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FUNCTIONAL PROPERTIES OF STARCH EXTRUDATES. PART I. DEPENDENCE OF EXTRUDATES PROPERTIES ON STARCH WATER CONTENT

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ABSTRACT

Starches such as potato, corn and wheat with 16 and 24% of moisture content were extruded in a single-screw extruder. Moisture content determines extruded starch properties. Extrudates from starch with a lower moisture content (16%) are characterized by lower density, higher expansion ratio, lower hardness and force used for crumbling as well as lower water binding capacity and higher solubility in comparison with extrudates from starch with a higher moisture content (24%).

Key words: extruded starches: corn, wheat, potato, physico-chemical properties

INTRODUCTION

Extrusion causes breaking of starch granular structure, changes in spatial arrangement of carbohydrate chains, changes in a degree of crystallization and sorption as well as rheological properties [Smietana and Szpendowski 1997]. Starch in extrusion process loses its inherent crystalline structure, is submitted to partial molecular degradation, and passes into gel phase [Colonna et al. 1987, Chiang and Jonson 1977]. The degree of pasting is dependent on a kind of substance, water content and parameters of extruder work, mainly temperature. The extent of gelatinization increases with increased moisture, as well as with an increase in temperature but only when the parameters of screw are proper [Owotsu-Ansah et al. 1983]. Wang et al. [1993] showed that at 15% of moisture prior to extrusion pasting is possible only in 11.4%. The remaining 88.6% may undergo melting when the amount of energy is sufficient enough for this conversion. The same authors emphasize that in starches extruded from cereal products phenomenon of binary coexisting of two structures occurs: gel and melt phase. The texture of extruded products is formed from those structures at the same time, but the proportion of those phases is controlled by water content in the system before extrusion as well as by an amount of energy indispensable for thermal decomposition of granular starch. The aim of the study, then was to investigate the texture and some physico-chemical starch extrudate properties, depending on water content of material prior to the process.

MATERIALS AND METHODS

The materials for investigation were native starches: wheat, corn and potato with 16 and 24% water content. Starches were subjected to extrusion in a single-screw labor extruder Laborextruder type 20DN produced by Brabender, using the following parameters: temperature in sections: - 80, 120 and 150°C, screw speed 210 rpm and diameter of die 3 mm.

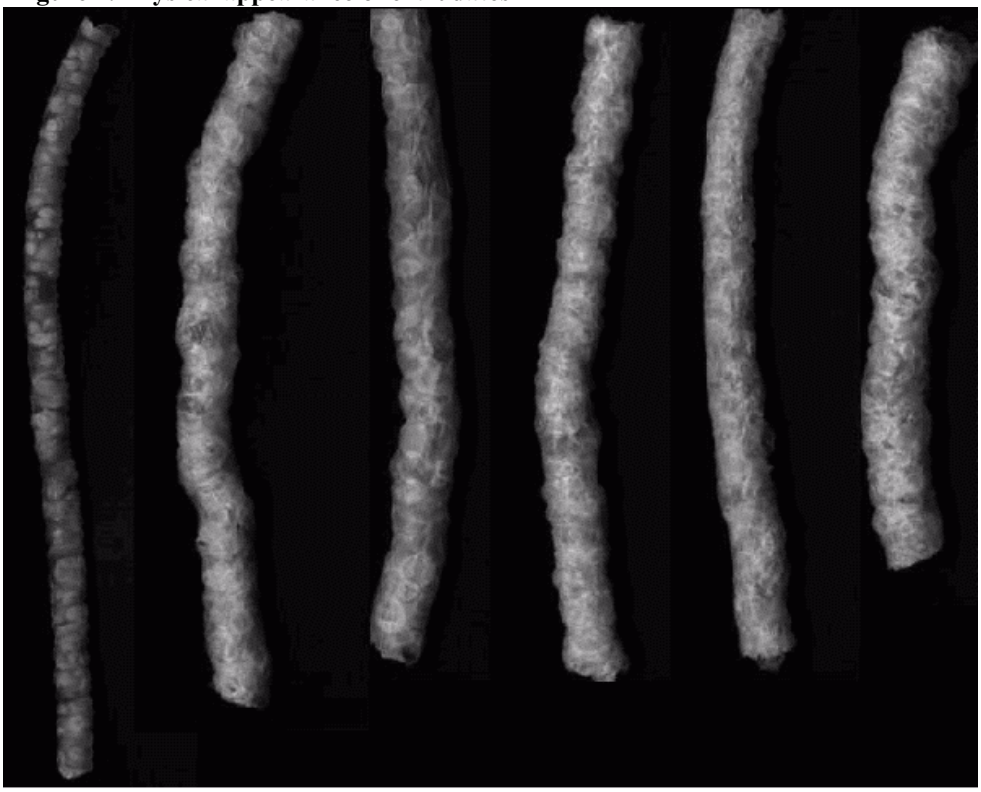
The ratio of expansion and bulk density [Ryu and Walker 1995], as well as texture parameters for final extrudates were checked by means of texture analyser TA XT2 produced by Stable Micro Systems, linked with a computer equipped with program XT.RA. Dimension v.3.7.

