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THE INFLUENCE OF EXTRUDER'S TEMPERATURE PROFILE ON THE CHARACTERISTICS OF PROCESSED STARCH

Summary

The study concerned the influence of extruder's temperature profile on physico-chemical characteristics of processed cereal starches. The products obtained at higher temperature were more expanded and less dense, however there were differences in response of various starches on the change of processing parameters. Solubility and water binding capacity of extruded corn starch strongly depended on thermal conditions in extruder while in case of rye and triticale no significant relation was observed.

Introduction

During extrusion cooking starch is being transformed by mechanical and thermal energy [1, 2]. The extent of physico-chemical changes occuring under extrusion depends on process parameters i.e. temperature, screw configuration and speed [1, 3, 12]. It also depends on moisture content in a raw material [1, 2, 3, 12].

Optimal values of these parameters, especially temperature and moisture content, depend on starch chemical characteristics such as amylose content [3, 4], that influence physical (and mainly rheological) parameters of starch melt inside extruder.

Although the relation between extrusion temperature and physico-chemical properties of extruded starch has been well documented, there are few reports comparing the behaviour of various starch sources under the same extrusion conditions. To check the differences corn, rye and triticale starch were examined.

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Material and methods

Commercial corn starch was obtained from Diacel (corn). Triticale, and rye starch were isolated by laboratory method [14]. Prior to extrusions moisture content of starch samples was adjusted to 16%. Extrusion was performed by using single screw laboratory extruder Brabender 20DN working at 210 rpm. Compression ration was 4:1 and die diameter 3 mm. High temperature (HT) experiments were done by maintaining 140, 160 and 170°C in subsequent extruder's sections. Low temperature (LT) profile was 95, 120 and 150°C.

Expansion ratio and density were measured according to Ryu and Walker [16]. Each mean was an average of ten replications. After milling in a laboratory roller mill the extruded starch samples were subjected to following analyses. Total phosphorus content by Marsh [9] method (standard deviation: $s_x = 0.93$, coefficient of variation: $v_x = 2.23\%$) and amylose content by Morrison and Laingnelet method [11] ($s_x = 0.44$, $v_x = 1.7\%$). Water binding capacity (at 60°C $s_x = 0.14$, $v_x = 2.5\%$; at 90°C $s_x = 1.0$, $v_x = 5.4\%$) and solubility (at 60°C $s_x = 0.26$, $v_x = 5.0\%$; at 90°C $s_x = 0.29$, $v_x = 2.5\%$) were measured by Richter [14] method modified for extrudates [18]. Molecular characteristics of native and extruded starch was obtained by means of size exclusion chromatography [13, 18]. All measurements were done twice.

Results and discussion

The quality of products obtained by extrusion depends on processing temperature. Chinnaswamy and Hanna [4] report, that maximal expansion occurs for corn starch samples over 125°C, depending on amylose content. They have also observed that 50% of amylose in sample is optimal for the product quality.

Triticale and rye starch samples extruded at higher temperature exhibited higher expansion and lower density in comparison to LT samples (fig. 1). In this aspect cereal starches seem to be different from potato starch, in which case the density of extrudates was higher when barrel temperature was elevated [8].

In order to compare extruded starches with native ones, they were milled and examined in a similar way. To eliminate the influence of variability in natural starch characteristics, the quotients of values measured for extruded and native starch were used.

Fig. 2 represents the change in apparent amylose content upon extrusion. In our previous study [7] significantly enlarged amount of unbranched potato starch constituents has been observed after extrusion. This increase is related to mechanical disruption of glycosidic bonds in amylopectin, which results in its partial debranching and release of linear glucans [5, 6]. However, in the present study such pattern has been observed only in case of corn starch. No substantial trends in this aspect has been found for HT and LT samples.

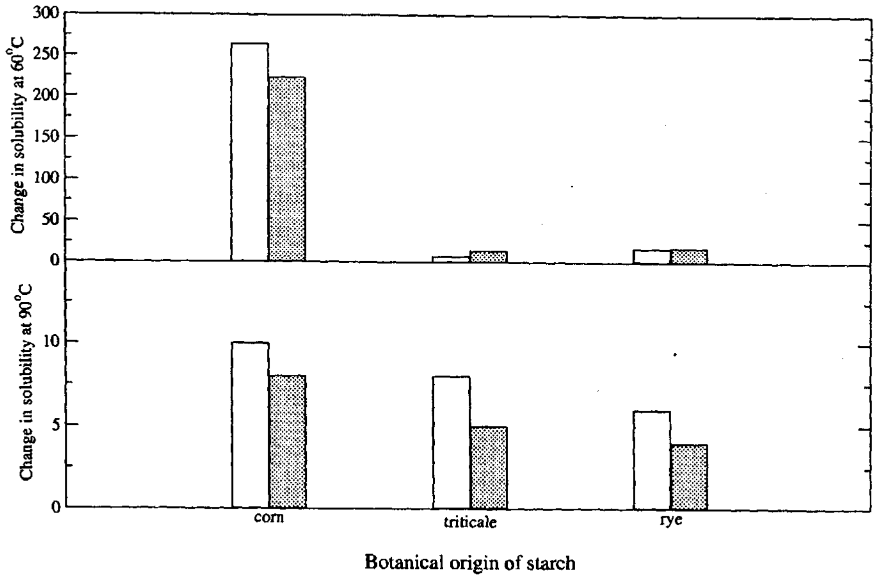

Fig. 1. Dependance of degree of expansion and density of starch extrudates on extrusion temperature (white - 140, 160, 170°C, gray - 95, 120, 150°C)

