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EFFECT OF HEMICELLULOSES ON THE PROPERTIES OF POTATO AND CORN STARCHES

Summary

Cereal hemicelluloses are plant cell wall polysaccharides which have a great influence on the processing and quality of starch-based food products due to the interactions between these polysaccharides. In this paper the influence of hemicelluloses isolated from non-food sources i.e. 4-O-methylglucuronoxylan from beech wood and arabinoglucuronoxylan from corn cobs on the rheological and pasting properties of corn and potato starches. A series of blends was prepared from the two starches in combination with both hemicellulose types added in concentration range of 1.0 to 2.0%. The rheological properties of the blends were characterised by flow curves and the retrogradation of starches/hemicellulose blends were investigated on the refrigeration and freeze-thawing. Both types of hemicellulose exhibited a significant, positive effect on the syneresis of starch at its ~2% concentration.

Introduction

Hemicelluloses are polysaccharides constituting, together with cellulose, the cell walls of higher plant tissues. Among hemicelluloses, the most representative are D-xylans with long chains of (1→4)-β-D-xylopyranose units carrying short side chains composed of L-arabinose, D-glucuronic acid and its 4-O-methyl ether, rarely D-glucose and D-galactose [1]. The average content of hemicelluloses in cereal flours reaches 2–4%. These hemicelluloses are represented mainly by arabinoxylans, have attracted considerable attention because of their important physiological effects incereal products and their effects on baking properties of flours and quality of baked and non-baked products [2]. Positive effects of arabinoxylans have been reported after their

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blending with low-quality flours or starches [3]. There are no reports concerning the effect of hemicelluloses on the quality of other starch-based food products such as soups, souces, puding, etc. In this paper we describe the rheological beahviour of pastes prepared from potato and corn starches with and without addition of model hemicelluloses isolated from beech wood meal and corn cobs.

Material and methods

Corn starch (Gustin) and potato starch (Solamyl) were fine corn starch produced by Dr. Oetker s.r.o. (Bratislava, Slovakia). As model xylans, the arabinoglucurono-xylan from corn cobs (AGX) and 4-O-methylglucuronoxylan (GX) from beech wood meal were produced in the pilot plant of the Institute of Chemistry, Slovak Academy of Sciences (Bratislava, Slovakia). The analytical characteristics of the xylans are summarised in Table 1.

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).

Table 1

Analytical characteristics of the model xylans.

Neutral saccharides composition (x_i /mol. %)	GX	AGX
Xylose	96.8	88.3
Arabinose	1.5	6.1
Glucose	0.8	3.1
Galactose	0.7	2.5
Mannose	0.2	-
Uronic acids (%) [a]	12.4	88.3
N (%)	0	2.5
Lignin (%) [b]	0.3	3.1
Mean molecular weight [c]	30 000	75 000
Solubility in water (%)	75	85

a) Expressed as the anhydro unit of 4-O-methylglucuronic acid.

b) Determined as Klason lignin.

c) Estimated by SEC using pullulan standards.

Preparation of starch pastes: Blends of corn starch with hemicelluloses added in concentrations of 1.0; 1.2; 1.5; 1.7; and 2.0% 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 within 2 h.

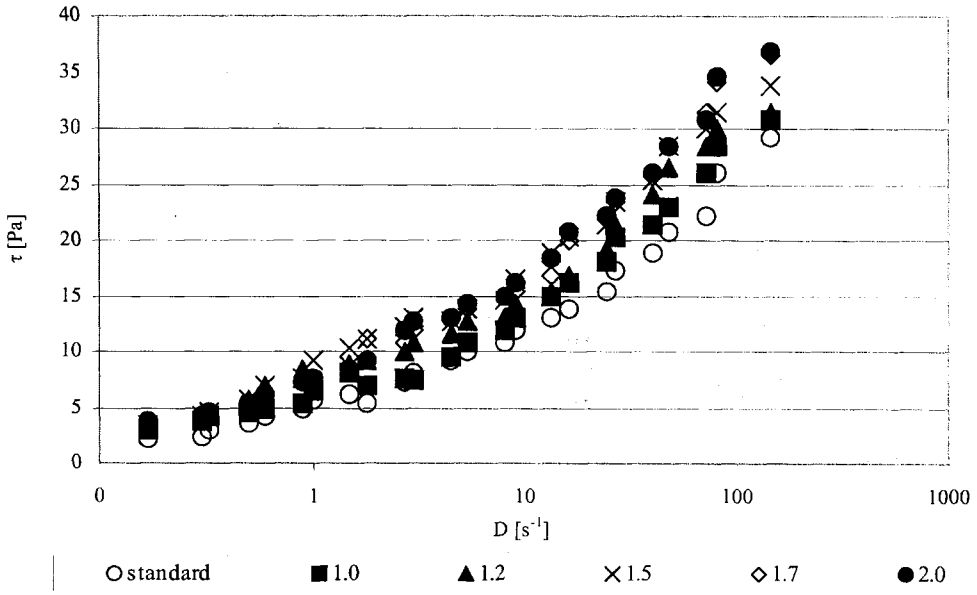
The retrogradation of the obtained starch pastes were measured after refrigeration at 4°C for one week and then heated to 40 °C for 2h (duplicated), and in four freeze-thaw cycles (-18°C for 16 h and 40°C for 2h). The amounts of absorbed and excluded water was determined in relation to the free water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

