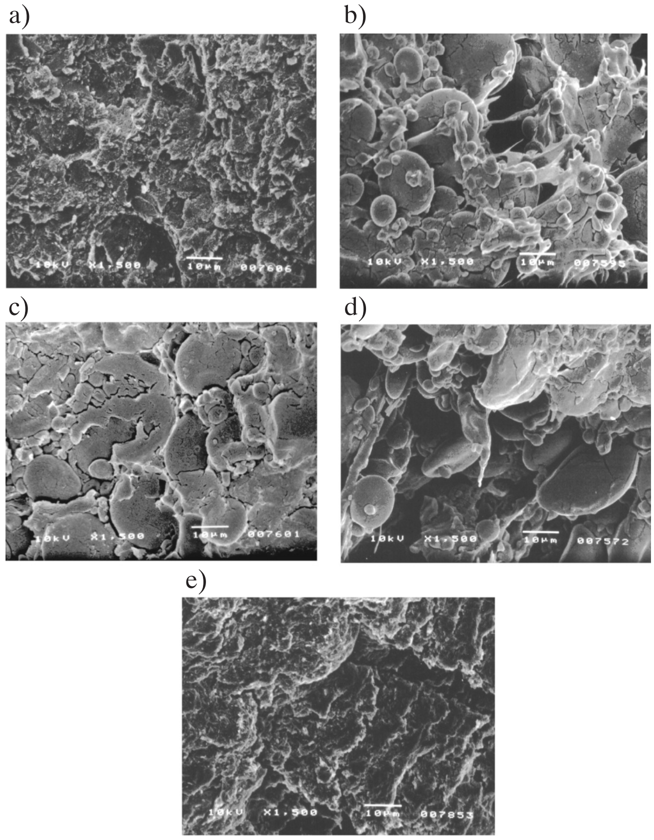

FIGURE 3. Cross-section of precooked pasta processed under different conditions at x1500 magnification: a) flour type 500, 28% m.c., 60 rpm, b) flour type 500, 30% m.c., 80 rpm, c) flour type 500, 32% m.c., 100 rpm, d) flour type 450, 30% m.c., 80 rpm, e) flour type 550, 30% m.c., 80 rpm.

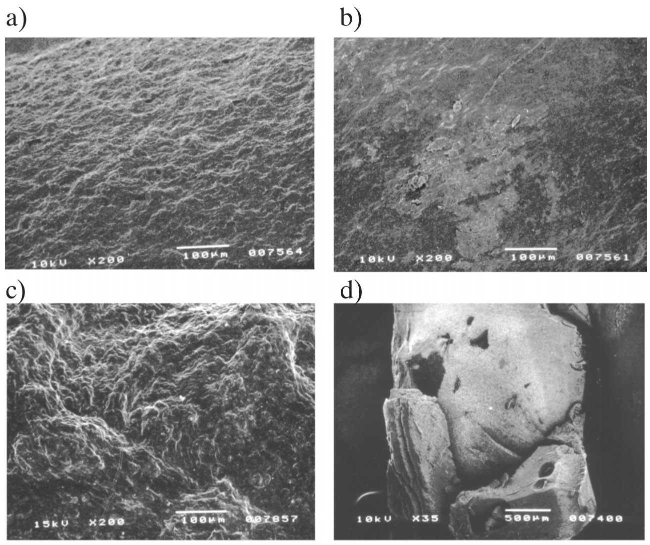

FIGURE 4. Surface of precooked pasta processed with different recipes: a) flour type 500, 2% egg powder, 30% m.c., 80 rpm (x200), b) flour type 500, 0.1% methylcellulose, 30% m.c., 80 rpm (x200), c) flour type 500, 0.1% ascorbic acid, 30% m.c., 80 rpm (x200), d) flour type 500, 1% disodium orthophosphate, 32% m.c., 120 rpm (x35).

starch at the highest one. Thomas & Atwel [1999] made similar observations.