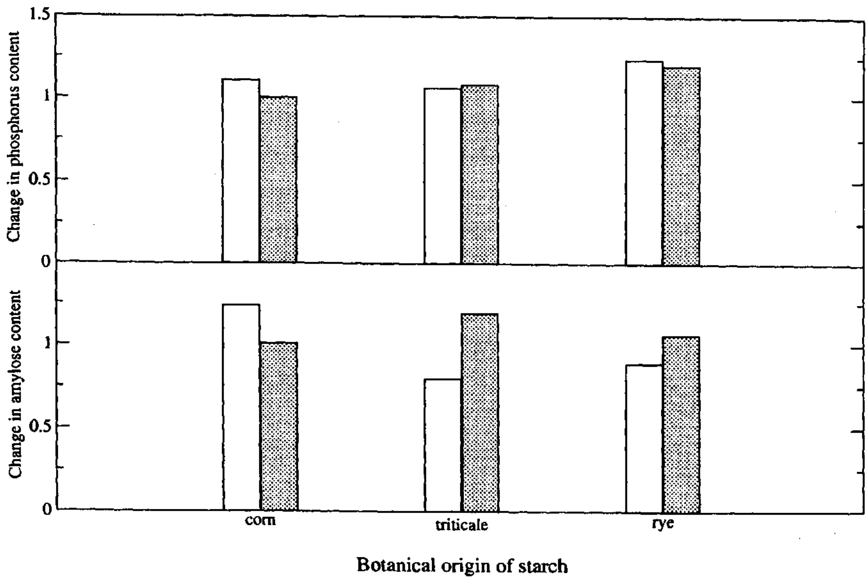

Fig. 2. Apparent changes in amylose and phosphorus content after extrusion at different thermal conditions (white - 140, 160, 170°C, gray - 95, 120, 150°C)

As it is well known, the phosphorus is present in cereal starches mainly in fat fraction consisting of lysophospholipids. As it was expected, the samples extruded in different conditions did not differ in this aspect (fig. 2). The slight aberrance from 1 observed in case of rye starch should not be considered as a real increase in phosphorus after extrusion, but is probably due to the different drying behaviour of native and extruded starch, which can result in varying dry mass of the samples.

Although under the applied process parameters only 1–2% of glycosidic bonds can be broken [15], and branching points are only a small part of them, the observed decrease in weight average molecular weight of starch and mainly its branched component is dramatic [18]. However it seems that such degradation is relatively independent on the applied temperature in the studied range (tab. 1).

Table 1

Weight average molecular weight of amylopectin present in starch samples extruded at different temperatures (HT - 140, 160, 170°C, LT - 95, 120, 150°C).

Starch origin	M_w of amylopectin [x10^6 g/mol]	
	LT	HT
Corn	2	1.7
Triticale	2	2.2
Rye	1.9	2

Mercier and Feillet [10] denote that corn, wheat and rice starches extruded at 180°C can absorbe maximum amounts of water. Our results (fig. 3) are in agreement with those findings. Water binding capacity at 60°C of HT starches was higher than of LT ones, although a pronounced effect was observed only in case of corn starch. At 90°C no such trend could be observed, probably due to excessive solubilisation of starch samples.

Solubility of extruded starch at 60°C was an order of magnitude higher than of native samples (fig. 4). This effect was especially visible in case of corn starch, which in native form is less soluble than other cereal starches [17]. Higher temperature of extrusion gave products more soluble in water at 90°C, which is in accordance with the results of Mercier and Feillet [10].

The results prove that extrusion temperature is an important parameter in starch processing and influences many important parameters of the obtained product. The extent of thermal effects depends however on starch origin.

