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INFLUENCE OF EXTRUSION-COOKING PROCESS PARAMETERS ON SELECTED PHYSICAL AND TEXTURAL PROPERTIES OF PRECOOKED MAIZE PASTA PRODUCTS

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Summary. The paper presents the results of measurements of selected physical and mechanical properties of precooked pasta made from maize flour using variable parameters of extrusion-cooking process. The different level of water addition to maize flour was used due to the moisture content from 30 to 34%. Processing of maize pasta products was performed at the temperature ranged 80-100°C on single-screw modified extrusion-cooker TS-45 with L/D = 18:1 using a differentiated screw speed: 60, 80, 100 and 120 rpm. Depending on the screw speed and the dough moisture content selected physical, textural and tensile properties of precooked maize pasta products were determined, like the expansion ratio, hardness of dry pasta, firmness and extension characteristics of hydrated products due to elongation tests. The expansion ratio of pasta increased with increased rpm applied during processing, the use of higher moisture content of raw materials affect the limiting expansion ratio of maize precooked pasta products. SME values ranged from 0.17 to 0.34 $kWh \cdot kg^{-1}$ and were strongly dependent the screw speed rotations during the extrusion-cooking of pasta. Hardness and firmness of maize precooked pasta products increased with the increase of the screw speed. Precooked maize pasta may be a valuable product for the nutrition as gluten-free carbohydrates source, because of its texture and convenience, especially for the consumers with celiac disease diet.

Key words: extrusion-cooking, maize pasta, gluten-free pasta, expansion ratio, SME, texture.

INTRODUCTION

Extrusion technique can be used to produce precooked or instant pasta and noodles which require any cooking and only hydration in hot water for several minutes. Modern systems of thermoregulation can produce a desired level of starch gelatinization, while screw variable speed and the proper geometry of plasticizing zone is able to formation a stable products' structure in contact with water and after preparation for consumption. According to extrusion-cooking process conditions, preservation and packaging of pasta are significantly simplified, the drying time is reduced, which reduces production costs. Equally important advantage is the ease of production, since the process does not require highly efficient dryers, or gelatinization by steam spraying or bath cooking [10, 20, 27]. Modifying of the process parameters allows formation the quality characteristics of extruded products, and the greatest influence on these characteristics of the finished products are the raw materials used, their moisture content and extrusion-cooking parameters, i.e. screw speed, temperature and pressure.

Extruded precooked gluten-free pasta can be a perfect complement to offer products for people on gluten-free diet without using any additional functional substances, and the convenience of the products allows the easy preparation for consumption by hydration in hot water without cooking. Extrusion causes complete or partial destruction of crystalline structure of starch due to gelatinization process as well as protein denaturation and the formation of complexes between starch and fats, and proteins and fats [1, 3, 7]. Thermal and mechanical interaction occurring during extrusion-cooking causing these changes can be used to produce a wide range of products based on starch, such as snacks, modified starches, breakfast cereals, instant porridge for children and dietetic food products [9, 14, 15].

Corn (maize) or rice products play an important role in the nutrition of people with gluten intolerance (celiac disease), which cannot consume products made from commonly used materials based on wheat, rich in gluten [6, 16]. Maize or rice pasta, traditionally made with the dough additional processing (steaming or frying) characterized glassy cross-section, firm consistency after cooking, limited cooking losses and colour characteristic for the raw material used. Sometimes, from technological reasons, some additives are used, like methylcellulose or diglycerides or other emulsifiers for proper pasta structure formation without presence of gluten [21]. However, availability of gluten-free pasta products on Polish market is limited. Specific physicochemical properties of raw materials of corn and rice, such as high starch content, no gluten, hypoallergenic and delicate flavor make them very desirable in the production of extrudates and a new generation of products and convenience foods intended for specific audiences [2].

Due to instant characteristics of precooked gluten-free pasta, its preparation for consumption is very easy by hot water hydration without cooking. For high starch gelatinization, which results in the stabile shape and soft texture of final products, pasta dough should be processed at temperature of 90-95°C to achieve proper starch gelatinization level and shape-keeping properties, than has to be quickly cooled down to prevent products' expansion. The extrusion-cooking treatment because of complex thermal and mechanical treatment, gives the gluten-free pasta specific characteristics of precooked products, which may be classified as convenient foods [12].