Some significant differences were recorded between the pasta samples enriched with additives that changed or improved the rheological and functional properties of these products. But their addition also changed the outside and inside structure of the pasta products. Quite smooth and regular surface was observed in the precooked pasta with an egg powder ingredient (Figure 4a). The inside structure was also regular, compact, with singular air bubbles inside it (Figure 5b). The addition of methylcellulose as an emulsifier yielded the extremely smooth, glasslike surface (Figure 4b) and excellent consistency. It was also found that an increased methylcellulose addition promoted more regular and compact inside structure (Figure 5c and 5d). Observation of the products with an ascorbic acid ingredient confirmed its utmost influence on the pasta appearance. The structure of products processed with an ascorbic acid addition was irregular with corrugated surface, being more intensive at a higher dose of ascorbic acid. The inside structure pictures of these pastas resembled the pictures of surface with characteristic uneven corrugated structure, not observed inside other pasta products, a higher ascorbic acid level induced more profound changes (Figure 5e and 5f). The addition of disodium orthophosphate caused high expansion of the pasta during extrusion, irregular surface (Figure 4 d) and visible large air bubbles in the inside structure (Figure 5a). These products earned the lowest scores in the organoleptic assessments.

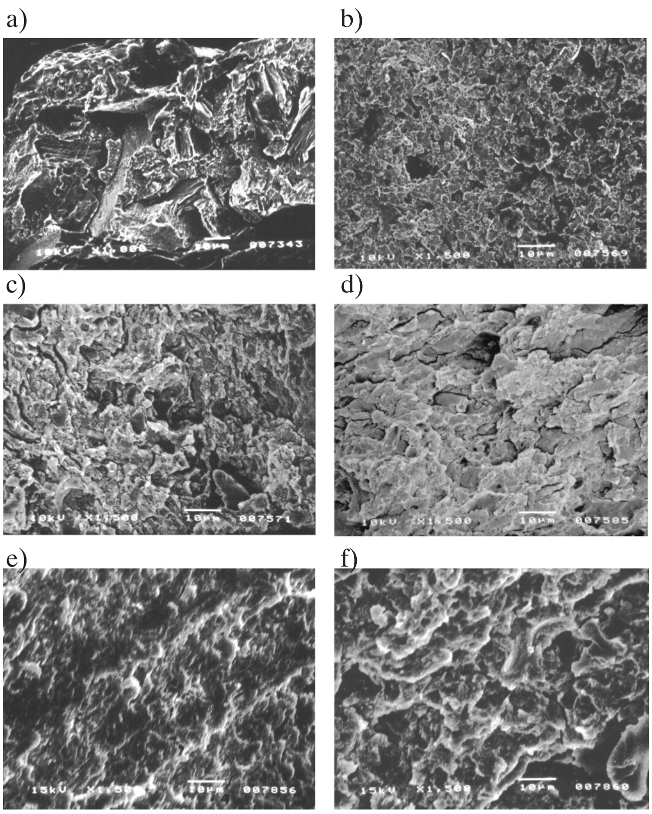

FIGURE 5. Influence of additives on the inside structure of precooked pasta with a flour type 500, 30% m.c. and 80 rpm at x1500 magnification: a) 1% disodium orthophosphate, b) 2% egg powder, c) 0.04% methylcellulose, d) 0.1% methylcellulose, e) 0.04% ascorbic acid, f) 0.1% ascorbic acid.

CONCLUSIONS

The analysis of the chosen quality parameters and the SME pictures of the precooked pasta processed with the extrusion-cooking technique on a modified single screw extrusion-cooker TS-45 showed a great influence of both processing parameters and additives on the functionality and microstructure of the instant pasta. The most preferable parameters for good quality products processed on this type of extrusion cooker proved to be a screw speed range of 80-100 rpm and an emulsifier addition, *e.g.* methylcellulose. They enabled obtaining a smooth surface and regular compact inside structure with a small amount of air bubbles and thus excellent properties of these products.

ACKNOWLEDGEMENTS

Dr A. Wójtowicz would like to express her thanks to The Director of the Institute of Animal Reproduction and Food Research of the Polish Academy of Sciencesin Olsztyn who has greatly facilitated taking the SME pictures at this Institute.

