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FLOW PROPERTY STUDY OF CORN STARCH AFTER ADDITION OF HEMICELLULOSES FROM BUCKWHEAT HULLS

Summary

Buckwheat seeds are an important pseudocereal used as flour in baking industry. Also hulls, a waste material produced in the de-hulling process is of certain interest. Hemicelluloses were isolated from buckwheat hulls. They were characterised and shown to be of the glucuronoxylan type. Their effect upon rheological properties of gels of corn starch with varying amount of hemicelluloses (0.3%; 0.5%; 0.7% and 1.0%) is described. The rheological properties of the blends were investigated using the Brabender viscograph and Rheotest 2 viscograph. At the same pasting temperature, pastes containing an optimum of hemicelluloses (0.5–0.7%), exhibited the highest viscosity and stability against mechanical stress. At this optimum concentration, hemicelluloses increased substantially the apparent viscosity of the pastes at low and high shear rates and this trend was observed also with increase in temperature. Effect of the hemicellulose addition to corn starch on retrogradation of the pastes was studied in the refrigeration as well freeze-thaw processes. A minimum addition of hemicelluloses (0.3%) significantly affected the syneresis of starch.

Introduction

In the recent years, ground buckwheat has found many applications as flour in bakery due to the higher content of proteins and essential amino acids in comparison to cereal grains. Buckwheat plants are not grasses, but the seeds are usually classified among the cereal grains because of similar use [1]. Except of the flour, the hulls of the seeds produced in the de-hulling process are of great interest because they represent a rich source of hemicelluloses of the glucuronoxylan type [2]. The aim of this contribu-

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tion was to study the effect of the addition of hemicelluloses of buckwheat hulls on the rheological properties of corn starch pastes.

Materials and methods

Corn starch (Gustin) was a fine corn starch produced by Dr. Oetker s.r.o., Bratislava. Hemicelluloses were isolated from buckwheat hulls in the Institute of Chemistry, Slovak Academy of Sciences, Bratislava.

The flow properties of the starch pastes were determined using the coaxial cylinder viscometer Rheotest 2 (2-50 Hz, VEB MLW Prüfgeräte Medingen, Germany) with the S_3 measuring system (r/R = 0.81, D = 0.17–146 s^{-1}). The rheological tests were performed at temperatures 55, 70, and 90°C. Starch pastes were characterised using the Brabender viscograph (Brabender, Duisburg, Germany) and the deformation of the starch gels was measured by the Penetrometer AP 4/1 (VEB Feinmes, Germany).

Preparation of starch pastes: Blends of corn starch with hemicelluloses added in concentrations of 0.3, 0.5, 0.7, and 1.0% were prepared. For testing by Rheotest, the blends were suspended in water and the suspensions were heated in a boiling water bath for 10 min and further boiled for 15 min at constant stirring. The pastes were cooled to room temperature and used for rheological measurements. For Brabender experiments, the aqueous suspension of the starch blends were prepared at ambient temperature and then the pasting behaviour was measured at various temperatures for 2 h.

The retrogradation of the obtained starch pastes were measured after refrigeration at 4°C for one week and then heated to 40°C for 2h (repeated twice), and in four freeze-thaw cycles (-18°C for 16 h and 40°C for 2h). The amounts of absorbed and excluded water were determined in relation to the free water content of the starting pastes determined by centrifugation (3000 rpm/min for 10 min) of starch pastes.

For the penetration tests, the boiled starch pastes were cooled to room temperature for 20h in cylinders of constant dimensions and penetration was measured the next day at 5, 30 and 60 seconds.

Results and discussion

Analytical characteristics of the buckwheat hemicelluloses (Table 1) indicated that they comprised mainly of 4-O-methylglucuronoxylan (GX).

Rheological properties of the corn starch paste (standard) and pastes prepared from starch/GX blends were characterised with the flow curves measured at 55, 70, and 90°C using Rheotest (Figure 1). The curves indicated a positive effect of GX on the pseudoplastic behaviour of starch paste. In comparison to the standard paste, the increase in shear stress (τ) versus shear rate (D) was most pronounced in pastes con-

taining 0.5–0.7% GX what indicated a higher resistance of against mechanical stress. The effect of GX addition on the flow behaviour at low and high shear rates is illustrated in Figures 2a and 2b. At the same pasting temperature, pastes containing 0.5–0.7% GX, exhibited the highest apparent viscosity values at low and high shear rates and this trend was followed also with an increase in temperature.

