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SUSCEPTIBILITY OF STARCH FROM VARIOUS BIOLOGICAL SOURCES ON DEGRADATION DUE TO EXTRUSION PROCESS

Abstract

In order to evaluate the importance of biological source in starch extrusion we processed wheat, rye, triticale, oat, corn and potato starch in a single screw extruder and compared the products. They varied mainly in hardness, density, solubility and water binding capacity. On the other hand, molecular weights and paste properties of the extruded starches showed a low dependence on the type of raw material.

Introduction

There are several important factors which influence the properties of starch extrudates. The type of an extruder (single or twin-screw), screw geometry and configuration provide a specific mechanical energy. Moisture content of the raw material (usually 10–30% wet basis) [1] regulates the ratio of melting and gelatinization of starch granules which take place simultaneously at high temperatures set in barrel sections. It has also an impact on viscosity of the melt being formed in the extruder barrel and therefore it is responsible for the extent of molecular degradation caused mainly by a mechanical shear [11]. Generally, it is hard to predict which of these factors will play a decisive role in a given situation [5], but all of them could be relatively well controlled.

However, some parameters which could influence an extrusion process are much more difficult to handle. It concerns physical and chemical properties. The proper selection of a starch source is therefore of great importance for obtaining a good product.

Amylose content is the main factor in determining starch susceptibility to extrusion [2], but it is not clear whether it is due only to the differences in molecular mass between amylose and amylopectin, but also to the presence of 1-6 glycosidic bonds in

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amylopectin. Moreover, amylose and amylopectin from different plants are not identical. Besides, other starch features such as crystalline structure, content of integral lipids and inorganic components also depend on botanical source. Thus, it would be reasonable to estimate the influence of these features on the important properties of the extruded products such as expansion ratio, density, textural properties, water solubility and water binding capacity and the behaviour of pastes.

In order to evaluate the importance of a starch source on extrudate properties we compared wheat, rye, triticale, oat and corn starch processed under the same conditions.

Materials and methods

The extrusion was performed in a single screw extruder (Brabender 20 DN). Water content in the material was adjusted before the extrusion to either 16% or 24% on a dry basis. The temperatures of 3 barrel sections were 80, 120 and 150°C and a screw speed was maintained at 210 rpm. The hardness, density and expansion ratios were measured for the obtained products, as it was described before [4]. After milling the extrudates the measurements of phosphorus content [6], water solubility, water binding capacity and viscosity were performed. Solubility and water binding capacity of the extrudates, measured in a standard way as for native starch [9] were unreliable. For this reason the method was modified and the sample was dissolved in the form of a homogenous dispersion. The method of Morrison and Laignelet [7] was modified to measure an apparent content of amylose in 5 ml fractions obtained by size exclusion chromatography [12] and these values were used to calculate a molecular weight distribution of the amylose and the amylopectin present in the samples, basing on the pullulan calibration. To measure paste properties we prepared dispersions in cold water and heated them up rapidly allowing to boil for 5 minutes. The flowcurves $\tau(\gamma)$ at a constant shear stress were measured using a Rheolab MC 1 rotational rheometer with a standard measuring system DIN 53019. After cooling the pastes to 20°C. The parameters n and K were calculated using the Ostwald model.

Results

The extrudates prepared at different moisture contents varied much in hardness, expansion and density (table 1.) as we reported before [4]. The expansion was lower for the samples extruded at 24% of water in the raw material. As expected these samples had a higher density and hardness (for potato this parameter was out of the measurement range), their solubility was lower at 30°C while at higher temperatures they became the same, or even more soluble (fig. 1). The results clearly show that there is no simple relation between expansion and solubility. The highly expanded (and presumably more degraded) starches have more components, which are water soluble at a low temperature, but while heating it becomes less important and at 90°C solubility of the starch extruded at 24% of moisture is almost the same or even higher (potato). Water binding capacity was higher for the samples with a higher initial water content, which is believed to be more gelatinized and less melted. As for potato starch extrudates, which were almost completely dissolved at 60°C, water binding capacity could not be measured (fig. 2).

Table 1

Physical characteristics of corn, wheat and potato starch, extruded at different moisture levels.

