INFLUENCE OF LEGUMES ADDITION ON PROCEEDING OF EXTRUSION-COOKING PROCESS OF PRECOOKED PASTA

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Summary. The paper presents results of process efficiency and specific mechanical energy consumption (SME) during the extrusion-cooking of precooked pasta processed from 450 type wheat flour with legumes addition. The additives: white bean, pea and lentil grounded to flour, were used at 10, 20, 30 and 40% of flour mass in recipes. Raw materials were moistened to 30% of moisture content and processed on modify single screw extrusion-cooker TS-45 with L/D=16 with screw speed 70, 90, 110 rpm at the temperature range of 75-96°C. Pasta was extruded through the die with 12 openings 0,8 mm each to strain shape. During processing the process efficiency and specific mechanical energy consumption (SME) were recorded depending on the extrusion-cooking parameters and recipe used. The efficiency of extrusion-cooking process of enriched pasta products increased with an increase of the screw rotational speed. An increase of legumes participation in pasta recipes resulted in lower process efficiency. The SME values were ranged from 0,29 to 0,84 kWh kg⁻¹ and were dependent on both the recipe and screw speed used.

Key words: extrusion-cooking, precooked pasta, legumes, process efficiency, SME.

INTRODUCTION

In recent years the production of pasta from raw materials other than durum flour and semolina, like rice, maize, barley, oat, and enriched mixtures, has been growing [Jurga, 2000]. In conventional pasta processing high level of these additives may deteriorate the gluten or other protein strength which decreases physical properties of the final product. The strength and elasticity of just extruded pasta become lower, their stickiness and cooking losses are higher [Jurga 2002]. So, in conventional durum pasta processing, the addition of high starchy raw materials should not exceed 10%.

In many European countries there is observed an interest in oriental, eastern pasta and noodles processed from rice or legumes. Processing of this kind of raw materials is based on mixing with water, forming the proper shape by rolling or pressing and starch gelatinization via steam or water cooking or oil frying [Jurga 2001, Wang et al. 1999].

An alternative option is an extrusion-cooker able to precoat starchy raw materials, which then need no other treatment. Many interactions occurring between plant compounds permit to form proper strength and sensory profile of the final product [Huber 1998, Wójtowicz, Mocicki 2000].
Extrusion-cooking, useful in precooked pasta production, is a HTST pressure-thermal process with short time heat treatment of the processed mass at high pressure [Moscicki et al. 2007, Singh et al. 1997]. The new thermoregulation systems allows for an achievement of homogenous starch gelatinization level and screw with changeable rotations and geometry warrantee to get the product which is stable during contact with water and after cooking. As a result of extrusion-cooking treatment the preservation and confectionery processes are simple, drying time is much shorter, which decreases production costs. Simplicity of this type of pasta does not require high energy dryers, water or steam bath or frying during processing [Huber 1998, Wang et al. 1999, Wójtowicz, Moscicki 2000].

Pasta products made by extrusion-cooking are similar to the conventional ones and due to new technological solutions producers can offer high quality, quick cooking or instant pasta products, also with nonconventional raw materials and additives. This type of products are easy to prepare, have a good taste, culinary and dietetic properties and may be of interest for fast foods producers, gastronomy and consumers for preparation of valuable pasta-based dish with soup, sauce or salad. Instant or precooked pasta require up to 5 minutes cooking or only hot water hydration for preparing to consumption [Wójtowicz 2006].

Available research results dedicated a small amount of attention for processing and quality aspects of extrusion-cooked pasta products. The aim of this work was to investigate an influence of legumes addition on process efficiency and energy consumption during the extrusion-cooking of precooked pasta.

MATERIALS AND METHODS

The extrusion-cooking process was carried out with a modified single screw extrusion-cooker type TS-45 (Polish design) equipped with elongated plastification section and additional barrel cooling section before the die. Technical parameters: L/D=16/1, compression ratio 3/1, screw rotation speed regulation from 50 to 130 rpm, forming die head with 12 openings 0.8 mm each.

In the experiments a standard common wheat flour type 450 (Polskie Młyny S.A.) was used, additives were: white bean, pea and lentil grounded to flour, used at 10, 20, 30 i 40% of flour mass in recipes. Raw materials were moistened to 30% of moisture content, mixed and rested for 0.5 hour to homogenise water dispersions onto flour. Prepared mixtures were processed by thermal treatment at the temperature range from 75°C to 96°C with screw speed 70, 90, 110 rpm.

The moisture content of moistened mixtures and products just after extrusion was tested by drying method at 130°C by 1 hour according to PN – 91/A – 74010 in 3 replications.

The process efficiency was measured by products collection after 10 minutes of regular production for each sample at different conditions. The measurements were registered in triple.