The aim of this work was an evaluation of processing parameters influence on selected physical and textural properties of gluten-free maize precooked pasta.

MATERIALS AND METHODS

As the raw material maize flour was used (protein - 5.13%, fat - 1.4%, ash - 0.45%, fiber - 2.0%). Raw material was moistened by proper water addition and mixed for final dough moisture content 30, 32 and 34%. After mixing and resting compounds were processed using the modified single screw TS-45 extrusion-cooker (ZMCh Metalchem, Poland) with screw length to diameter ratio L/D=18:1, compression ratio - 3:1, equipped with additional glycol cooling section just before the die, at the temperature ranged from 80 to 105°C. Pasta products were shaped for threads with application a forming die with 12 opens 0.8 mm in diameter. Gluten-free pasta products were processed at different screw speed at the level of 60, 80, 100 and 120 rpm. After short drying samples were stored in plastic bags before testing.

Based on the data collected during multiple trials the energy requirement of extrusion-cooking process was evaluated at different screw speed and with different initial moisture content of raw material. Power consumption was measured using standard register connected to extruder's motor during processing of each recipe at different screw speed used. After the consideration of motor load and process output ($kg \cdot h^{-1}$), the SME (specific mechanical energy) values ($kWh \cdot kg^{-1}$) were calculated on the base of method described by Wójtowicz [22, 25].

The expansion ratio index of precooked maize pasta was designated as the ratio of the diameter of the pasta thread to a diameter of forming die opens (0.8 mm) [25, 26]. Measurements of pasta diameter were performed with a caliper with digital display with an accuracy of 0.01 mm. The measurements were made in 15 replications, as final result the average of the measurements was taken into account.

Universal testing machine Zwick BDO-FB0.5TH (Zwick GmbH & Co., Germany) was used for texture evaluation. For hardness of dry products the Warner-Bratzler steel blade with 3 mm thick and 60 mm long, double-face truncated at an angle 45° was used. Hardness of dry pasta processed under different screw rpm was measured as breaking force (N) for single pasta during breaking test as mean of 10 replications. Hardness was evaluated as maximum force at break [8]. Texture of hydrated products after 5 minutes of hot water hydration for firmness evaluation was measured as maximum force (N) during test in five-blade Kramer cell, where 100g of hydrated pasta was placed and double compression test was performed with a head speed 100 mm·min^{-1}. *TestXpert*® 10.11 program was used for curves analysis, depend on moisture of raw materials and processing screw speed [28].

Results were analyzed using the statistical software Statistica 6.0, examining the relationships between the moisture content of raw materials and screw rpm to all tested parameters. Analysis of variance was conducted at a confidence level of 95% (p=0.05), significance of differences was assessed by Duncan's range test.

RESULTS

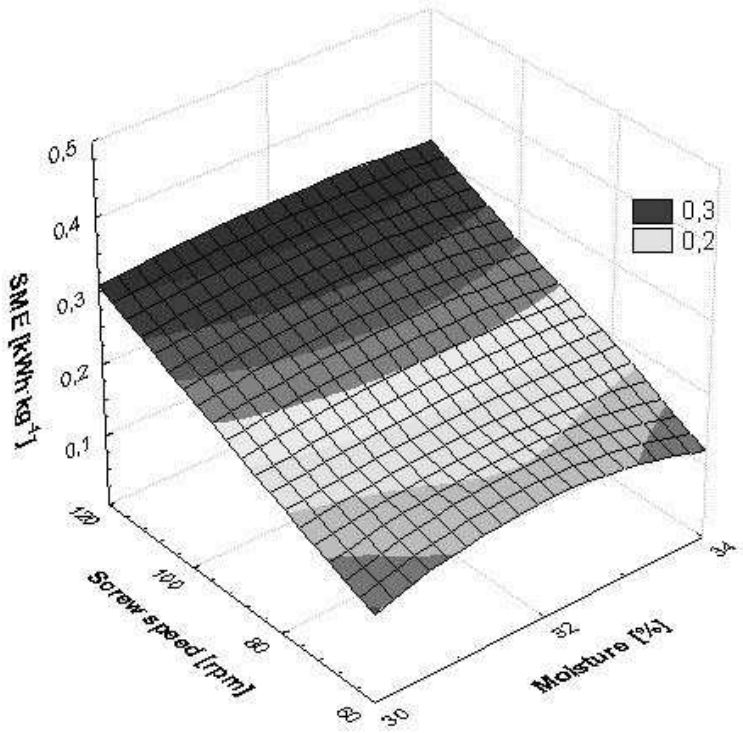

Fig. 1. Specific mechanical energy registered for precooked maize pasta processed at different screw speed and initial moisture content of raw materials