Results

The rheological properties of corn starch paste (standard) and pastes prepared from starch/AGX and starch/GX blends were characterised by the flow curves measured at 55, 70, and 90°C using the Rheotest (Figs. 1a, 1b). The curves indicated a pseudoplastic behaviour of all corn starch, significantly affected only by addition of GX at the highest concentration (2%) what indicates a higher resistance against mechanical stress. The effect of GX and AGX addition on the flow behaviour at low and high shear rates is illustrated in Figures 2a and 2b. As seen, after addition of AGX, the apparent viscosity of the pastes increased continuously within the concentration range applied in the low and high shear rate regions and this trend was retained also at higher temperature. In contrast, a similar behaviour was observed for GX only at higher concentrations. At the lowest dose (1%), the viscosity of the pastes decreased in comparison to the standard, but about the same effect was observed at the highest dose applied (2%) with GX and AGX.

The flow behaviour of potato starch/xylan blends are illustrated on Fig. 1c and 1d. The η_{app} of the potato starch pastes are substantially higher in comparison to that of corn starch pastes. As shown in Fig. 3a and 3b, a significant decrease in η_{app} at the lowest dose of added xylans (1%) in comparison to the standard, was observed in the case of potato starch blend pastes with both GX and AGX. With the increasing amount of added xylans, the η_{app} of the influence of GX was also less pronounced in comparison to that of AGX, even at the highest dose applied (2%).

a)



b)

