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Energy consumption during corn starch extrusion-cooking

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Summary. This paper presents the results of energy consumption measurements during extrusion-cooking of corn starch. The extrusion-cooking process was performed using a single screw extruder with L/D = 16 at variable screw speed ranging from 60 to 120 rpm. Native corn starch of varying humidity was used as the raw material. Changes in energy consumption depending on the moisture content, processing temperature, screw speed were measured during testing. Higher screw rpm increased specific mechanical energy. Corn starch with higher moisture content caused a decrease in energy consumption during the extrusion-cooking process. Processing temperature had no important effect on SME changes.
Key words: extrusion-cooking, corn starch, energy consumption.

INTRODUCTION

Extrusion-cooking technology is now one of the modernest grain processing technologies [1, 2, 9]. Currently, extrusion-cooking as a method is used for the manufacture of many food, feed and agrochemical products, ranging from the thermoplastic starch to pasta and aqua feed [10, 12, 13]. Wheat, corn and rice belong to one of the most often applied raw materials in the extrusion-cooking [3, 6].

Native starch has different industrial applications, however, due to many disadvantages (e.g. insolubility in cold water), its use is limited. Disadvantages of native starch can be reduced or even eliminated through its modification by various methods. The simplest method of physical modification of starch is thermal or pressure-thermal treatment. Humidity, temperature, pressure and mechanical shear – under the influence of these factors starch and protein components are plasticized and cooked during the extrusion-cooking, followed by rapid evaporation of the water when extrudates are leaving machine. This leads to further changes in the physical properties of the obtained products. Extrudates can be finished or semi-finished products and are characterized by new, chemical and dietary physical properties [8, 13].

The properties of the extrudates may be affected by many factors related to selecting various parameters of the extrusion-cooking process [5, 7, 14]. These include raw material processing time in the extruder, the intensity of shear stress during extrusion-cooking and the amount of energy supplied to the device [15, 16].

During extrusion-cooking, the primary source of thermal energy is the energy caused by friction forces and therefore derived from the conversion of mechanical energy into heat energy in the processed material. The process, despite popular opinions, is associated with a relatively low expenditure of energy [11]. The single screw extruder-cooker requires energy input in the range of 0.1 to 0.2 kWh (excluding energy required to prepare the raw material).

MATERIALS AND METHODS

Corn starch Meritena 100 type produced by T&L (Slovakia) was used. During our investigations the 4 levels of moisture content of raw material (17, 20, 25 and 30%) were used by mixing with sufficient amount of water. The obtained samples were stored for 24h in air tight polyethylene bags at room temperature to make the 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. Processing was carried at different temperatures (100, 120 and 140 °C) and a variable speed of the screw (60, 80, 100, 120 rpm).

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 [4, 5, 7, 10]. 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}].

RESULTS

Extrusion-cooking of the corn starch was characterised by good efficiency, ranging between 10.8 kgh^{-1} and 26.6 kgh^{-1}, depending on the applied process parameters. Changes in the extruder output depended mainly on the screw speed and starch moisture content, less on the process temperature.

Measurements have shown that the increase of the screw speed increased the efficiency of the extrusion-cooking (Fig. 1). This effect was observed in the whole range of applied temperatures.

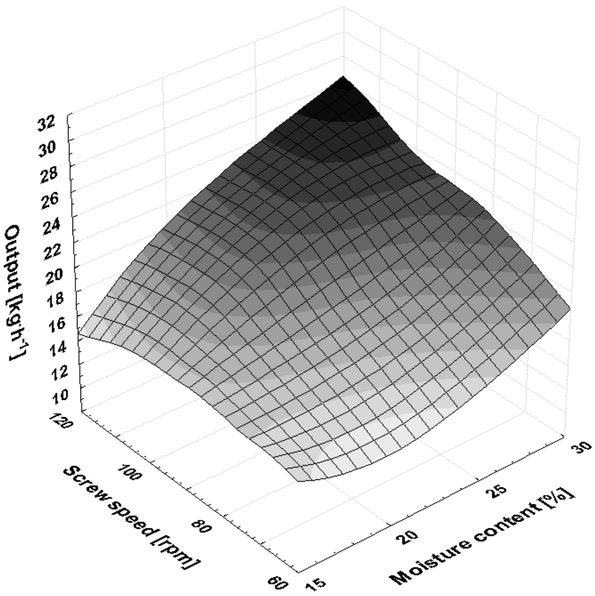

Fig. 1. Changes in the process output during corn starch extrusion-cooking at 100 °C

The extrusion-cooking of the corn starch with 17% of moisture content was hampered, especially at temperature of 140 °C. It was manifested by uneven flow of the material through the extrusion-cooker. During processing at all used temperatures, an increase of the process efficiency with increase of starch moisture content was observed.

