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PHYSICAL PROPERTIES OF TRITICALE STARCH. PART I. CHARACTERISTIC OF STARCH PASTING

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Key words: triticale starch, pasting characteristics with Brabender amylograph and Rheotest 2 viscosimeter, limiting viscosity of starch pastes.

Starches of 53 Polish triticale breeding lines were investigated. Gelatinization characteristics and limiting viscosity of starch were determined. The studied properties of triticale starch are similar to those of wheat starch, although viscosities of triticale starch pastes were in the majority of samples higher than in the "Grana" wheat standard. In the total population tested, a few starches show a considerably low viscosity of starch pastes which may be a result of enzymatic degradation.

INTRODUCTION

In both Polish and world literature there is little information about triticale starch [1-3, 6]. Given the existence of the first varieties of this cereal in Poland and in view of the strong chances for the introduction of its wide-scale cultivation, triticale may be considered a potential new source of starch in this country. Accordingly, studies were made of the usefulness of this cereal in starch production [2].

In this research we concentrated on one of the more important practical properties of starch, namely on the pasting of starch grains during the heating of their suspension in water. This property of triticale starch has so far received very little attention.

Lii and Lineback [6] determined the range of pasting temperature for triticale starch with the microscopic method, while Berry et al. [1] studied the characteristic of the gelatinization of starch pastes in a Brabender amylograph. The viscosity values for triticale starch obtained by these authors were higher than those for wheat and rye starch [1-3, 6]. Lii and

Lineback [6] explain this fact by the higher degree of branching of amylopectin in triticale starch. In another research Berry et al. [4] measured the limiting viscosity of triticale amylose and amylopectin pastes.

MATERIAL

The material for study were starches isolated by the laboratory method [8] from 48 winter and 5 spring triticale breeding lines and from 2 lines of „Grana" wheat used as the standard. The winter triticale and the „Grana" wheat breeding lines were sown in 1978 and 1979 in a joint field experiment at the Experimental Station of Plant Breeding and Acclimatization in Ożańsk and cultivated in uniform agrotechnological conditions. The samples for study were collected when fully mature.

The samples of spring triticale were obtained directly from the Experimental Station of Plant Breeding and Acclimatization in Małyszyn. A detailed characteristic of the investigated breeding lines is given in [2].

METHODS

1. The pasting temperature range of starch was determined by observing the loss of starch grain birefringence under a microscope with a heating stage (Boetius) [8].

2. The determination of pasting characteristics in a rotary viscosimeter Rheotest 2 for 7.4% dry substance starch water dispersions was performed according to our own modification described in the previous publication [2].

3. The pasting characteristic of 7.2% dry substance starch dispersions was performed in a Brabender amylograph according to the basic program, using a 250 cm·g measurement cardridge and rotation velocity of 75 r.p.m. The pasting temperature was read when viscosity was 20 J.B.

4. The limiting viscosity of alkaline starch pastes was determined with an Ubbelohde-Rafikow capillary viscosimeter at 30°C; measurements were made for the following concentrations: 0.4, 0.3, 0.2, 0.15 and 0.1% dry substance [8].

RESULTS AND DISCUSSION

The pasting characteristic of triticale starch was similar to that of wheat starch [5].

Table 1 shows results of measurements of the pasting temperature range. The temperature of pasting beginning in the analysed triticale starches was as reported in the literature [4, 6] but the temperature of pasting end was slightly lower from that reported by Lii and Lineback [6].

Table 1. Range of pasting temperature in triticale starch; i_t — inicial temperature of pasting; f_t — final temperature of pasting; Δt — range of pasting temperature