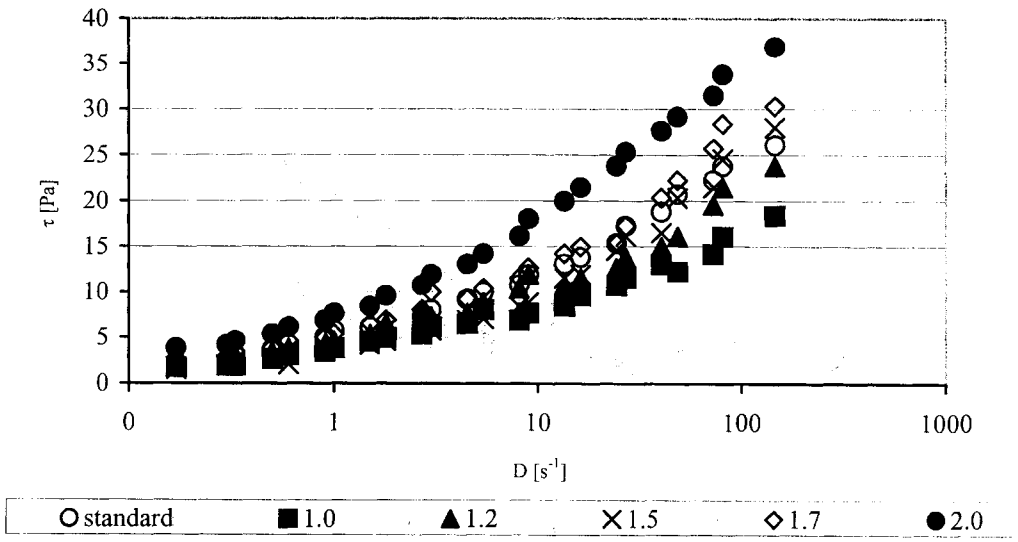
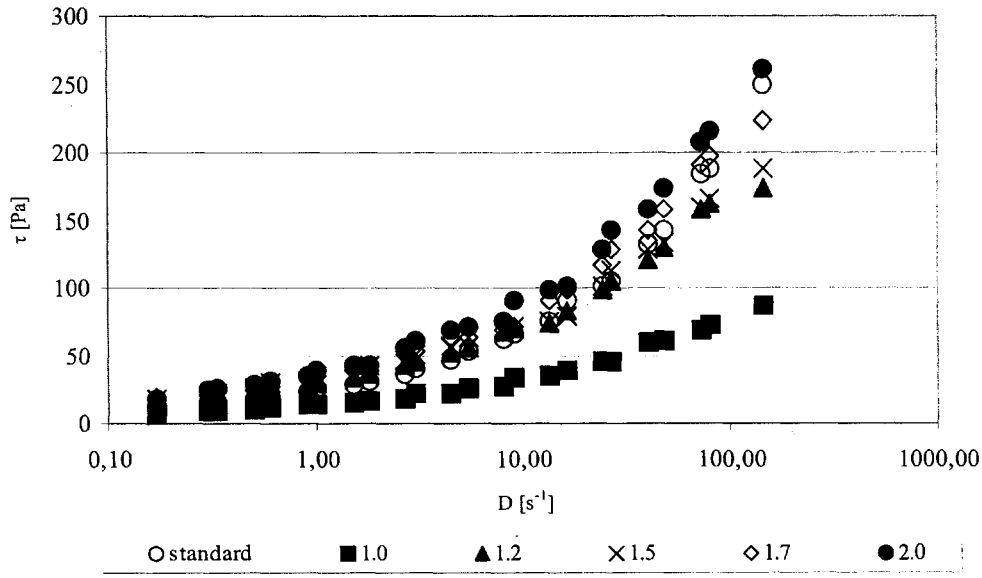


Fig. 1a, b. Flow curves measured at 55°C:
a) corn starch/AGX blends,
b) corn starch/GX blends.

c)



d)

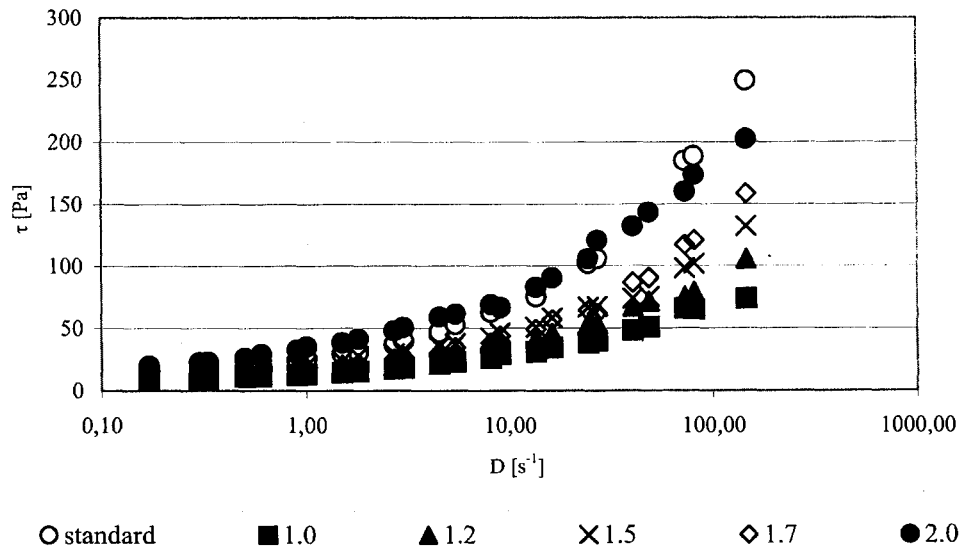


Fig. 1c, d. Flow curves measured at 55°C:
c) potato starch/AGX blends,
d) corn starch/GX blends.