REFERENCES

1. Cunin C., Handschin S., Walther P., Escher F., Structural changes of starch during cooking of durum wheat pasta. Lebensm. Wiss. Technol., 1995, 28, 323–328.
2. Dalbon G., Grivon D., Pagani M., Pasta. Continuous manufacturing process. 1996, *in*: Pasta and Noodle Technology (eds. J. Kruger., R. Matsuo, J. Dick). AACC, Minnesota, USA, pp. 13–58.
3. Every D., Simmons L., Sutton K., Ross M., Studies on the mechanism of the ascorbic acid improver effect on bread using flour fractionation and reconstitution methods. J. Cereal Sci., 1999, 30, 147–158.
4. Harper J., Extrusion of starches and starchy materials. 1981, *in*: Extrusion of Foods vol. II, CRC Press Inc., Florida, USA, pp. 41–58.
5. Kim S., Instant noodles technology. Cereal Foods World, 1996, 41, 213–218.
6. Kim Y., Wiesenborn D., Lorenzen J., Berglund P., Suitability of edible bean and potato starches for starch noodles. Cereal Chem., 1996, 73, 302–307.
7. Kubomura K., Instant noodles in Japan. Cereal Foods World, 1998, 43, 194–197.
8. Larsson H., Eliasson A., Phase separation of wheat flour dough studied by ultracentrifugation and stress relaxation. II. Influence of mixing time, ascorbic acid and lipids. Cereal Chem., 1996, 73, 25–31.
9. Lee E., Lim K., Lim J., Lim S., Effect of gelatinization and moisture content of extruded starch pellets on morphology and physical properties of microwave-expanded products. Cereal Chem., 2000, 77, 769–773.
10. Liu C., Shepherd K., Rathjen A., Improvement of durum wheat pastamaking and breadmaking qualities. Cereal Chem., 1996, 73, 155–166.
11. Mościcki L., Gantner A., Mitrus M., Pasta production in Poland. Post. Techn. Przetw. Spoż., 2002, 1, 48–51 (in Polish).

12. Pagani M., Pasta products from nonconventional raw materials. 1986, *in*: Pasta and Extrusion Cooked Foods (eds. Mercier Ch., Cantarelli C.). Proceedings of an International Symposium in Milan Italy, Elsevier Applied Science Publishers Ltd. London, England, pp. 52–68.
13. PN-A-79011-11, 1998, Dry food mixes – Test methods – Determination of degree of starch gelatinization.
14. PN-A-74131, 1999, Macaroni products.
15. Thomas D., Atwell W., Starch analysis methods. 1997, *in*: Starches (eds. D.Thomas, W. Atwell), AACC, Minnesota, USA, pp. 13–25.
16. Thorvaldsson K., Stading M., Nilsson K., Kidman S., Langton M., Rheology and structure of heat-treated pasta dough: influence of water content and heating rate. Lebensm. Wiss. Technol., 1999, 32, 154–161.
17. Vansevenant P., Instant pasta: a short story. Food Ingredients Anal. Int., 1996, 18, 17–18.
18. Wójtowicz A., Studies on the extrusion-cooking process of precooked pasta. 2003, Ph.D. Thesis, Agricultural University, Lublin, pp. 62–67 (in Polish).

Received October 2004. Revision received May and accepted September 2005.

WPŁYW WYBRANYCH DODATKÓW FUNKCJONALNYCH NA MIKROSTRUKTURĘ MAKARONÓW PODGOTOWANYCH

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W badaniach zastosowano dodatek wybranych substancji funkcjonalnych i obserwowano ich wpływ na wybrane cechy jakościowe oraz mikrostrukturę wyrobów makaronowych otrzymanych z zastosowaniem techniki ekstruzji, która umożliwia wytworzenie z mąki pszenic zwyczajnych wyrobów podgotowanych, gotowych do spożycia po hydratacji w gorącej wodzie. Zaobserwowano wpływ parametrów ekstruzji przeprowadzanej w zmodyfikowanym ekstruderze jednoślimakowym TS-45 z użyciem różnych typów mąki pszennej na wszystkie oceniane cechy. Najistotniejsze zależności zaobserwowano podczas oceny wskaźnika ekspandowania promieniowego od prędkości obrotowej ślimaka ekstrudera oraz wilgotności surowców (rys. 1) oraz na mikrostrukturę makaronów (rys. 3). Zastosowanie dodatków: soli, proszku jajecznego, ortofosforanu sodowego, metylocelulozy oraz kwasu askorbinowego wpływało w zróżnicowanym stopniu na charakterystykę fizykochemiczną wyrobów makaronowych, przy czym wyraźne różnice odnotowano podczas określania wskaźnika absorpcji wody WAI (rys. 2) oraz wskaźnika skleikowania skrobi. Zastosowanie proponowanych dodatków wpłynęło także na zróżnicowanie powierzchni (rys. 4) oraz struktury wewnętrznej wytworzonych makaronów (rys. 5). Najbardziej jednorodną i zwartą strukturą oraz dobrymi cechami użytkowymi charakteryzowały się wyroby otrzymane z mąki pszennej z dodatkiem emulgatora – metylocelulozy, wytwarzane przy zastosowaniu prędkości obrotowej ślimaka 80–100 obr.min^{-1} oraz 30% wilgotności początkowej surowców.