Sample No.	i_t (°C)	f_t (°C)	Δt (°C)	Sample No.	i_t (°C)	f_t (°C)	Δt (°C)	Sample No.	i_t (°C)	f_t (°C)	Δt (°C)
1	52.5	55	2.5	20	52.5	58	5.5	39	51	56	5.0
2	51.5	56	4.5	21	51	55.5	4.5	40	51	56	5.0
3	52	56	4.0	22	50.5	55	4.5	41	51.5	54	3.0
4	52	56	4.0	23	52	55	3.0	42	51	55	4.0
5	53	58	5.0	24	51.5	56	4.5	43	51	57	6.0
6	52	57	5.0	25	50.5	55.5	5.0	44	52	55	3.0
7	53	58	5.0	26	53	58	5.0	45	52	56	4.0
8	51	55	4.0	27	50.5	54	3.5	46	52	57	5.0
9	51.5	56	4.5	28	51	56	5.0	47	52	56	4.0
10	51	56	5.0	29	53.5	58.5	5.0	48	53	58	5.0
11	52	56	4.0	30	52	57	5.0	49	51	54.5	3.5
12	51	56	5.0	31	52.5	57.5	5.0	50	51	57	6.0
13	52	56	4.0	32	52.5	57	4.5	51	51.5	56.5	5.0
14	53	58	5.0	33	51	57	6.0	52	51.5	57	5.5
15	51	55	4.0	34	52	57	5.0	53	51.5	56.5	5.0
16	51.5	56.5	5.0	35	53	58	5.0		for triticale		
								mean value	52	56.5	4.5
17	52	56	4.0	36	52.5	57.5	5.0				
18	53	58	5.0	37	53	58.5	5.5	G_1	51.5	55	3.5
19	51	57	6.0	38	51.5	55	3.5	G_2	54	59	5.0

The pasting of triticale starch took place in a narrow temperature range: $\Delta t = 2.5\text{-}6.0°C$ (mean 4.5°C). Similar results were obtained for starch from the standard "Grana" wheat: $\Delta t = 5°C$.

The lower temperature of pasting end, compared with that of whaet and triticale starch [5, 6], was most probably the result of a different process of grinding grain into flour from which starch was subsequently isolated. According to Kulp [5], the grinding of grain destroys the crystalline structure of starch grains and this causes the drop in pasting temperature.

The determinations of the pasting characteristic of the studied starches are collected in Table 2. The data show the starches to be considerably differentiated in this respect.

The temperature of pasting ranged from 80.5 to 92°C with a mean of 87°C. The highest temperatures were found in starches from 7 breeding lines marked by the lowest viscosity of pastes.

T a b l e 2. Pasting characteristic of 7.4% dry substance water pastes of triticale starch (performed with rotary viscosimeter Rheotest 2)

Sample No.	Pasting temperature °C	Maximum viscosity mPa · s	Temperature at maximum viscosity °C	Viscosity at 96°C mPa · s	Viscosity after 20 min at 96°C mPa · s	Viscosity after cooling to 50 °C mPa · s
1	88.5	302	92.5	217	338	685
2	88	438	92	48	109	767
3	80.5	257	90.5	142	115	377
4	88	314	92	109	257	613
5	87	362	91	30	79	568
6	86	317	91	178	166	465
7	86	257	91.5	145	148	386
8	87	389	92	48	193	825
9	87.5	371	92	54	88	758
10	87	314	92.5	151	199	577
11	89	275	93	211	281	489
12	86	353	91.5	100	121	637
13	88	299	92	112	251	565
14	87.5	139	91.5	94	72	236
15	85	281	92	193	166	619
16	85.5	226	92	181	214	465
17	85.5	269	93	217	338	694
18	84	320	91.5	73	190	794
19	86	268	91.5	166	196	444

Sample No.	Pasting temperature °C	Maximum viscosity mPa · s	Temperature at maximum viscosity °C	Viscosity at 96°C mPa · s	Viscosity after 20 min at 96°C mPa · s	Viscosity after cooling to 50°C mPa · s
20	86	317	91	39	166	734
21	84.5	356	91	60	133	894
22	89	57	91	24	18	94
23	89	240	94	201	231	445
24	91	48	92.5	24	12	78
25	85	408	91.5	27	85	793
26	86	154	91.5	124	109	302
27	86	402	91.5	48	193	930
28	86	723	92.5	208	278	531
29	87.5	51	90.5	24	15	88
30	89	66	91.5	39	30	124
31	86.5	344	91	39	85	625
32	88	308	92.5	36	296	580
33	91	27	92	12	6	57
34	87.5	272	92.5	196	335	722
35	88	474	91.5	106	97	888
36	87.5	450	91	36	121	888
37	86	436	91	24	85	829
38	87	248	92.5	151	169	441