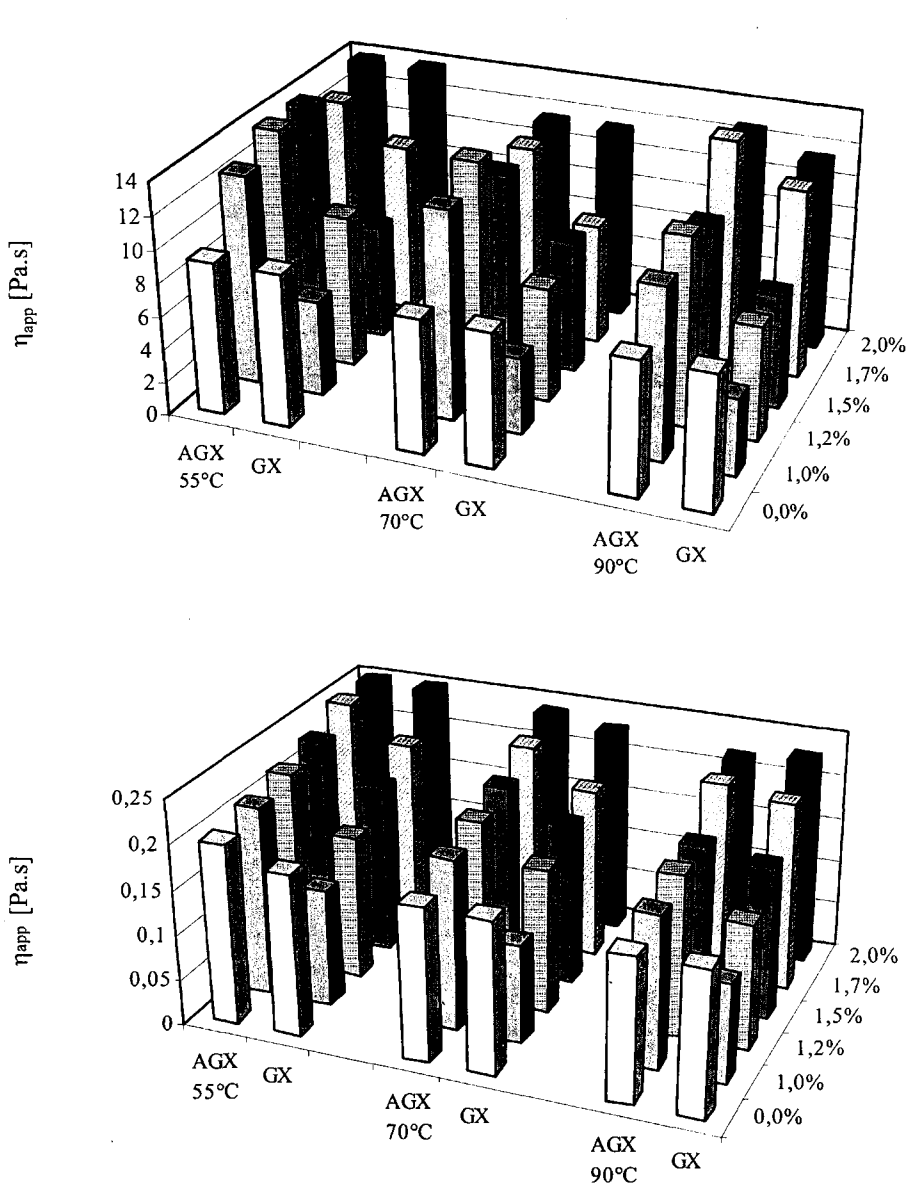


Fig. 2. Influence of AGX and GX on viscosity of corn starch pastes at shear rate;
a) $D = 0.33\ s^{-1}$,
b) $D = 146\ s^{-1}$.

The results of the pasting behaviour of the pastes prepared from blends obtained from corn strach and various amounts of added AGX are presented in Table 2. At 1%

addition of both xylans, the viscosity (P) decreased. In contrast to GX, it did not reach the value of the standard at the highest dose with AGX. The effect of AGX addition is best expressed by the breakdown value, retrogradation ratios C/P and C/H and breakdown ratio (H/P) at 2% of added xylan. Except of the H/P parameter, similar effect were found for GX at the highest concentrations (1.7 and 2%). The low retrogradation parameters (C/P and C/H) indicate high stability of the pastes.

