A C T A A L I M E N T A R I A P O L O N I C A

Vol. XII (XXXVI), No. 2 1986

ANNA NOWOTNA
MIECZYSŁAW PAŁASIŃSKI

PHYSICO-CHEMICAL CHARACTERISTIC OF STARCH IN SOME SOLANUM SPECIES *)

Institute of General Chemistry and Food Technology, Hugo Kołłątaj Agricultural Academy, Kraków

Key words: wild potato varieties, uncultivated potato varieties physico-chemical characteristics of starch.

The physico-chemical properties of starch in some uncultivated potato varieties were determined. No significant differences were found between the examined samples and cultivated potato starches except for a lower content of amylose in some samples and certain variations in the morphology of starch grains.

Wild and uncultivated potato varieties are used in plant breeding as initial forms for hybridization in view of their favourable immunity properties [1, 14, 18, 19, 22]. In addition, there are reports in the literature [4, 12, 15] that some wild and uncultivated primitive Solanum forms are marked by a high starch content, sometimes even in excess of 30%. Studies of amylose and amylopectin contents [7, 16] showed them to be more varied than in cultivated potatoes.

The uncultivated potato varieties have attracted the attention of Polish breeders in the past few years. They were studied, among others, by the Scientific Research Division of the Potato Institute in Młochów [18, 19, 22]; properties of wild and uncultivated Solanum varieties important in potato industry were investigated by the Institute of General Chemistry and Food Technology of the Agricultural Academy in Cracow [21]. Particular attention was devoted to various clones of *Solanum chacoense* [11] and physico-chemical properties of their starches were characterized. The data published so far are incomplete and it thus seemed worthwhile to launch more comprehensive studies of more diversified biological material.

*) The work was submitted to the International Symposium "Fundamental Studies in Starch Chemistry", Bratislava, 1979.

MATERIAL

The studied potato samples (Table 1) came from the fields of the Potato Institute in Młochów near Warsaw. The varieties belong to the series Commersoniana, wild Tuberosa and Hybrids (Haploid Wulkan x *S. chacoense* PK 133). Moreover, potatoes of the Lenino variety and industrial starch from the Potato Industry Plant in Trzemeszno were used as standards.

Table 1. Botanic origin of the studied Solanum samples

Serial No. of sample	Symbol of sample	No. of clone	Name and origin of species
Commersoniana series			
1	LII-37p	31/31	*S. chacoense* (schickii)PK*/133
2	LII-39p	31/48	*S. chacoense* (schickii)PK*/133
3	LII-41p	31/93	*S. chacoense* (schickii)PK*/133
4	LII-15p	60/9	*S. chacoense* (gib/GLKS**)66.51/6/6
5	LII-76	—	*S. tarijense* Hof. 1902
6	LII-29p	73/9	*S. yungasense* GLKS** (67.107)3R
Tuberosa wild series		—	
7	LIII-35i	—	*S. berthaultii* PI***) 265857
8	LIII-36i	—	*S. berthaultii* PI***) 265857
9	LIII-61i	—	*S. spergazinii* Hof. 1754
Hybrids		—	
10	LII-54p	35/32	$D_3 \times A_3$ (Haploid Wulkan × *S. chacoense* PK*)133)
11	LII-62p	35/58	,, ,, ,, ,,
12	LII-63p	35/59	,, ,, ,, ,,
13	LII-64p	35/60	,, ,, ,, ,,
14	LII-66p	35/76	,, ,, ,, ,,
Potato of Lenino variety		—	
15	LII-26p	—	
16	LII-93p		
Starch from Institute Trzemeszno Plant			
17			

*) Collection Laboratory of Potato Institute in Bonin, Poland

**) Potato Collection Laboratory Institute of Plant Breeding in Gross-Lusewitz, GDR

***) Plant Introduction, Wisconsin, USA

METHODS

Starch was extracted from the potato samples by the laboratory method [17]. The following determinations were made:

— total phosphorus content by Marsh's method [8];

— amylose content by the method of "blue value" [13, 23];

— graininess by determining grain size under a lanometer-type projection microscope, and by determining the weight percentage of the fraction of grains with diameter of $\geqslant$ 30.7 μm with a Sartorius sedimentation scales;

— temperature of gelatinization on a microscope with a heating stage [13], and by the viscosimetric method; the temperature at the first increase of viscosity ($\alpha \neq 0$) perceptible on a Rheotest 2 viscosimeter during the heating of starch suspension mixed with the speed 12a = 243 r.p.m. was assumed as the temperature of gelatinization;

— 0.3% reduced viscosity of paste prepared by Leach's alkaline method [6], on an Ostwald capillary viscosimeter;

— characteristic of gelatinization on a Rheotest 2 rotary viscosimeter modified according to Koubek [5] by adding a mixing device; the gelatinization characteristic determination was based on Winkler's method [25], with the mixing device being replaced by the measuring cylinder (S1) when $\alpha = 30$ units on the apparatus' scale; during determination the temperature rose from 50 to 96°C at a rate of about 1°C min on the average, the temperature of 96°C was maintained for 20 min, and then the paste was cooled down to 50°C at the rate of 3°C min; paste of 7% dry substance concentration was used in the assay of gelatinization characteristic;

— grain morphology under a microscope.