Sample No.	Pasting temperature °C	Maximum viscosity mPa · s	Temperature at maximum viscosity °C	Viscosity at 96°C mPa · s	Viscosity after 20 min at 96°C mPa · s	Viscosity after cooling to 50°C mPa · s
39	86.5	287	92.5	112	335	664
40	88.5	281	93	230	275	550
41	88	275	93	205	229	577
42	88.5	187	92	130	145	350
43	90.5	33	90.5	12	6	60
44	92	39	92	21	12	69
45	88.5	329	94	157	103	565
46	88	296	92	45	103	586
47	88	296	92.5	196	254	525
48	88	166	92	103	91	272
49	85.5	444	90.5	54	97	879
50	87.5	317	91.5	85	320	695
51	86.5	199	91	145	157	429
52	86	387	91	51	100	734
53	88	323	91.5	145	281	580
for triticale						
mean value	87	273	92	105	160	537
G_1	89	254	93.5	169	284	477
G_2	87	223	92.5	175	169	404

The maximum viscosity of triticale starch pastes was in the range 27-474 mPa·s, with the mean value of 273 mPa·s which slightly exceeded the maximum standard viscosity of wheat starch pastes: 254 and 223 mPa·s. It is noteworthy that 7 od the studied starches, from breeding lines 22, 24, 29, 30, 33, 43 and 44, exhibited very low viscosity of their pastes also in the remaining points of the pasting characteristic. These same starches, however, showed the highest values of pasting temperature measured in the Rheotest 2 viscosimeter. The maximum viscosity of most of the investigated triticale starch pastes (65%) was higher than the respective viscosity of the Grana wheat starch pastes.

The triticale pastes attained their maximum viscosity in a narrow

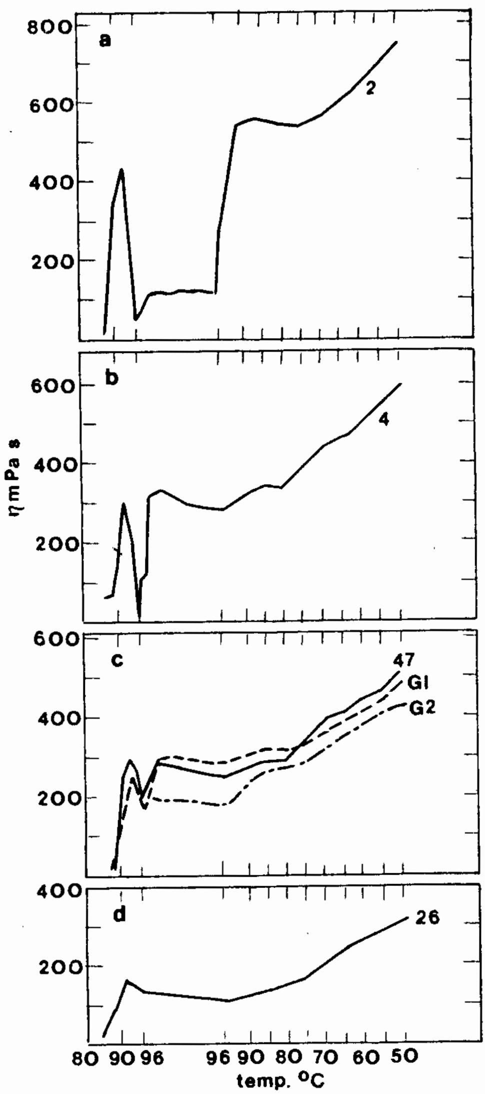

Fig. 1. Pasting characteristic of 7.4% dry substance water pastes of triticale starches determined with the rotary viscosimeter Rheotest 2; a — group I, b — group II, c — group III, d — group IV; the numbers next to the curves are sample numbers

temperature range: 90.5-94°C (mean — 92°C). The figures for wheat starches were similar: 93.5 and 92.5°C.

The viscosity of pastes at 96°C was considerably lower than the maximum value (by about 60% on the average), namely it ranged from 12 to 230 mPa·s (mean value — 105 mPa·s). In the "Grana" wheat starch pastes this decrease was not as severe and viscosity at this temperature was 169 and 175 mPa·s.