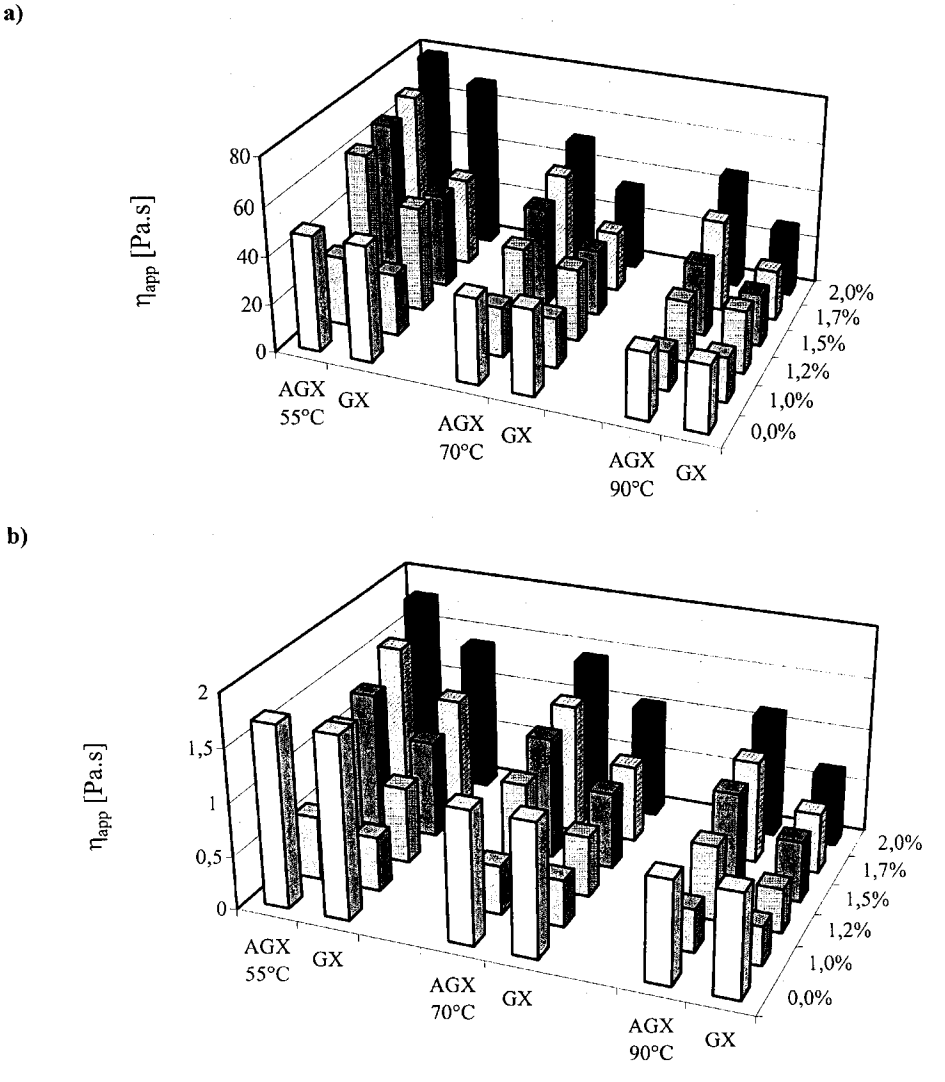


Fig. 3. Influence of AGX and GX on viscosity of potato starch pastes at shear rate:
a) D = 0.33 s^{-1},
b) D = 146 s^{-1}.

Table 2

Pasting data from the viscograms of corn starch/AGX and corn starch/GX blends.

	PT [°C]	P [BU]	H [BU]	C [BU]	BD [BU]	SB [BU]	C/P	C/H	H/P	T_{max} [°C]	P_t [min]
Standard	77.8	410	350	560	60	210	1.37	1.60	0.85	82.6	39.0
AGX											
1.0 %	81.3	290	270	440	20	170	1.52	1.63	0.93	89.0	42.7
1.2 %	79.8	330	310	490	20	180	1.49	1.58	0.94	79.4	36.5
1.5 %	79.4	340	320	510	20	190	1.50	1.59	0.94	85.8	41.5
1.7 %	74.6	340	330	530	10	200	1.56	1.61	0.97	84.2	37.0
2.0 %	76.2	370	350	460	20	110	1.24	1.31	0.95	87.4	38.0
GX											
1.0 %	77.8	260	255	440	5	185	1.69	1.72	0.98	87.4	35.2
1.2 %	79.4	280	275	490	5	215	1.75	1.78	0.98	87.4	36.3
1.5 %	79.4	340	335	570	5	235	1.68	1.70	0.98	84.2	36.3
1.7 %	85.8	340	330	370	10	40	1.09	1.12	0.97	93.8	40.5
2.0 %	85.8	420	290	540	130	250	1.29	1.86	0.69	87.4	40.5

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

As shown in Tab. 3, the addition of GX and AGX to potato starch in the concentration range of 1–1.7% had similar effects as shown for the corn starch/xylan blends, i.e. the viscosity of the blends reached about the value of the standard at the highest dose (2%). At this dose, both GX and AGX improved significantly the retrogradation ratios C/P and C/H.