Generally, extrusion-cooking of the corn starch was characterised by low energy consumption (SME) within a range 0,08-0,29 $kWhkg^{-1}$ (288-1044 $kJkg^{-1}$). Changes in SME depended mainly on the extruder screw speed and starch moisture content, less on process temperature.

A significant impact of the screw speed on the SME changes during corn starch processing was observed. The screw rotational speed increase caused a rise in mechanical energy consumption, independently of the process temperature (Fig. 2 and 3).

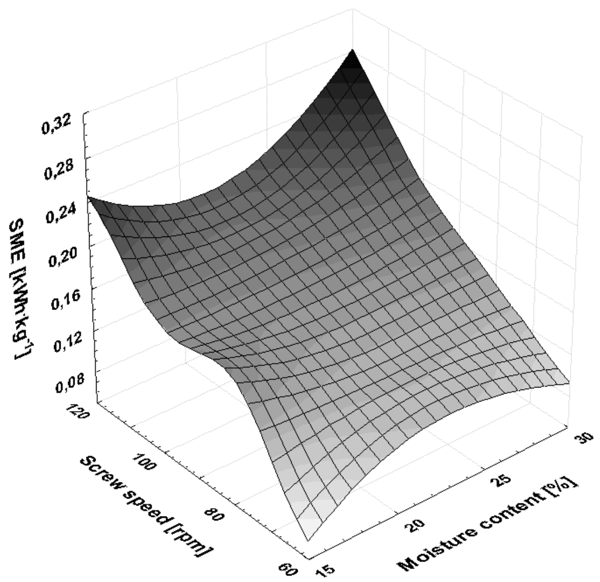

Fig. 2. SME changes during corn starch extrusion-cooking at 120°C

At a higher temperature, the influence of moisture content in the raw material on the process energy consumption was inconclusive. During the extrusion-cooking at 120 and 140 °C conducted with low screw speed range (60 and 80 rpm), the influence of moisture content on SME was neutral. The increase of energy consumption with raw material moisture content growth was only observed for a high screw speed range (100-120rpm).

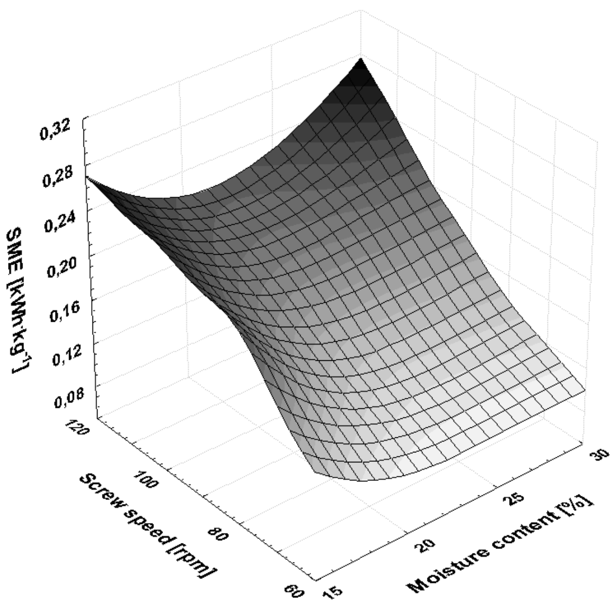

Fig. 3. SME changes during corn starch extrusion-cooking at 140°C

Generally, it can be stated that the temperature of extrusion-cooking had no significant effect on the energy consumption changes.

CONCLUSIONS

Extrusion-cooking of corn starch is characterized by relatively low specific mechanical energy consumption, ranging from 288 to 1044 $kJkg^{-1}$ (0,08-0,29 $kWhkg^{-1}$). A significant impact on the SME was exerted by the screw speed and moisture content of the raw material. The process temperature had a neutral impact on energy consumption changes.

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ENERGOCHŁONNOŚĆ PROCESU EKSTRUZJI SKROBII KUKURYDZIANEJ

Streszczenie. W pracy przedstawiono wyniki pomiarów energochłonności procesu ekstruzji skrobi kukurydzianej. Proces ekstruzji przeprowadzono na ekstruderze jednoślimakowym o L/D=16 przy zmiennych obrotach ślimaka w zakresie 60 – 120 obr×min-1. W badaniach zastosowano skrobię kukurydzianą o zróżnicowanej wilgotności. W trakcie prowadzonych badań odnotowano zmiany energochłonności procesu ekstruzji w zależności od wilgotności surowca, obrotów ślimaka ekstrudera i temperatury obróbki. Wzrost prędkości obrotowej ślimaka ekstrudera przyczyniał się do wzrostu energochłonność procesu ekstruzji. Zastosowanie skrobi kukurydzianej o wyższej wilgotności skutkowało obniżeniem energochłonności procesu ekstruzji. Temperatura procesu nie miała istotnego wpływu na zmiany SME podczas przetwarzania skrobi kukurydzianej.

Słowa kluczowe: ekstruzja, skrobia kukurydziana, energochłonność.