Table 1

Analytical characteristics of hemicelluloses from buckwheat hulls

Protein %	Neutral sugar composition $x_i$mol %						
	Rha	Fuc	Ara	Xyl	Man	Glc	Gal
8.87	1.6	0.7	7.8	43.8	1.1	40.3	4.7

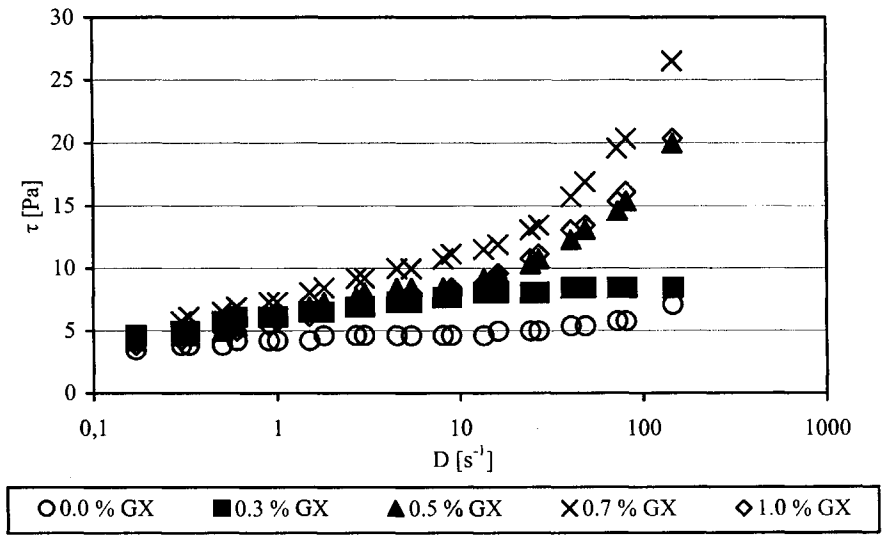
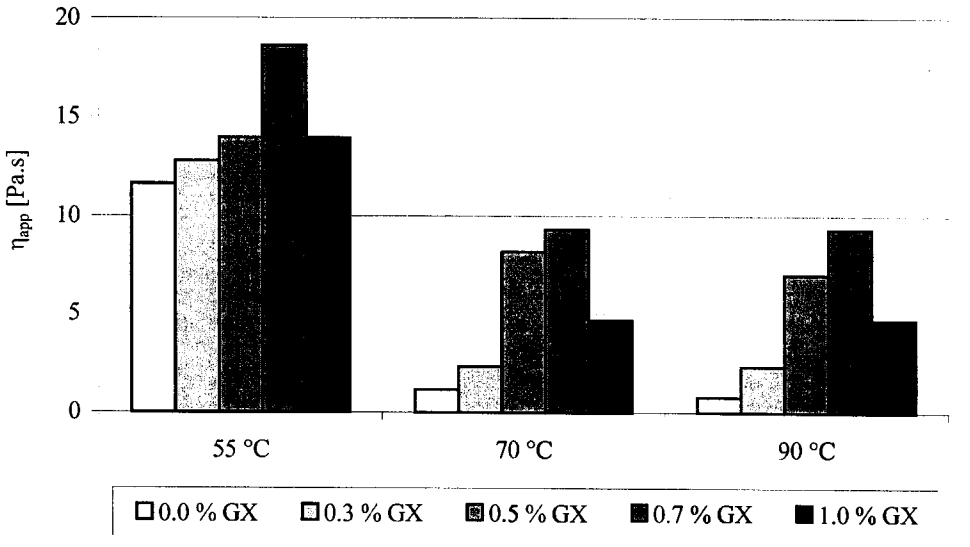


Fig. 1. Flow curves measured at 55°C.