Origin of starch	water content in a raw material	Hardness	Expansion ratio	Density
Wheat	16	36	3.5	0.12
	24	90	2.9	0.28
Corn	16	51	3.2	0.23
	24	93	3.1	0.30
Potato	16	150	3.1	0.32
	24	out of range	1.7	0.52

Table 2

Physical characteristics of starches from various botanical sources extruded at 16% of moisture.

Starch origin	Hardness	Expansion	Density
Wheat	36	3.5	0.12
Rye	98	2.8	0.18
Triticale	77	2.8	0.33
Oat	70	2.9	0.18
Corn	51	3.2	0.23
Potato	151	3.1	0.32

Better textural parameters were obtained for the starches extruded at 16% water content, so they were chosen for further studies. Physical properties of the samples, are shown in table 2. It is worth to noticing that the expansion of the product does not correlate with density and hardness, but under these conditions (which we suppose are close to optimal) it is comparable for all the studied starches. Some dependence could be observed between hardness and density, but it needs a larger data set to be proved.

In all the extruded starches, especially oat one, phosphorus content was higher than in native ones (table 3), which suggests some inadequacy of the method. Perhaps, to some extent, it could be due to the loss of the chemically combined water from the starch granules during extrusion, which would reduce dry mass the samples. This seems likely, because similar effects of extrusion on mineral components content were already reported [10].

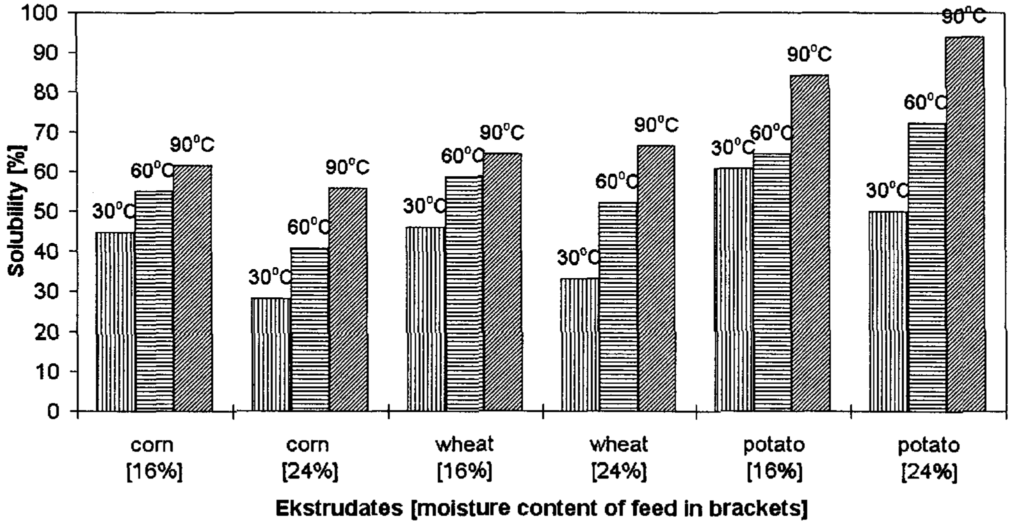

Fig. 1. Solubility of starch extrudates obtained at different moisture levels.

