TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11c, 200–207

CHANGES OF SPECIFIC MECHANICAL ENERGY DURING EXTRUSION-COOKING OF POTATO STARCH

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Summary. The simplest method of physical modification of starch is extrusion-cooking. Changes of the extruder efficiency and specific mechanical energy (SME) during extrusion-cooking of potato starch are presented in the paper. Extrusion-cooking process was characterised by good efficiency. The output depended mainly on the extruder screw speed and starch moisture content, less on process temperature. It ranged between the 11.3 kgh^{-1} and 28 kgh^{-1} depending on process parameters. SME measurements showed that extrusion-cooking of potato starch is related with rather low energy input ranged from 0.083 to 0.275 $kWhkg^{-1}$. Significant impact on the values of the SME had a screw speed, very little impact had a moisture content of the raw material.

Key words: potato starch, extrusion-cooking, efficiency, specific mechanical energy.

INTRODUCTION

Extrusion-cooking technique is widely used in food processing for production of various types of food such as snacks, meat analogs, pet food and aquafeed. In general terms, extrusion-cooking of the raw material of plant origin is the extrusion of bulk material under high pressure and high temperature. This causes the significant changes in physical and chemical quality of the processed material. During baro-thermal treatment, material is mixed, compacted, compressed, liquefied and plasticity in the end zone of the extruder. Extrusion pressure can reach up to 20 MPa and temperature of the slurry to 200 °C. The scope of physical and chemical changes in processed raw materials depends mainly on the assumed parameters of the extrusion-cooking process and the construction of the extruder [4, 9, 14, 15].

Native starch is used in different industrial sectors, however, due to some disadvantages (eg. insolubility in cold water), its use is severely limited. Disadvantages of native starch can be reduced or even eliminated, through its modification by various methods [5, 11, 20]. The simplest method of physical modification of starch is thermal or baro-thermal treatment. As a result of heating the grain structure is destroyed and there is a partial starch gelatinization. During this process hydrogen bonds, that stabilize the tertiary and quaternary conformational structure of macromolecules, are disrupted [17]. Various forms of drying, extrusion or high pressure treatment are used for this purpose [1, 8, 11, 20].

Due to environmental considerations native and modified starches are now attracting increased attention as raw materials in the production of biodegradable plastics. Extrusion-cooking technique can be successfully applied for this purpose [6, 16].

MATERIALS AND METHODS

The basic material for investigations was potato starch Superior type produced by the Food Industry Plant "PEPEES" S.A. in Lomza (Poland). Its moisture content was 17%. During our investigations the 4 levels of moisture content of raw material (17, 20, 25 and 30%) were used. In order to obtain expected moisture content, starch was mixed with sufficient amount of water. The obtained samples were stored for 24h in air tight polyethylene bags at room temperature to make whole sample material homogeneous.

Extrusion-cooking of potato starch was carried out using a modified single screw extrusion-cooker TS-45 (Polish design) with L / D = 16. The die with one opening of 3 mm diameter was used. Extrusion-cooking was carried at different temperature (100, 120 and 140 °C), using a variable speed of the screw (60, 80, 100, 120 rpm) [13].

The extruder output was measured as a mass of the extrudate produced during 10 minutes; measurements were performed in 6 replications.

Power consumption measurement was performed with a standard method using wattmeter connected to the extruder electric panel [7, 10, 12, 18, 19]. The obtained results were converted to an index of specific mechanical energy consumption (SME) after the following formula:

$$SME = \frac{n \cdot P \cdot O}{n_m \cdot Q} [kWhkg^{-1}], \quad (1)$$

where: n - screw rotations [min^{-1}],
n_m - maximal screw rotations [min^{-1}],
P - power [kW],
O - engine loading [%],
Q - extruder output [kgh^{-1}].

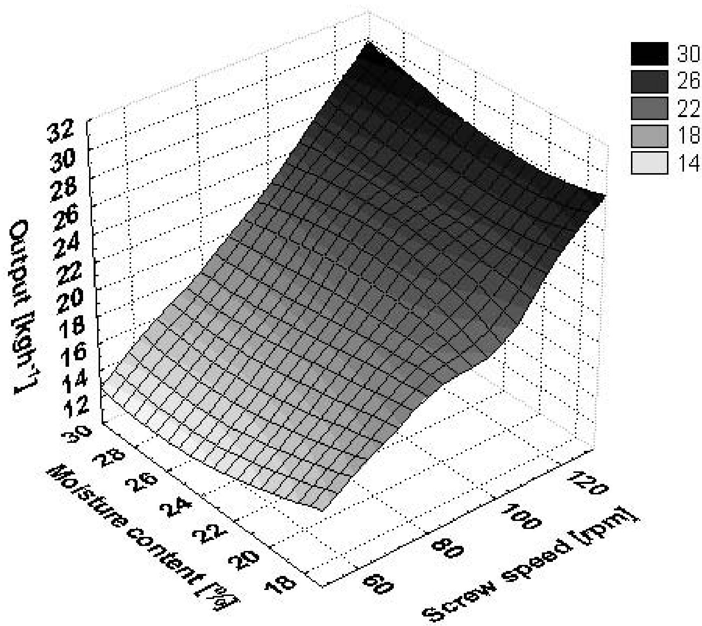

Fig. 1. Changes of the process output during potato starch extrusion-cooking at 100 °C