All the results were analyzed in three dimension arrangement and correlation coefficients were set both for influence of moisture content of the dough and screw speed used during the extrusion-cooking. SME values, designated as the specific mechanical energy during extrusion of maize precooked pasta ranged from 0.17 to 0.34 $kWh \cdot kg^{-1}$ and depended mainly on the screw speed used during processing (Fig. 1). The higher screw speed was used, the higher the SME were determined for maize pasta. There were no significant effects of the moisture content on SME values of maize precooked pasta.

Hot water hydration time for ready-to-eat properties of maize precooked pasta varied from 4 to 6 minutes and any traditional cooking was needed. Low expansion of precooked products is preferable because of its short preparation time. The expansion ratio results of maize precooked pasta products not exceed 1.8 (Fig. 2). This parameter evaluated for maize precooked pasta processed at varied screw speed and raw materials moisture content was dependent on both of these process conditions. The higher extrusion-cooking screw speed was applied, the higher expansion ratio was observed with a high correlation coefficient (r=0.8). The lowest expansion was noted for maize pasta processed at 30 and 34% of dough moisture content and lowest screw speed. Increasing of dough moisture content processed at higher screw speed lowered products' expansion. Higher screw speed applied during the extrusion-cooking increased pasta expansion and therefore longer the time of hot water hydration was observed.

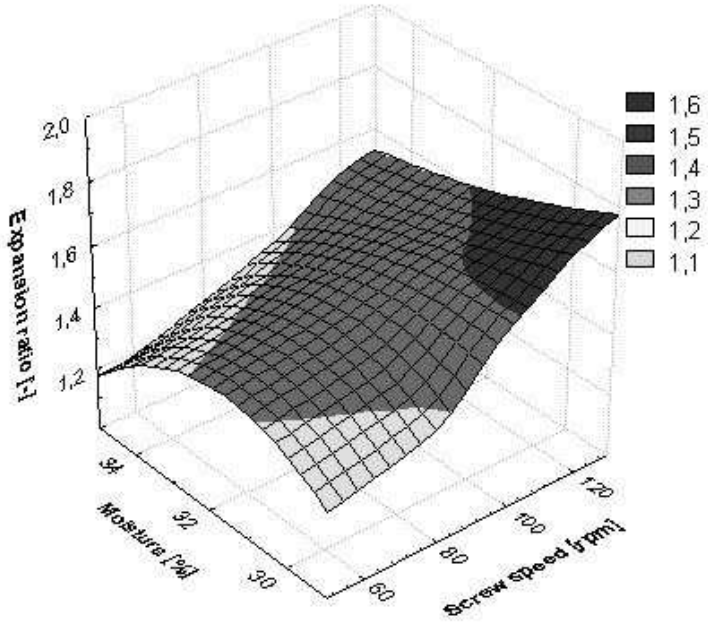

Fig. 2. The expansion ratio of precooked maize pasta processed at different screw speed and initial moisture content of raw materials

Textural features of both dry pasta and cooked or hydrated products are very often seen as quality indicators. Instrumental methods for evaluation of hardness, firmness, cohesiveness, adhesiveness and stickiness of pasta products primarily utilize cutting and compression tests using universal testing machines [4, 5, 11, 17, 18, 30]. For measuring the hardness of pasta and noodles

cutting test may be used by setting the maximum forces required to destroy the samples [13, 23, 29], and to measure the characteristics of the cooked products' texture it can be used Kramer cell, which make it possible to identify a series of measurements in the double compression tests wide range of textural characteristics, depending on the software used for analysis and interpretation of measurement results [24].

Hardness of instant dry pasta made from maize flour is shown in Figure 3. Hardness of dry gluten-free pasta was strongly affected by extrusion screw speed applied (r=0.87); it was the most important factor responsible for higher hardness of pasta products. At 100 and 120 rpm and low moisture level hardness was the highest. Hardness of dry pasta lowered with increased water addition and lower screw speed applied. The moisture content of the dough was less important factor according to maize pasta hardness (Figure 3).