RESULTS

The obtained results are presented in Tables 2 and 3. We can see that the total phosphorus content in the investigated starches does not differ from that reported in literature for starch in cultivated potatoes [9]. The highest content was in two starches from S. Commersoniana (Nos 5 and 6), but the most even and at the same time high phosphorus contents were found in starches isolated from the Hybrids.

The amylose content in the studied starches is low compared to this content in cultivated potatoes [9]. Particularly low values were found in two samples of *S. berthaultii* (Nos 7 and 8) and in one sample of *S. tarijense* (No. 5).

The analysis of graininess of the investigated starches showed them to be fairly diversified in this respect. In addition to coarse-grained starches

Table 2. Content of total phoshorus, amylose and starch graininess

No.	Total phosphorus mg P/100 g dry matter	Amylose % dry matter A	Graininess of starch: estimated by microscopic method (diameter in μm)		Graininess of starch: estimated by sedimentation method
			longest	shortest	grain % by weight Ø ≥ 30.7 μm
1	70	19	84	6	56
2	79	17	85	4	65
3	87	18	100	5	54
4	59	18	95	4	50
5	132	12	83	3	52
6	120	19	73	3	17
7	112	13	94	3	30
8	118	13	78	4	25
9	78	18	88	3	23
10	102	15	82	8	51
11	102	15	80	4	57
12	92	17	—	—	55
13	88	16	97	3	49
14	84	17	86	5	42
15	78	19	77	3	58
16	78	18	71	3	28
17	64	—	—	—	—

(nearly all samples from the Commersoniana and Hybrid series) there were fine-grained starches (No. 6 of the Commersoniana series, and the wild Tuberosa series).

The grain size range in the studied starches is similar to that in the starch of cultivated potatoes [9] (Table 2). There are differences, however, in grain shape. In some of the investigated starches the microscope revealed irregularly shaped grains (elongated, spindle-shaped, triangular — Figs 1, 2).

The gelatinization temperature range (Table 3) determined microscopically is not much different from the values for the starch in cultivated potatoes [9]; only in some starches (Nos 7 and 8 of the wild Tuberosa series) there was observed an increase of temperature of the end of gelatinization by several degrees Centigrade. The gelatinization temperature determined viscosimetrically (Rheotest 2) also varies widely. The obtained results cannot be compared with the findings of other authors because of the different measurement methods, apparatus and concentration used [5, 20, 25]. The highest temperatures of gelatinization beginning (t_o), of the end of gelatinization (t_1), and of the gelatinization temperature determined viscosimetrically (R_{tk}) were found in samples 7 and 8 of the

Table 3. Gelatinization temperatures and pasting characteristics

No.	Pasting temperature			R_{tk}(°C)**) pasting temperature	R_{max} (mPa · s) viscosity peak	$R_{t\,max}$(°C) temperature at maximum viscosity	$R_{96°0}$ (mPa · s) viscosity at 96°C	$R_{96°20}$ (mPa · s) viscosity after 20 min. at 96°C	$R_{50°0}$ (mPa · s) viscosity at 50°C	Reduced viscosity η
	t_0(°C) start	t_1(°C) end	t_1-t_0							
1	57.5	68.0	10.5	63.5	1858	78.0	1310	917	1264	3.20
2	60.0	68.0	8.0	65.0	2206	82.5	1602	1139	2729	2.87
3	59.5	69.0	9.5	65.5	2109	83.5	1587	1164	2833	2.53
4	57.0	66.0	9.0	61.0	1639	71.5	994	621	1713	2.30
5	63.0	70.0	7.0	67.5	1960	74.5	1290	871	1911	1.73
6	61.0	71.0	10.0	66.5	1802	88.5	—	—	2949	2.13
7	64.0	73.0	9.0	69.5	822	76.0	687	550	1093	1.90
8	63.0	73.0	10.0	70.5	1193	86.5	1139	982	2176	2.03
9	57.5	67.0	9.5	62.5	1454	80.5	945	550	1647	2.73
10	61.0	69.5	8.5	65.5	2400	82.5	1722	1,277	2719	2.67
11	61.0	68.0	7.0	65.0	2326	76.0	1539	1,052	2384	2.33
12	61.0	69.0	8.0	66.0	1969	88.5	1775	1,193	3114	2.47
13	61.0	68.0	7.0	65.0	2415	80.0	1688	1,242	2787	2.73
14	57.5	69.5	12.0	65.5	2158	78.5	1467	1,043	2732	2.73
15	59.0	68.5	9.5	65.0	2264	75.5	1533	1,103	2768	3.23
16	59.5	67.5	8.0	64.0	2351	73.0	1397	1,019	2661	3.17
17	—	—	—	61.5	1305	72.5	727	510	1477	2.67