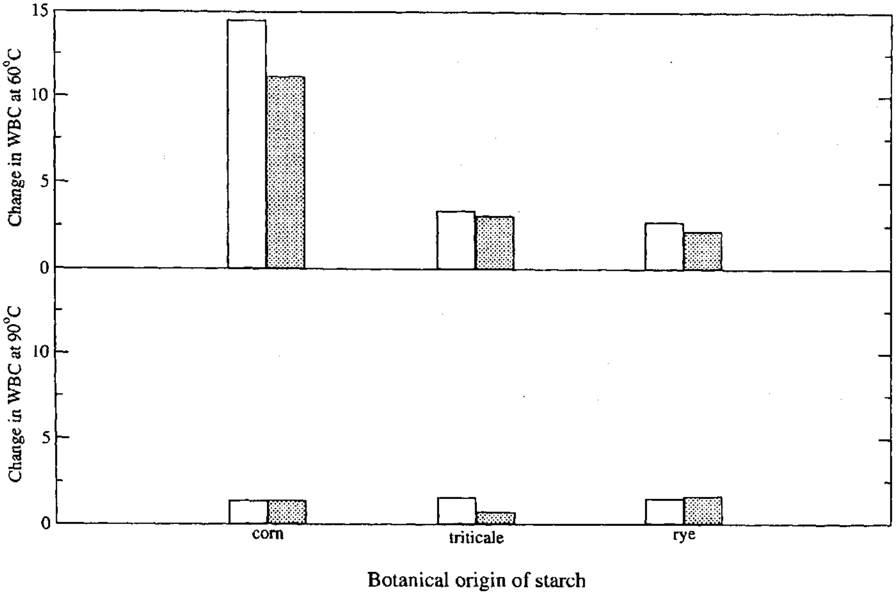

Fig. 3. Change in water binding capacity of starch samples after extrusion at different thermal conditions (white - 140, 160, 170°C, gray - 95, 120, 150°C)

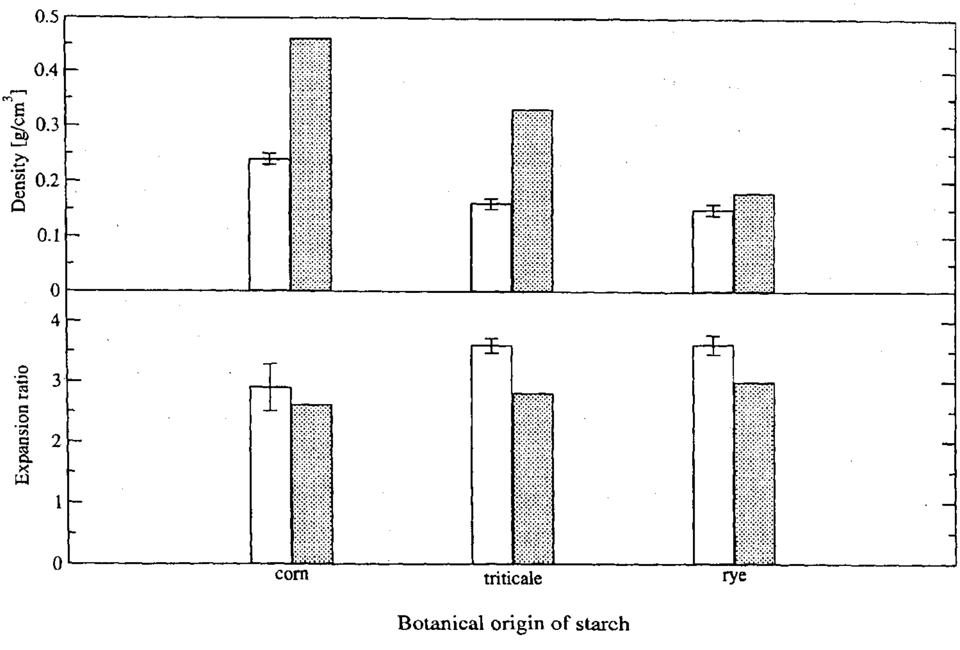

Fig. 4. Change in solubility of starch samples after extrusion at different thermal conditions (white - 140, 160, 170°C, gray - 95, 120, 150°C)

Conclusions

1. Products obtained at lower temperatures had lower expansion ratio and higher desity in comparison to those produced at high temperature.
2. The use of different temperature did not significantly influence total phosporus, irrespective of starch origin. The change in apparent amylose content was different for various samples.
3. The use of higher temperature resulted in higher water binding capacity and solubility at 60°C.
4. Weight average molecular mass of starch extrudates calculated from SEC profiles did not considerably change with different processing conditions.

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WPŁYW TEMPERATURY PROCESU NA WŁAŚCIWOŚCI EKSTRUDOWANYCH SKROBI

S t r e s z c z e n i e

W pacy przebadano fizycznochemiczne i molekularne właściwości skrobi kukurydzianej, pszenżytniej i żytniej poddanej procesowi ekstruzji w jednoślimakowym ekstruderze w temperaturze 140-160-170°C, jak również w (80-95)-120-150°C. Produkty otrzymane w niższej temperaturze charakteryzowały się mniejszą ekspansją i większą gęstością. Ponadto ekstrudowana skrobia kukurydziana, uzyskana w niższej temperaturze, charakteryzowała się mniejszą zdolnością wiązania wody i rozpuszczalnością w wodzie, w porównaniu do otrzymanej w wyższej temperaturze.