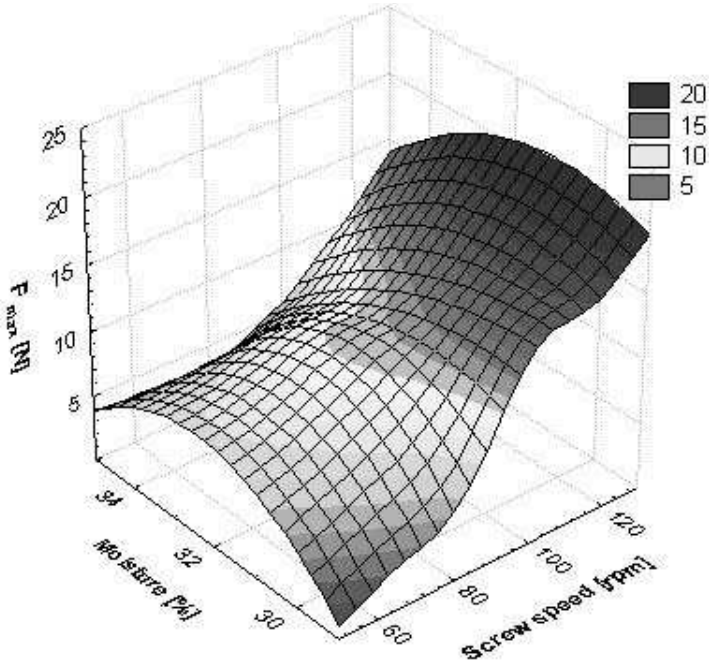

Fig. 3. Hardness of precooked maize pasta processed at different screw speed and initial moisture content

The texture of pasta prepared for consumption by a few minutes or longer cooking or by hot water hydration allows the assessment of the characteristics of flexibility, elasticity and stickiness of pasta and noodles [17, 19]. The use of five-blade Kramer cell gives the possibility for a series of measurements in the compression-shearing tests and determination of a wide range of textural characteristics, depending on the software used for analysis and interpretation of measurement results [28]. Figure 4 shows an example texture measurement profile during evaluation the texture of maize precooked pasta upon hydration.

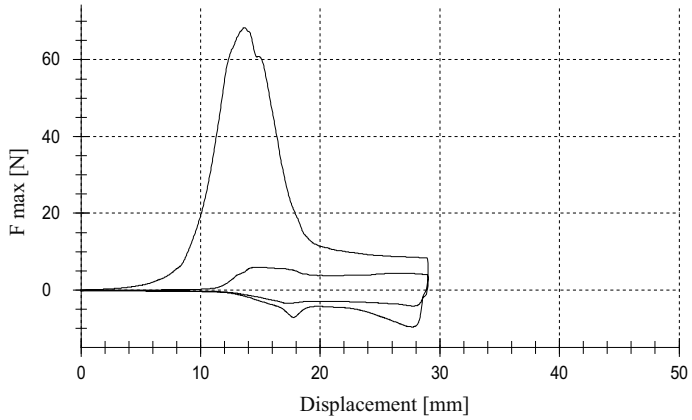

Fig. 4. Sample of texture measurement of maize precooked pasta after 5 minutes of hot water hydration (30% of moisture content, screw speed 80 rpm)

Firmness evaluated in the double compression test showed significant effect of extrusion-cooking screw speed on the gluten-free pasta firmness (r=0.78). Increasing the moisture content of raw material caused a slight decrease of firmness of pasta corn after hydration when screw speed not exceed 100 rpm (r =- 0.36). At highest rpm an influence of moisture content of raw materials was important with correlation coefficient r=-0.6. Firmest consistency was observed for maize pasta processed at 120 rpm and 30% of dough moisture (Fig. 5). The higher screw speed was used during extrusion-cooking, the firmer the products were obtained.