The viscosity of pastes after 20 min of heating at 96°C changed variously. Most of the pastes showed an increased viscosity after this time but in over a dozen or so cases the viscosity dropped slightly. The wheat starch pastes too showed here both an increase and a decrease of viscosity.

After cooling to 50°C the viscosity of starch pastes of all the triticale breeding lines increased considerably, remaining in the range 57-930

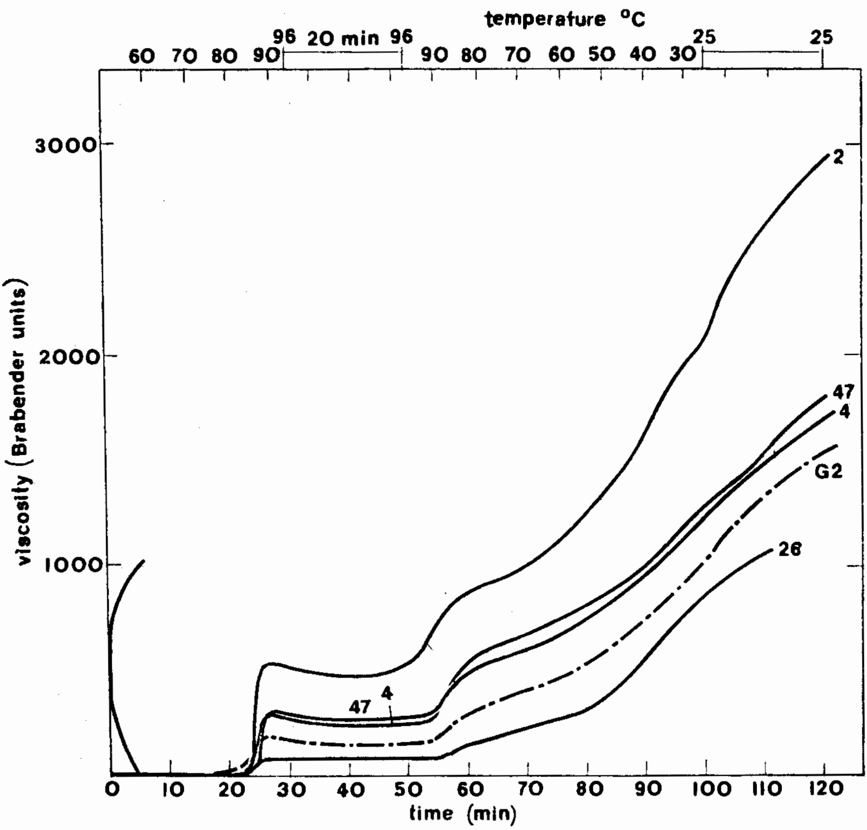

Fig. 2. Pasting characteristic of water pastes of selected triticale starches determined with the Brabender viscograph. Concentration: 7.2% dry substance (35 g dry substance of starch+450 ml H_2O); measurement cartridge 250 cm·g, mixing velocity 75 r.p.m. Numbers next to curves are sample numbers: starch 2 — group I, starch 4 — group II, starches 47 and G_2 — group III, starch 26 — group IV

mPa·s, the mean figure being 537 mPa·s. The viscosity of pastes from the standard wheat starch also rose to 477 and 404 mPa·s. However, at this temperature the viscosity of about 63% of the triticale starch samples was higher than the viscosity of "Grana" starch pastes. Compared to the viscosity after 20 min of heating at 96°C, the viscosity of triticale starch pastes increased 2-9-times while that of wheat starch pastes rose only about 2-times. This fact indicates that the triticale starch pastes have a greater tendency to undergo retrogradation.

Fig. 1 shows diagrams of the pasting characteristics performed in a Rheotest 2 viscosimeter for selected starch samples. Given the clearly differentiated shape of the curves, four groups of triticale starch pastes were distinguished. The pastes belonging to the separate groups differed as to maximum viscosity (group I — ca. 400 mPa·s, group II — ca. 300 mPa·s, group III — ca. 250 mPa·s, group IV — ca. 100 mPa·s), viscosity decrease immediately after reaching 96°C, viscosity increase during the first minutes of heating at 96°C, and as to viscosity after cooling down to 50°C (group I — ca. 800 mPa·s, group II — ca. 600 mPa·s, group III — ca. 500 mPa·s, group IV — ca. 200 mPa·s).