RESULTS

Extrusion-cooking of the potato starch was characterised by good efficiency, ranged between 11.3 kgh^{-1} and 28 kgh^{-1} dependently of process parameters used. Changes in extruder output depended mainly on the extruder screw speed and starch moisture content, less on process temperature.

During processing potato starch with moisture content ranged from 20% to 30% the higher process temperature caused a decrease of the extrusion-cooking efficiency. Generally we can say that the highest output was recorded at 100 °C with one exception the case when the starch of 17% moisture content was processed. The highest output of 28 kgh^{-1} was observed during extrusion-cooking at 140 °C.

Measurements have shown that the increase of the extruder screw speed increased the efficiency of the extrusion-cooking (fig. 1 and 2). This effect was observed in the whole range of applied temperature.

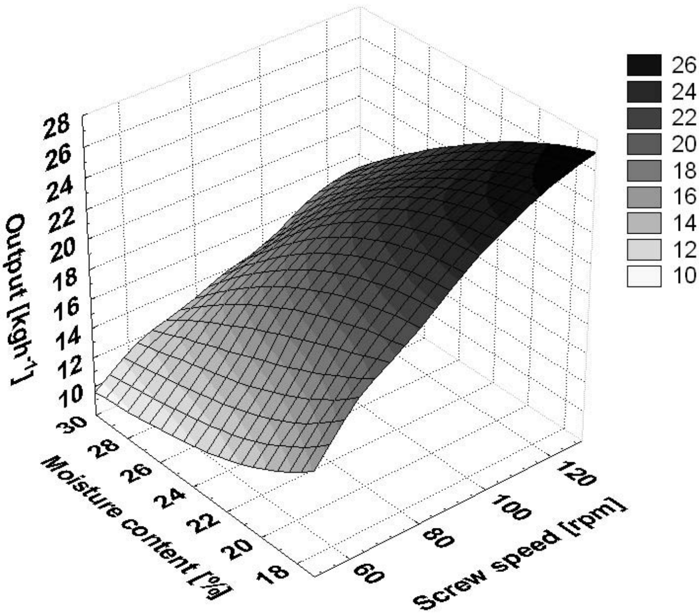

Fig. 2. Changes of the process output during potato starch extrusion-cooking at 120 °C

During processing at 100 °C, an initial decrease and than increase of the process efficiency with increase of starch moisture content was observed. In the course of processing at temperatures: 120 and 140 °C it was found that water addition decreased the extruder capacity (fig. 2).

Application of extrusion cooking technique for plant starch processing needs a very significant factor - determination of specific mechanical energy (SME) necessary to obtain product mass unit. Della Valle et al. [2, 3] processing the potato starch on twin screw extrusion-cooker indicated that SME changed within the interval 0.1 to 0.32 $kWhkg^{-1}$.

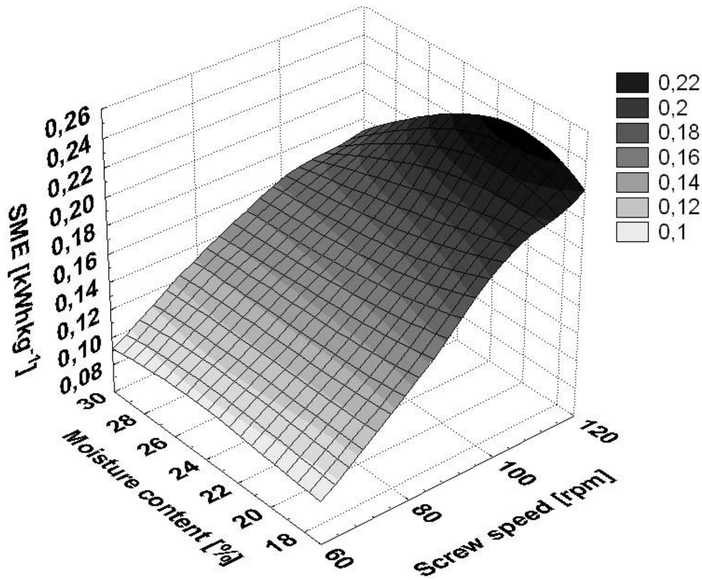

Fig. 3. SME changes during potato starch extrusion-cooking at 100 °C

The present authors' studies showed that the moisture content of the raw material and extruder screw rotation speed exerted a substantial impact on SME during extrusion-cooking of potato starch. The research revealed that the values of SME were within a range 298.8-990 $kJkg^{-1}$ (0.083-0.275 $kWhkg^{-1}$). The lowest energy consumption was observed during the extrusion-cooking of potato starch at 140 °C. The highest SME was recorded during the extrusion-cooking at a temperature of 100 °C (at moisture content of 17 and 20%) and at 120 °C (moisture content 25 and 30%). Screw rotational speed increase caused rise in mechanical energy consumption, independently of the process temperature (fig. 3).