Extrudates milled in a laboratory roller mill were subjected to the following analyses: total phosphorus content by Marsh [1959] method and amylose content by Morrison and Laignelet method [1983] as well as water binding capacity and solubility by Richter method [1968] and were compared with properties of native starches.

RESULTS

The results of investigation are presented in Tables 1-4 whereas physical appearance of extrudates is shown in Fig.1. With all other extrusion conditions, starches with least water content (16%) show higher expansion ratio (Table 1, Fig. 1), as compared to those with a higher water content (24%). Since expansion is the function of the amount of shear force delivered during this process, a low water content caused great shear of extruded starch. As a result, the final product is more expanded, which is in agreement with earlier investigation [Davidson et al. 1984, Chinnaswamy and Hanna 1988a,b]. This also inclines to support a thesis, that the moisture of starch influences the degree of expansion of starch extrudates more than temperature [Sokhey et al. 1994, Chinnaswamy and Hanna 1988a,b]. Chinnaswamy and Hanna [1988a] estabilished the optimal humidification of raw material at 13-14% water content to get maximum expansion.

Figure 1. Physical appearance of extrudates



P-24 P-16 C-24 C-16 W-24 W-16

P-16, P-24- obtained from potato starch with 16 and 24 % moisture content
C-16, C-24- obtained from corn starch with 16 and 24 % moisture content
W-16, W-24- obtained from wheat starch with 16 and 24 % moisture content

Table 1. Properties of starch extrudate

Kind of starch extrudate	Expansion ratio [mm]		Density [g/cm^3]	
	16% water	24% water	16% water	24% water
Corn	3.23	3.08	0.23	0.30
Wheat	3.50	2.90	0.12	0.28
Potato	3.12	-	0.32	-

With a higher expansion ratio a lower extrudate density is connected which can be seen in Table 1. Texture parameters of extruded starches were evaluated by investigating their resistance to shear (by measuring shear force and work) as well as compression by measuring the work of compression, brittleness and hardness. According to data in Table 2, the moisture of initial material significantly influences the texture parameters of final products. Extrudates from starch with a lower water content (16%) are characterized by lower hardness and lower force needed for crumbling as compared with extrudates from starches with a higher water content (24%). This effect was probably influenced by higher expansion, as well as lower share of gel rather than melted phase in extrudate made from lower moisture starches. It is common knowlege that starch extrudate texture is dependent on proportion between those two phases [Wang et al. 1993]. Lower hardness and higher brittleness of extrudate is connected with smaller force and work used during its shearing, which simultaneously confirms a more delicate structure of extrudate made from starch with a lower water content. It is worth

emphasizing, that we succeeded in obtaining a final product (by) using starch alone without any plastificators. This was possible thanks to the selection of appropriate parameters of the (extrusion) process mostly the moisture content. The product characterized by interesting texture, can be used as a semi-finished product in food industry, but also after suplementing it with additinal taste ingredients can serve for direct consumption.