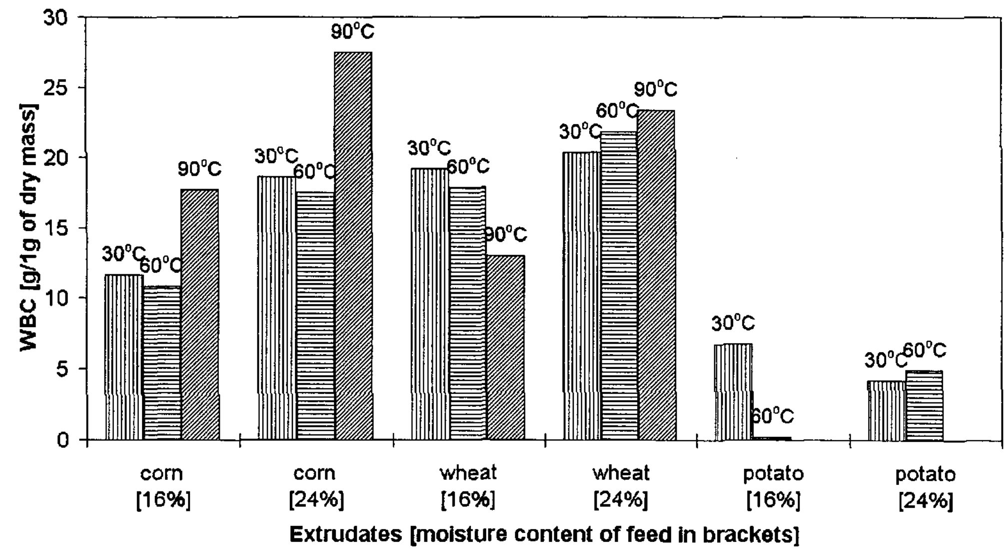

Fig. 2. Water binding capacity of starch extrudates obtained at different moisture levels.

Wheat, rye and triticale starch extrudates did not differ significantly in their solubility but lower values were measured for oat and corn starches. All the extrudates were much more soluble, than native starches, especially at low temperatures (fig. 3).

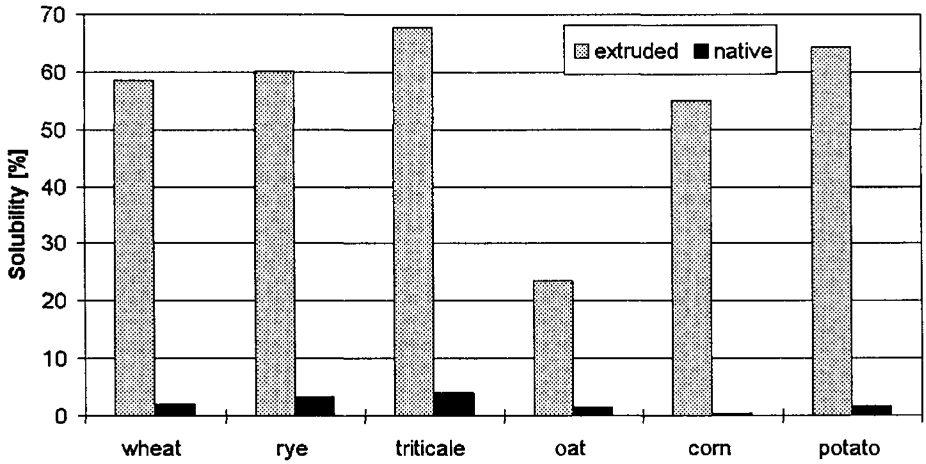

Fig. 3. Solubility of starch extrudates of different botanical origin obtained at 16% moisture content.

Table 3

Phosphorus content in native and extruded starches.

Starch type	Phosphorus content [mg %]		
	native	extruded	
		16 %	24 %
Rye	30	36	-
Triticale	47	51	-
Oat	80	101	-
Wheat	64	59	60
Corn	19	21	22
Potato	68	70	79

The obtained amylose content was confirmed by many other experiments. However, we obtained a bimodal distribution of iodine-stained glucans, as previously reported by Chinnaswamy and his colleagues [3]. While accepting the view of these authors that some part of amylopectin can give blue complexes, we did not try to separate this fraction from the apparent amylose. The results of weight-average molecular weights of the branched fraction present in native starches were similar (table 4) and lower, than the usually reported data. We believe this is due to a few reasons: the insufficient separation in this range of glucan sizes, the use of the pullulan calibration, and last, but not least the described method of amylose/amylopectin signal separation, which gave wide distributions of these glucans. Potato, corn and rye starches had slightly higher masses than the other ones. The extrusion at the described conditions caused in all the cases significant reduction of molecular weight of amylopectin, but smaller of amylose which is in agreement with the reports of Politz et al. [8].

Table 4

Molecular characteristics of native and extruded starches.

Origin of starch	Amylose content[%]		M_w of amylose [$\times10^6$]		M_w of amylopectin [$\times10^6$]	
	native	extruded	native	extruded	native	extruded
Corn	22.5	18.6	1.8	1.1	8.3	3.7
Wheat	18.9	18.0	1.5	0.7	6.4	3.6
Rye	24.6	19.5	1.1	1.4	8.3	3.5
Oat	16.5	17.9	2.0	1.2	6.7	4.7
Triticale	23.3	21.2	2.0	2.0	7.8	4.3
Potato	27.6	22.4	2.3	2.2	9.2	4.1

Table 5

Ostwald model constants n and K for 3% pastes of native and extruded starches.