Table 3. Limiting viscosity [η] of triticale starch pastes determined with the Übbelohde-Rafikow viscosimeter

Sample No.	[η] g/100 cm^3/$^{-1}$	Sample No.	[η] g/100 cm^3/$^{-1}$	Sample No.	[η] g/100 cm^3/$^{-1}$
1	1.57	20	2.20	39	2.56
2	1.55	21	2.74	40	2.03
3	2.06	22	1.01	41	1.67
4	1.53	23	1.79	42	1.72
5	1.86	24	0.77	43	1.10
6	1.86	25	2.30	44	1.53
7	1.66	26	1.53	45	2.09
8	1.92	27	2.03	46	2.05
9	2.30	28	2.02	47	1.57
10	2.43	29	1.23	48	1.52
11	2.40	30	1.20	49	1.90
12	1.78	31	2.12	50	2.06
13	1.98	32	2.07	51	1.62
14	1.46	33	0.88	52	2.08
15	2.13	34	2.31	53	1.79
16	2.05	35	2.32	mean value	for triticale
17	2.10	36	2.05		
18	3.32	37	2.10	G_1	1.97
19	1.56	38	1.46	G_2	1.87

The pasting characteristic curves of pastes of the standard „Grana" wheat starches were similar to those of triticale starch in group III.

We also measured the pasting characteristic for four triticale starches representing all the groups mentioned above and for one standard starch of the „Grana" wheat using a Brabender amylograph (Fig. 2). The amylographic curves of all the starches were of the same shape: after attaining the maximum the paste viscosity remained considerably stable troughout the 20-min heating at 96°C and then sharply increased during the cooling down to 25°C.

The curves conformed to the typical shapes known from the literature on cereal starches. There were deviations from the typical shape of the pasting characteristics obtained with the viscosimeter Rheotest 2 and these consisted in a drop of viscosity after passing the viscosity maximum. This is most probably due to the more severe destruction of the paste structure in the rotary viscosimeter Rheotest 2.

Basing on the pasting characteristic determined in both the viscosimeters, we may claim that the triticale starch pastes were stable during boiling (in the viscosimeter Rheotest 2 after 2-3 min of heating the pastes at 96°C).

Starches from seven triticale breeding lines (22, 24, 29, 30, 33, 43 and 44) were interesting from the theoretical viewpoint: they exhibited lowest viscosity in all points of the pasting characteristics. The samples probably came from grains of higher enzymatic activity which caused that the obtained starches were partly decomposed by enzymes already in the cereal grains or during the extraction of starch. This hypothesis was also confirmed by determinations of limiting viscosity of the pastes of these

Table 4. Correlation coefficients (r) for dependences between triticale starch properties at significance level $\alpha = 0.01$

Dependence between	Pasting temperature (R)	Solubility in water at 60°C	Maximum viscosity	$\Delta\eta$96°C = = viscosity at 96°C minus viscosity maximum	„n" constant
Maximum viscosity	-0.52	-0.83		+0.84	
Viscosity at 96°C		-0.40			
Viscosity after 20 min at 96°C		-0.61			
Viscosity at 50°C	-0.53	-0.85	+0.94	+0.78	
$\Delta\eta$ 50°C — viscosity at 50°C minus viscosity after 20 min at 96°C			+0.90	+0.91	
„K" constant*)		-0.67			-0.31
Limiting viscosity [η]	-0.63	-0.68			

*) For significance level α — 0.05

starches which was also considerably lower than in the remaining samples (Table 3).

Table 3 presents the values of limiting viscosity of all the studied starches. The triticale starches differed greatly in this respect: the results ranged from 0.77 to 3.32 [g/100 $cm^3/^{-1}$] with a mean of 1.82 [g/100 $cm^3/^{-1}$]. The limiting viscosity of "Grana" wheat starch was 1.97 and 1.87 [g/100 $cm^3/^{-1}$].