Effect of moisture content on the SME was inconclusive. When carrying out the process at 100 °C with lower screw speed (60-80 rpm) minimal changes in mechanical energy consumption was observed with increase in starch moisture content. Higher moisture content of the starch caused SME decrease when higher screw speed (100-120 rpm) was used. When processed at higher temperature an increase of moisture content of starch increased the rate of the SME (fig. 4). It was most likely caused by increasing of the viscosity of processed slurry. Due to the presence of water the starch melts and underwent liquefaction, resulting in lower glass transition temperature.

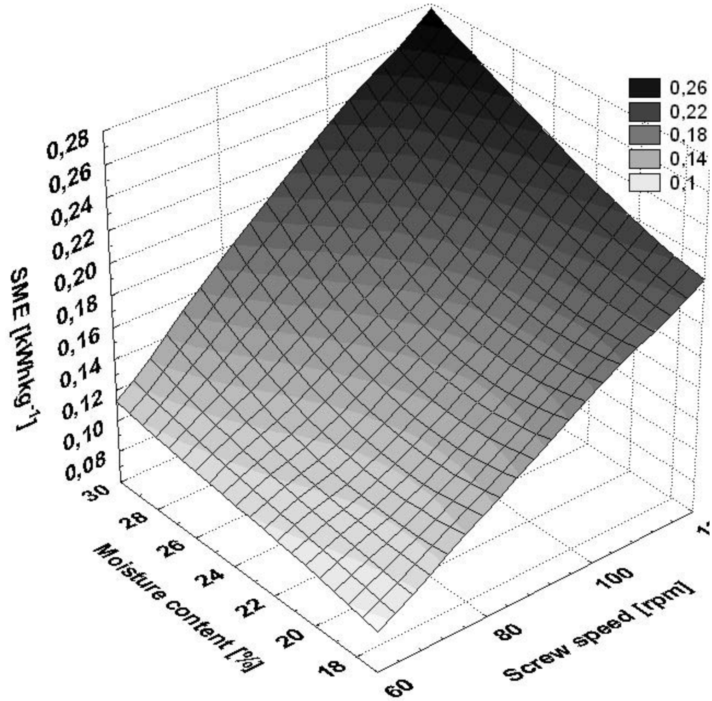

Fig. 4. SME changes during potato starch extrusion-cooking at 120 °C

CONCLUSIONS

Extrusion-cooking process of the potato starch was characterised by good efficiency. It ranged between 11.3 kgh^{-1} and 28 kgh^{-1} dependently of the process parameters.

Changes in the extruder output depended mainly on the extruder screw speed and starch moisture content, less on process temperature.

Modification of starch by extrusion-cooking technique is characterized by relatively low specific mechanical energy consumption a range from 298.8 to 990 kJkg^{-1} (0.083-0.275 kWhkg^{-1}). Significant impact on the values of the SME had a screw speed, very little a moisture content of the raw material.

Acknowledgments

This scientific work was supported by Polish Ministry of Science and Higher Education founds on science in the years 2009-2011 as a research project NN 313065936.

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ZMIANY ENERGOCHŁONNOŚCI PODCZAS EKSTRUZJI SKROBI ZIEMNIACZANEJ

Streszczenie. Najprostszą metodą fizycznej modyfikacji skrobi jest ekstruzja. W pracy przedstawiono wyniki pomiarów wydajności i energochłonności procesu ekstruzji skrobi ziemniaczanej. Proces ekstruzji skrobi ziemniaczanej charakteryzował się wysoką wydajnością. Zmiany wydajności ekstrudera zależały głównie od zmian prędkości obrotowej ślimaka ekstrudera i wilgotności skrobi, w mniejszym stopniu od temperatury procesu. Wydajność zmieniała się w granicach 11.3-28 kgh^{-1} w zależności od zastosowanych parametrów procesu. Wyniki badań wskazują, że procesu ekstruzji skrobi ziemniaczanej związany jest z relatywnie niską energochłonnością (0.083-0.275 $kWhkg^{-1}$). Znaczący wpływ na zmiany SME miała prędkość ślimaka ekstrudera, nieduży wpływ miała wilgotność przetwarzanej skrobi.

Słowa kluczowe: skrobia ziemniaczana, ekstruzja, wydajność, energochłonność.