The pasting behaviour of the pastes prepared from blends of corn strach and various amounts of GX are presented in Table 2. As seen, at 0.5% GX addition, the viscosity (P) reached a maximum. However, at higher GX concentrations, the viscosity values decreased but remained were higher as compared to that of pure starch paste (standard). The effect of GX addition is best expressed by the retrogradation ratios C/P and C/H, retrogradation and total retrogradation ratios, respectively. At the optimum of the GX concentration, both ratios showed the lowest value what indicates a high stability of the paste. With increasing GX concentrations, the ratios decreased but the values were lower than of the standard paste.

a)



b)

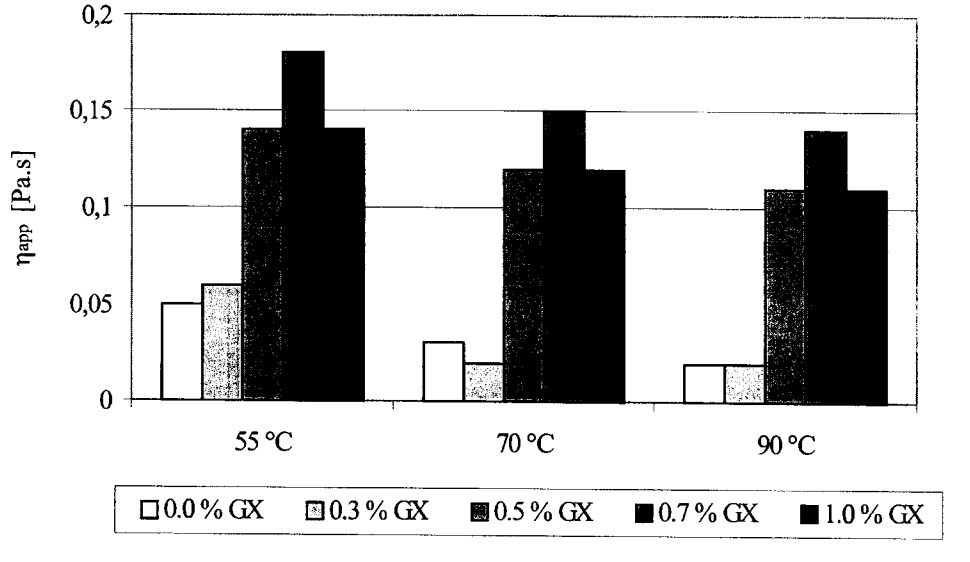


Fig. 2. Influence of hemicelluloses from buckwheat hulls on the viscosity of potato starch pastes at shear rate:
a) D=0.33 s^{-1},
b) D=146 s^{-1}.

Table 2

Pasting characteristics of corn starch/GX blends.

% GX	PT [°C]	P [BU]	H [BU]	C [BU]	BD [BU]	SB [BU]	C/P	C/H	H/P	T_{max}	P_t [min]
0.0%	83	350	340	890	10	550	2.54	2.62	0.97	89	38
0.3%	84	345	340	810	5	470	2.35	2.38	0.99	92	45
0.5%	86	420	410	850	10	440	2.02	2.07	0.98	92	45
0.7%	84	365	360	790	5	430	2.16	2.19	0.99	93	43
1.0%	83	345	340	780	5	440	2.26	2.29	0.99	92	44

PT: Pasting temperature (temperature at which the viscogram first ascends from the baseline).
P: Maximum viscosity in Brabender units (BU).
P_t: Time of reaching maximim viscosity.
H: Hot paste viscosity.
C: Cooled paste viscosity.
DB: Breakdown (P-H)
SB: Setback (C-H)
C/P: Retrogradation ratio
C/H: Total retrogradation ratio
H/P: Breakdown ratio

Retrogradation of the starch pastes prepared in the Brabender viscograph was characterised by means of the volume of excluded water after refrigeration and freeze-thaw cycles, respectively as shown in Table 3. With increasing amount of added GX, the volume of free water of starch/GX pastes decreased from 82 to 17.6% due to the high swelling capacity of GX and ability to bind water molecules [3]. The syneresis of starch was expressed as the volume of water excluded by the recrystallised amylose according to equation: S (%) = (% excluded water + % absorbed water) - % free water. The addition of GX showed non-signifcant effects on the syneresis during the two refrigaration cycles. However, distinct effects with an increasing tendency were observed during the freeze-thaw cycles. As seen in Figure 3, there is an optimum GX concentration influencing the syneresis. It was situated at 1.0% in the first three cycles and at 0.5% in the last cycle. This concentration fitted optimum of added GX found on the studies of the rheological and pasting behaviour.