The final syneresis of the standard corn starch paste is substantially lower than that of the standard potato starch paste. There are differences between the process of syneresis of standard pastes based on corn and potato starch as well on the blends. Whereas, the syneresis with corn starch/AGX blends started in the third freeze-thawing cycle, no syneresis was observed with corn starch/GX blends. In the case of the standard and blends of potato starch with both xylans, syneresis was observed only in the first cycle. The blends containg 2% of GX showed the lowest syneresis.

Table 3

Pasting data from the viscograms of potato starch/AGX and potato starch/GX blends

	PT [°C]	P [BU]	H [BU]	C [BU]	BD [BU]	SB [BU]	C/P	C/H	H/P	T_{max} [°C]	P_t [min]
Standard	87.4	260	260	370	0	110	1.42	1.42	1.000	93.8	41.6
AGX											
1.0 %	85.8	140	140	160	0	20	1.14	1.14	1	93.8	40.5
1.2 %	85.8	200	200	280	0	80	1.40	1.40	1	94.0	40.5
1.5 %	81.0	210	210	330	0	120	1.57	1.57	1	94.0	37.3
1.7 %	73.0	250	250	350	0	100	1.40	1.40	1	93.8	32.0
2.0 %	84.2	260	260	330	0	70	1.26	1.26	1	93.8	39.5
GX											
1.0 %	81.0	150	150	190	0	40	1.26	1.26	1	92.2	37.3
1.2 %	87.4	160	160	220	0	60	1.37	1.37	1	94.0	41.6
1.5 %	82.6	180	180	240	0	60	1.33	1.33	1	92.2	38.4
1.7 %	90.6	200	200	280	0	80	1.40	1.40	1	94.0	43.7
2.0 %	87.4	280	280	280	0	0	1.00	1.00	1	93.8	41.6

Conclusions

The results indicated that both xylans exhibited a pronounced improvement in the flow properties of blends prepared from corn as well as potato starch at higher concentrations (1.7–2%). Despite of the differences in the pasting properties of the parent starches, those of their blends with both xylan types were significantly improved, particularly in the same concentration range. In comparison to AGX, GX had a higher positive effect on the syneresis of blends prepared from both starches. The result suggest that both xylan types represent potential additives used for stabilisation and thickening of starch-based food products.

Acknowledgement

This work was supported by the Slovak Grant Agency VEGA, Grant No. 2/7138 and SAS - COSTD10/0016/99 MC-D10.

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WPŁYW HEMICELULOZ NA WŁAŚCIWOŚCI SKROBI ZIEMNIACZANEJ I KUKURYDZIANEJ

Streszczenie

Hemiceluozy zbożowe pochodzą z polisacharydowych elementów ścian komórek roślinnych. Wywierają one olbrzymi efekt na sposób przeróbki oraz jakość produktów spożywczych zawierających skrobię, a przyczyną tego są oddziaływania między makrocząsteczkami polisacharydów. W niniejszej pracy opisano wpływ hemiceluloz wyodrębnionych z surowców niespożywczych, tzn. 4-O-metyloglucoronoksylanu z drewna bukowego i arabinoglukoronoksylanu z kolb kukurydzianych, na właściwości reologiczne i żelowanie skrobi ziemniaczanej i kukurydzianej. Przygotowano szereg mieszanek obu skrobi z obydwoma typami hemiceluloz dodanymi w ilości 1,0 do 2,0%. Właściwości reologiczne tych mieszanek charakteryzowano za pomocą krzywych płynięcia i skłonności do retrogradacji w trakcie trzech kolejnych zamrażań i rozmrażań. Oba rodzaje hemiceluloz przy stężeniu 2% bardzo wyraźnie polepszają synerezę skrobi.