Power consumption was measured using standard register connected to extruder’s motor for each recipe and screw speed used. After the consideration of motor load and process efficiency, the SME (specific mechanical energy) values were calculated according to the method described by Ryu i Ng [2001]:

\[
\text{SME} = \frac{\text{rpm (test)} \times \% \text{ motor load} \times \text{motor power (rated)}}{100 \times \text{feed rate}},
\]

where:

The unit of SME is kWh·kg\(^{-1}\), feed rate is process efficiency kg·h\(^{-1}\).
RESULTS

The moisture content of wheat flour used in the experiments was 10.8% and for additives the moisture was specified at the level 13.8% for white bean flour, 12.2% for pea and 13.1% for lentil. After moistening of mixtures, the moisture content ranged from 27.5 to 29.7%. The results are presented in Table 1. The data achieved during the experiments were app. 1% lower than the ones offered by water evaporation during mixing and resting pasta dough before the extrusion-cooking.

The typical single screw extrusion-cooking process for directly expanded products require the moisture content of raw material at the level 10-28%. Higher moistening (25-48%) of raw materials is useful for pellets or pasta products processing [Mościcki et al. 2007]. On the basis of the results presented by Wójtowicz [2001] 30% moisture content was used as the optimal one for this type of pasta products processed with single screw extrusion-cooking.

The moisture content of pasta directly after the forming die ranged from 20.7 to 23.9% as a result of initial mixtures moisture, processing conditions and water evaporation from the pasta surface. Except these, a significant influence of the applied screw speed was observed. Independently on type and amount of additives used, pasta obtained at 70 rpm was characterised by 1-2% higher moisture content than for pasta processed at 110 rpm. Higher screw speed causes higher mechanical shearing, the temperature inside the extruder is growing and final product after the die is strongly dried [Wójtowicz 2001]. The conventional pasta before drying was characterised by the moisture content at 27-28% level [Obuchowski 1997]. The research results performed by Wang et al. [1999] showed a lower moisture content of raw pasta processed by extrusion than the conventional one and amounted to 18 to 23%. The presented results are compared to the previous ones.

Table 1. Results of the moisture content of mixtures and processed pasta directly after the extrusion-cooking.

<table>
<thead>
<tr>
<th>Additive</th>
<th>Moisture content of mixtures [%]</th>
<th>Moisture content of raw pasta [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Additive amount [%]</td>
<td>Additive amount [%]</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>White bean</td>
<td>29,3</td>
<td>29,0</td>
</tr>
<tr>
<td>SD</td>
<td>0,05</td>
<td>0,25</td>
</tr>
<tr>
<td>Pea</td>
<td>29,3</td>
<td>28,9</td>
</tr>
<tr>
<td>SD</td>
<td>0,55</td>
<td>0,25</td>
</tr>
<tr>
<td>Lentil</td>
<td>27,5</td>
<td>27,9</td>
</tr>
<tr>
<td>SD</td>
<td>0,12</td>
<td>0,25</td>
</tr>
</tbody>
</table>

SD – standard deviation
a,b,c – different letters depending on the material’s moisture content show significant mean differences in Duncan test at α=0,05

An application of modified section of extruder equipped with additional cooling system allowed for the maintenance of the process temperature at an established level, not exceeding 100°C, similar to results presented by Wójtowicz [2000] for precooked pasta products made from common wheat flour with different moistening level. In the present research the temperature range was a little modified because of the used additives. Wang et al. [1999] described an application of temperature from 90 to 110°C in twin screw extruder’s sections during the processing of pasta products with legumes addition. During the tests insignificant temperature fluctuations were observed in both extruder sections and at the die, an increase of the temperature ~2 to 5°C was observed with an
increase of the screw speed as an effect of shearing and transmission of mechanical to thermal energy.

The results of process efficiency measurements showed a linear tendency of an increasing capacity accompanying an increase of the screw speed during the extrusion-cooking of pasta products. Similar observations were presented by Wójtowicz [2000] for common wheat pasta depending on the raw materials initial moisture content. At 30% m.c. the process efficiency rated from 11 to 19 kg/h⁻¹.

Fig. 1. The extrusion-cooking process efficiency of precooked pasta with addition of legumes at different screw speed: a – white bean, b – pea, c – lentil
In the present results an influence of legumes addition amount on process efficiency was observed. The highest capacity was observed during the extrusion-cooking of pasta with addition of 10% white bean and 20% of pea in the recipe at 100 rpm processing, the lowest when 20% of additives were used at lowest screw speed (Fig. 1). An increase of legumes amount level up to 20%
in the recipe boosted the capacity. But when 40% addition was applied a small decrease of process efficiency was observed, which may be connected to higher level of proteins and fats in raw materials dating from legumes. This limits the capacity and makes a proper course of the process difficult, especially at low, as for extrusion-cooking, temperatures applied in the tests.