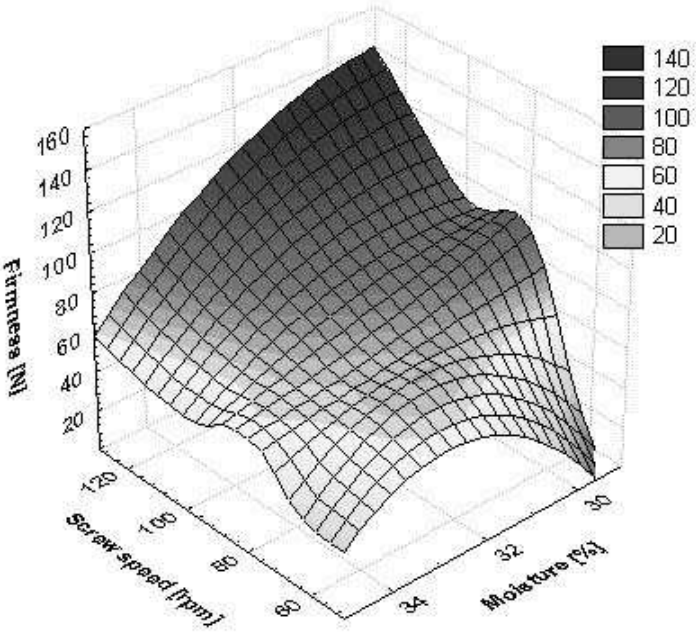

Fig. 5. Firmness of precooked maize pasta processed at different screw speed and initial moisture content

CONCLUSIONS

A study of the influence of processing parameters like screw speed and dough moisture content during the extrusion-cooking of precooked maize pasta allowed to establish the relationships between process parameters and product characteristics. The use of the proper moisture content of raw materials and processing intensity for maize precooked pasta using modified single screw extruder TS-45 influenced the low expansion ratio which decreased as the moisture content of the material increased. The SME requirements increased with increasing of extrusion screw speed, which increased the expansion of pasta products. Precooked maize pasta products were ready for consumption after 4-6 minutes hydration in hot water. After hydration gluten-free precooked pasta showed stabile consistency, low stickiness and acceptable firmness. Precooked gluten-free maize pasta may be valuable for the nutrition, because of its texture and convenience as carbohydrates source, especially for the consumers with celiac disease diet.

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WPŁYW PARAMETRÓW PROCESU EKSTRUZJI NA WYBRANE CECHY FIZYCZNE I TEKSTURĘ PODGOTOWANYCH MAKARONÓW KUKURYDZIANYCH

Streszczenie. W artykule przedstawiono wyniki pomiarów wybranych właściwości fizycznych i tekstury kukurydzianych makaronów błyskawicznych ekstrudowanych przy zmiennych parametrach procesu. Zastosowano zróżnicowany poziom dowilżenia mąki kukurydzianej do wilgotności od 30 do 34%. Ekstruzję podgotowanych makaronów kukurydzianych przeprowadzono w temperaturze 80-100°C z zastosowaniem zmodyfikowanego ekstrudera jednoślimakowego TS-45 z L / D = 18:1 przy użyciu zróżnicowanych prędkość ślimaka: 60, 80, 100 i 120 obr·min^{-1}. W zależności od obrotów ślimaka i wilgotności ciasta przeprowadzono ocenę wybranych właściwości fizycznych, tekstury i cech wytrzymałościowych podgotowanych makaronów kukurydzianych, m.in. zapotrzebowanie SME, wskaźnik ekspandowania promieniowego, twardość makaronów suchych i jędrność uwodnionych produktów bezglutenowych. Wskaźnik ekspandowania makaronu wzrastał w miarę zwiększania prędkości ślimaka stosowanych podczas ekstruzji, zastosowanie wyższych wilgotności surowców wpłynęło na ograniczenie ekspandowania podgotowane makaronów kukurydzianych. Wartości SME wahały się od 0,17 do 0,34 kWh·kg^{-1} i były głównie uzależnione od obrotów ślimaka podczas ekstruzji makaronu. Twardość oraz jędrność podgotowanych makaronów kukurydzianych zwiększały się wraz ze wzrostem zastosowanej prędkości obrotowej ślimaka. Podgotowany makaron kukurydziany może być cennym żywieniowo produktem jako bezglutenowe źródło węglowodanów, ze względu na jego teksturę i wygodę przygotowania, zwłaszcza dla konsumentów chorych na celiakię wymagających diety bezglutenowej.

Słowa kluczowe: ekstruzja, makaron kukurydziany, makaron bezglutenowy, ekspandowanie, SME, tekstura.