Starch origin	Native		Extruded starch	
	K	n	K	n
Wheat	0.08	0.77	0.003	1.23
Corn	0.87	0.44	0.014	1.04
Triticale	0.59	0.54	0.005	1.13
Rye	0.01	1.03	0.006	1.13
Oat	1.76	0.46	0.003	1.21

Native starches varied significantly in their paste properties. The Ostwald model constants n ranged from 0.4 to 1 (table 5.). The structural degradation caused by extrusion was reflected by these values. In all cases n value was close to 1, which is characteristic for Newton type fluids. The loss of structural viscosity was reflected in a dramatic decrease of K values.

Conclusions

The most important differences between the extrudated starches from different botanical sources are: hardness, density, solubility and water binding capacity. All these properties are also affected by the extrusion parameters, so it seems possible to optimize them for special purposes.

On the other hand, molecular weights and gel properties of the extruded starches are not so much different, as not to be used interchangeably for many applications.

REFERENCES

[1] Chinnaswamy R.: Basis of cereal starch expansion, Carbohydrate Polymers, **21**, 1993, 157.

[2] Chinnaswamy R., Hanna M.A.: Relationship between amylose content and extrusion-expansion properties of corn starches, Cereal Chem., **65** (2), 1983, 138.

[3] Chinnaswamy R., Hanna M.A., Zobel H.F.: Microstructural, physicochemical, and molecular changes in extrusion-cooked and retrograded corn starch, Cereal Foods World, **34** (5), 1989, 415.

[4] Gambuś H., Golachowski A., Bala-Piasek A., Ziobro R., Nowotna A., Surówka K.: Functional properties of starch extrudates. Part I. Dependance of extrudates properties on starch water content, Electronic Journal of Polish Agricultural Universities, Volume 2, Issue 2, series Food Science and Technology, 1999.

[5] Lai L.S., Kokini J.L.: Physicochemical changes and rheological properties of starch during extrusion (A Review), Biotechnol. Prog., **7**, 1991, 251.

[6] Marsh B.B.: The estimation of inorganic phosphate in the presence of adenosine triphosphate. Biochim. Biophys. Acta, **32**, 1959, 357.

[7] Morrison W.S., Laignelet B.: An improved colorimetric procedure for determining apparent and total amylose in cereal and other starches. J. Cereal Sci., **1**, 1983, 9.

[8] Politz M.L., Timpa J.D., Wasserman B.P.: Quantitative measurement of extrusion induced starch fragmentation products in maize flour using nonaqueous automated gel-permeation chromatography, Cereal Chem., **71** (6), 1994, 532.

[9] Richter M., Augustat S., Schierbaum F.: Ausgewählte Methoden der Stäekechemie. VEB Fachbuch verlag, Leibzig, 1968, 53.

[10] Śmietana Z., Szpendowski J., Soral-Śmietana M., Świgoń J.: Skrobia ziemniaczana ekstruzyjnie modyfikowana, Przemysł Spożywczy, **3**, 1997, 13.

[11] Zheng X., Wang S.S.: Shear induced conversion during extrusion, J. Food Sci., **59** (5), 1994, 1137.

[12] Ziobro R., Gambuś H., Nowotna A., Bala-Piasek A., Sabat R.: Starch extrudates as a source of low molecular dextrins slowing down bread staling, Żywność. Technologia. Jakość, **4** (17), 1998, 251.

PODATNOŚĆ SKROBI RÓŻNEGO POCHODZENIA BOTANICZNEGO NA DEGRADACJĘ SPOWODOWANĄ PROCESEM ELESTRUZJI

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

W celu określenia istotności związku pochodzenia botanicznego a ekstruzją skrobi, procesowi temu (w jednoślimakowym ekstruderze laboratoryjnym) poddane zostały informacje skrobie pszenna, żytnia, pszenżytnia, owsiana, kukurydziana i ziemniaczana. Największe różnice zaobserwowano w twardości, gęstości, rozpuszczalności i wiązaniu wody uzyskanych produktów. Wszystkie te cechy zależały w znacznym stopniu od parametrów ekstruzji. Z drugiej strony masy cząsteczkowe i właściwości kleików ekstrudowanych skrobi wykazywały niską zależność od rodzaju surowca.