Abecassis et al. [1994] reported that during conventional pasta pressing in a single screw pasta extruder at the temperature not exceeding 50°C and up to 30 rpm, SME reached values from 0.03 to 0.12 kWh·kg⁻¹. Le Roux et al. [1995] achieved the SME values ranging from 0.007-0.034 kWh·kg⁻¹ during conventional durum semolina pasta pressing at 15-30 rpm when the dough moisture content 44-48% was used. In the present results, during the extrusion-cooking of precooked pasta enriched with legumes, a significant influence of screw speed on SME values was observed. With the screw rpm escalation, the specific mechanical energy consumption increased (Fig. 2). Ryu and Ng [2001] have proved higher SME values at higher screw rotational speed during the extrusion-cooking of wheat flour and corn meal, double screw speed escalation has caused almost double SME consumption (from 0.155 to 0.293 kWh·kg⁻¹ in the process of duration of wheat flour at 120°C). An increase of the initial dough moisture content resulted in a significant decrease of the SME (from 0.125 to 0.068 kWh·kg⁻¹ during processing at 160°C). Della Valle et al. [1995] for extruded potato starch reported the SME consumption ranging from 0.107-0.320 kWh·kg⁻¹ depending on the used process conditions and temperature.

Additives used in the experiments and their amount in the recipes also influenced SME. The highest energy consumption was registered for pasta with white bean processing (max. 0.84 kWh·kg⁻¹ at 110 rpm), an amount of additive used in the recipe significantly changed the SME values (Fig. 2a). The lowest SME was observed during the extrusion-cooking of 10% lentil enriched pasta at 70 rpm, it was 0.29 kWh·kg⁻¹. The most aligned and lowest results were found for pasta enriched with pea (Fig. 2b), which characterised the lowest protein content and the highest fat content from among the researched, acting as lubricant, the same as emulsifiers, which facilitated the processing [Sing and Smith 1997, Sing et al. 1998]. At the highest rpm applied, there was recorded an insignificant effect of additives on SME measurements. When white bean and lentil were added to pasta, the similar tendencies of SME changes were observed, but for lentil a bit lower values of the tested parameter appeared. White bean was characterised by the highest protein content, and requires a higher energy consumption for processing by extrusion-cooking [Le Roux et al.1995, Mościcki et al. 1999].

CONCLUSIONS

The obtained results allow for the following conclusions:
1. The moisture content of raw and dry precooked pasta products was approximately 5-7% lower than the conventional one and it guarantees the shelf life stability of final products.
2. Application of thermal processing of wheat flour enriched with legumes ranged from 75-96°C and screw speed at the level of 70-110 rpm allows to keep stable the extrusion-cooking conditions; small fluctuations were observed in the ending barrel section.
3. The process efficiency during the extrusion-cooking of precooked pasta enriched with legumes increased with an increase of screw speed used. An influence of the applied additive and its amount in the recipe on the capacity was observed. The highest process efficiency was reached during the processing of pasta enriched with 10% of lentil at 110 rpm, it amounted to 23.5 kg·h⁻¹, the lowest, 10.5 kg·h⁻¹, was noted when 40% of white bean was added and processed at 70 rpm.
4. The energy consumption during precooked pasta processing by extrusion-cooking was higher than for the traditionally pressed, but lower energy is required for pasta drying. In presented
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results the SME values varied from 0.29 for pasta enriched with 10% of lentil processed at 70 rpm to 0.84 for pasta with 40% of white bean addition extruded at 110 rpm.

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Streszczenie. W pracy przedstawiono wyniki pomiarów wydajności i energochłonności ekstruzji makaronów błyskawicznych wytwarzanych z mąki pszennej typ 450 z dodatkiem mąki z nasion roślin strączkowych. W badaniach zastosowano jako dodatki mąkę z fasoli, grochu oraz soczewicy w ilości 10, 20, 30 i 40% udziału w recepturze. Mieszanki dowilżano do 30% i poddawano ekstruzji w jednoślimakowym zmodyfikowanym ekstruderze TS-45 przy prędkości obrotowej ślimaka 70, 90 i 110 obr∙min⁻¹, w zakresie temperatury 75-96°C, wytwarzając makaron w formie nitek przez matrycję z otworami o średnicy 0,8 mm. W czasie procesu rejestrowano profil temperaturowy, wydajność oraz jednostkowe zapotrzebowanie energii mechanicznej SME w zależności od parametrów ekstruzji i receptury surowcowej. Wydajność procesu ekstruzji podczas wytwarzania makaronów z dodatkiem nasion roślin strączkowych wzrosła wraz ze wzrostem zastosowanych obrotów ślimaka roboczego, zwiększenie udziału strączkowych w recepturze powodowało obniżenie wydajności procesu. Wartości SME wynosiły od 0,29 do 0,84 kWh∙kg⁻¹ i zależne były zarówno od receptury surowcowej, jak i od prędkości wytwarzania makaronów.

Słowa kluczowe: ekstruzja, makaron błyskawiczny, strączkowe, wydajność, SME.