All the obtained results were analysed statistically (Table 4). This analysis showed that the greater the maximum viscosity of pastes the greater was the viscosity drop (maximum viscosity minus viscosity at 96°C) r = 0.84 and the greater was the increase of paste viscosity during its cooling to 50°C (viscosity at 50°C minus viscosity after 20 min at 96°C) r = 0.90. There was also another dependence: the higher the temperature of pasting measured in the Rheotest 2 viscosimeter the lower was the viscosity of pastes at the maximum (r = -0.52 and after cooling to 50°C (r = -0.53). These dependences indicate that when starch undergoes pasting with difficulty (i.e when it has a higher pasting temperature *) and hence a stronger grain structure) the resultant pastes do not attain high viscosity values. In such a case the paste structure is strong and there is no loss of viscosity in elevated temperatures and there is no viscosity increase during cooling.

The positive correlation coefficients between limiting viscosity and viscosity maximum (r = 0.58) and between limiting viscosity and viscosity at 50°C (r = 0.66) confirm the interdependence between starch paste viscosities measured with different methods, in different instruments and at various concentrations.

The overall conclusion is that the obtained results of measurements of viscosity of pastes from the starch of Polish triticale breeding lines indicate that the starch from this new cereal is suitable for processing.

CONCLUSIONS

1. The starches of Polish breeding lines of triticale displayed various viscosities. Most of them were more viscuous than pastes of standard wheat starch.

2. Triticale starch pastes were stable during heating at 96°C and their viscosity increased greatly during cooling; this is indicative of their increased tendency to undergo retrogradation.

3. Pastes from starches of seven triticale breeding lines were marked by very low viscosity which might have been due to an enzymatic decomposition of starch already in the cereal grains.

*) This pertains to the viscosimetric determination of pasting temperature, in our case in the viscosimeter Rheotest 2.

4. Statistical analysis revealed significant dependences (at significance level $\alpha = 0.01$) between:

— maximum paste viscosity and viscosity decrease during heating (maximum viscosity minus viscosity at 96°C) — $r = +0.84$,

— maximum paste viscosity and viscosity increase during cooling (viscosity at 50°C minus viscosity after 20 min at 96°C) — $r = +0.90$.

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WŁAŚCIWOŚCI FIZYCZNE SKROBI PSZENŻYTA.
I. CHARAKTERYSTYKA KLEIKOWANIA SKROBI

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

Przebadano skrobie wyodrębnione metodą laboratoryjną z 53 polskich rodów pszenżyta i dwóch odmian pszenicy „Grana" stanowiących wzorzec. Skrobie te przebadano pod względem: temperatury kleikowania (metodą mikroskopową), charakterystyki kleikowania w wiskozymetrze rotacyjnym Rheotest 2 oraz wiskografie Brabendera i lepkości granicznej.

Wykresy charakterystyki kleikowania skrobi pszenżyta, otrzymane w amylografie Brabendera, miały typowe kształty znane z literatury dla skrobi zbożowych (rys. 2). Natomiast inne kształty krzywych tej charakterystyki otrzymano za pomocą wiskozymetru rotacyjnego Rheotest 2. Odchylenia od typowego kształtu polegały na znacznym spadku lepkości po przekroczeniu maksimum lepkości (rys. 1). Ze względu na zróżnicowany kształt tych krzywych podzielono badane skrobie na 4 grupy.

Z praktycznego punktu widzenia interesujący był fakt, że ponad 60% kleików skrobi pszenżyta odznaczało się lepkością maksymalną oraz lepkością w temp. 50°C wyższą od wzorcowych kleików skrobi pszenicy „Grana" (tab. 2). Ponadto kleiki skrobi pszenżyta były stabilne podczas gotowania oraz wykazywały dużą tendencję do retrogradacji.

Z teoretycznego punktu widzenia interesujące były skrobie 7 rodów pszenżyta, które odznaczały się najniższymi lepkościami swoich kleików we wszystkich punktach charakterystyki kleikowania. Wydaje się, że skrobie te były częściowo rozłożone przez enzymy jeszcze w ziarnie zbożowym lub podczas wyodrębniania skrobi. Hipotezę tę potwierdziły wyniki lepkości granicznej kleików tych skrobi, które były znacznie niższe od pozostałych próbek (tab. 3).

Wszystkie otrzymane wyniki poddano analizie statystycznej i obliczono współczynniki korelacji pomiędzy badanymi właściwościami skrobi pszenżyta (tab. 4).