Table 2. Texture parameters of extruded starches

Kind of extruded starches	Starch moisture [%]	Shear force [N]	Shear work [N·s/cm^2]	Compression work [N·s]	Brittleness [N]	Hardness [N]
Corn	16	ad47.3+9.35	ab8.28+1.68	a23.9+6.04	15.7+6.79a	51.2+6.21cd
	24	c63.4+10.60	a8.74+2.76	ac28.3+5.34	57.9+17.85b	93.5+16.37b
Wheat	16	a41.4+2.63*	ab7.55+0.84	a23.6+3.84	16.3+2.66a	35.7+4.09
	24	b110.5+20.38	c14.66+2.31	ab28.5+5.47	58.3+21.32b	90.11+11.21b
Potato	16	b118.7+15.16	d21.50+2.115	e55.6+8.69	92.1+27.33d	150.7+26.52f
	24	XX				

*- arithmetrical mean + standard deviation

a,b,c,d,e,f- values in the same columns marked with the same letter do not differ essentially($p>0.05$)

XX- extrudate from potato starch with 24% moisture content showed almost total lack of expansion and therefore its hardness exeeded measuring range of the texture analyzer

Table 3. Solubility and water binding capacity of starch extrudates

Kind of starch		Solubility [%]		Water binding capacity [g/1 dry matter]	
		60°C	80°C	60°C	80°C
Corn	native	0.28	2.64	1.28	7.58
	ekstruded 16%	8.79	10.18	2.15	2.51
	ekstruded 24%	6.85	7.41	7.61	8.00
Wheat	native	1.92	3.50	5.69	7.00
	ekstruded 16%	8.13	11.25	7.18	4.18
	ekstruded 24%	7.51	9.12	7.90	8.12
Patato	native	1.61	9.36	5.45	38.33
	ekstruded 16%	no reliable data were obtained			

Extrusion makes starch soluble in cold water [Davidson et al. 1984, Chinnaswamy and Hanna 1990]. Starch solubility increases with an increasing temperature and a decrease in moisture of the product prior to extrusion [Mercier and Feillet 1975]. The confirmation of investigation by the above mentioned authors are the data in Table 4, which testify for a higher solubility at 60 and 80°C of extruded starches with a lower water content before extrusion. Hovewer, water bindig capacity by extruded starches at two temperatures applied, is higher than in native starch, with the increase being specially pronounced in the case of starch with a higher moisture content - 24%. The observed parameters of extrudate swelling are connected with higher degradation of starch product during extrusion of material of lower moisture [Tang and Ding 1994]. It is caused by the fact, that with a lower starch moisture, a higher mechanical

force is involved than with a higher moisture content. The higher the pressure developed in the extruder, the lower the moisture of extruded material [Davidson et al. 1984].

Table 4. Properties of extruded starches

Kind of starch		Apparent amylose content [%]	Total phosphorus content [%]
Corn	native	21.64	0.019
	extruded 16%	26.70	0.021
	extruded 24%	27.12	0.022
Wheat	native	23.28	0.064
	extruded 16%	22.64	0.059
	extruded 24%	27.08	0.060
Patato	native	24.05	0.068
	extruded 16%	33.99	0.070

In extruded starches the amylose content was found to be higher than in native starch, irrespective of the origin of the starch and its moisture prior to extrusion (Tab. 4). Since in a single-screw extruder it is amylopectine that is subjected to the highest mechanical degradation, [Davidson et al. 1984, Chinnaswamy and Hanna 1990], probably because of side chains of this polimer, degradation increased the content of linial chains, which are indicated as amylose.

As can be predicted, extrusion process did not influence total phosphorus content in starch.

Inspire of showing unquestionable differences concerning the texture parameters and physico-chemical properties of starch extrudate from starches with different water content, the explanation of those differences seens possible only on the basis of molecular changes occurring in extrusion process.

CONCLUSIONS

1. Moisture content of native starch influences significantly texture parameters and physico-chemical properties of starch extrudates, irrespective of starch origin.
2. Extrudates made of starches with lower water content (16%) are characterized by smaller density, higher expansion parameters, smaller hardness and lesser force needed for crumbling as compared to extrudates made of starch witch higher moisture (24%) and having share of gel phase than melted phase.
3. Irrespective of moisture content in starches, as higher amount of amylose in extrudates as compared to native starches was measured, while phosphorus content did not undergo any changes.
4. All obtained extrudates exhibited higher solubility in water at 60 and 80°C as compared with native starches while solubility and lower water binding capacity were displayed by extrudates with a lesser moisture content.

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