Effect of the GX addition on the penetration of gels prepared from the boiled pastes is demonstrated in Figure 4. The penetration decreased as the concentration of the GX increased with a discontinuity at the concentration of 0.5–0.7%. The results indicatd that the gels containing GX were more rigid and resistant to deformation by pressure what might be explained by the gel-forming properties of GX-type hemicelluloses [4].

Table 3

Final syneresis [%].

Sample	Free water [%]	Refrigeration cycles		Freeze-thaw cycles			
		I	II	I	II	III	IV
0.0% GX	3.4	0	0.1	17.2	7.8	5.6	3.4
0.3% GX	2.8	0	0.2	11.2	6.0	4.4	2.0
0.5% GX	2.0	0	0.2	7.8	5.0	3.8	0.8
0.7% GX	1.3	0	0.3	6.1	3.9	3.1	1.1
1.0% GX	0.6	0	0	5.2	3.0	2.4	1.2

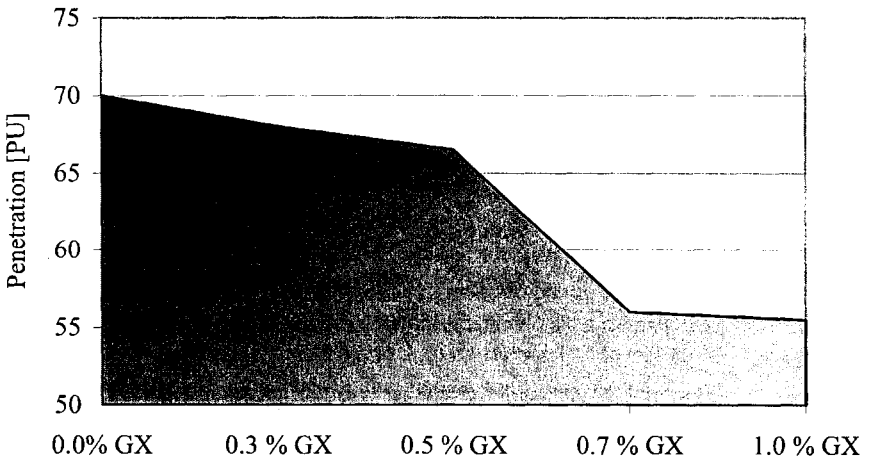


Fig. 4. Penetration of starch/GX gels after 5 sec of pressure deformation.

Conclusions

The results indicated that hemicelluloses of the GX type, isolated from the hulls of buckwheat seeds, significantly affected rheological and pasting properties of corn starch pastes at very low concentrations in comparison to studies [5] where water-insoluble GX from beech pulp were applied in concentrations above 20%. It can be suggested that GX from buckwheat hulls represented a potential additive in various corn starch-based food products due to their ability to force the structure of pastes, prevent retrogradation of starch, and improve staling properties of baked products.

Acknowledgement

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BADANIE PŁYNIĘCIA SKROBI KUKURYDZIANEJ PO DODANIU HEMICELULOZ Z ŁUSEK KASZY GRYCZANEJ

Streszczenie

Kasza gryczana jest ważnym pseudozbożem używanym przez przemysł piekarski. Także łuski kaszy gryczanej stanowiące odpad stają się obiektem zainteresowania. Można z nich wydzielić hemicelulozy glukuronoksylanowe. Zbadano wpływ ich dodatku (0,3, 0,5, 0,7 i 1,0%) na właściwości reologiczne skrobi kukurydzianej. W badaniach posłużono się wiskografami Brabendera i Rheotest-2. Przy tej samej temperaturze żelowania żele zawierające optymalną ilość hemiceuloz (0,5 do 0,7%) miały najwyższą lepkość i odporność na działanie mechaniczne. Przy tym optymalnym stężeniu hemiceuloz wyraźnie wzrastała lepkość pozorna żeli przy niskiej i wysokiej szybkości ścinania i ta tendencja utrzymywała się też w zakresie wyższej temperatury. Wpływ dodatku hemiceluloz do skrobi kukurydzianej na retrogradację żeli badano przez kolejne zamrażanie i rozmrażanie. Już minimalny (0,3%) dodatek hemiceluloz wywoływał znaczne zmiany synerezy żelu.