*) Estimated by microscopic method
**) Estimated by viscosimetric method (Rheotest 2)

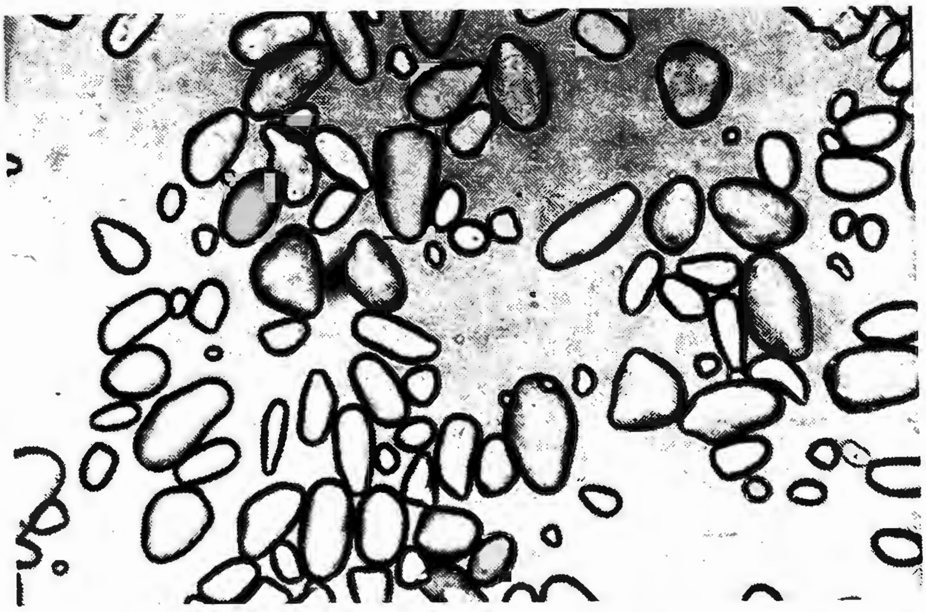

Fig. 1. Microscopical appearance of starch grains — magnification × 240 (series Tuberosa wilde — *Solanum berthaultii* No. 7)

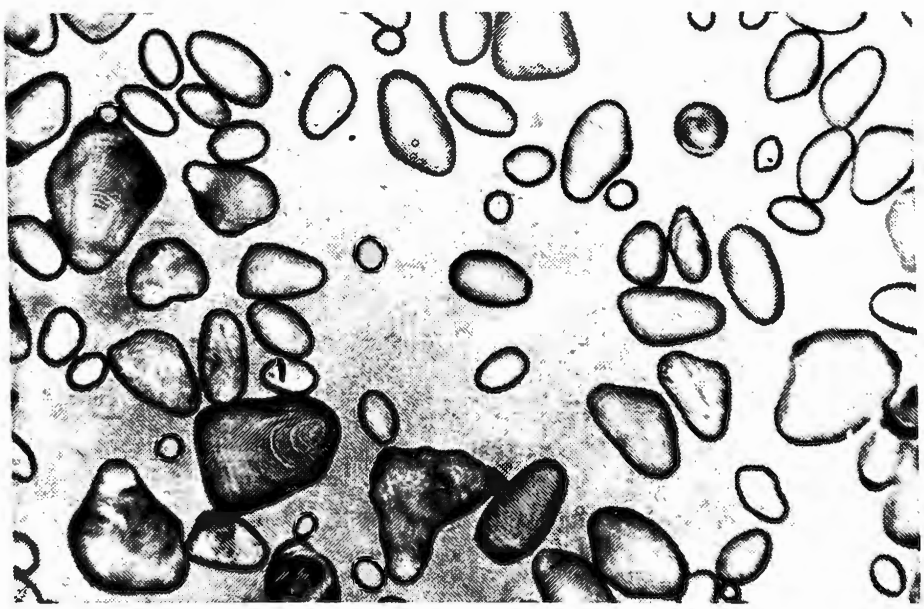

Fig. 2. Microscopical appearance of starch grains — magnification × 240 (series Commersionana — *Solanum chacoense* No. 2)

wild Tuberosa series and in sample 5 of the Commersoniana series. The results show a good agreement between the gelatinization temperature range determined microscopically and the gelatinization temperature assayed viscosimetrically. Also observed was the $t_1 > R_{tk}$ relation given by Göring [13].

The characteristic of gelatinization on the rotary viscosimeter is presented in Table 3. As can be seen, the starches of the Hybrids display the highest viscosity values (on the level of the Lenino standard), smaller values are found in the Commersoniana series, and the lowest — in the wild Tuberosa series (on the level of the starch standard from the Potato Industry Plant in Trzemeszno). This dependence is observed in all measurement points. The R_{tmax} values vary considerably within each series. Most of the studied samples have R_{tmax} higher than in the standard. It seems that Winkler [25] is right in claiming that maximum viscosity and temperature at maximum viscosity are to be regarded as characteristic indices of starch viscosity in view of the considerable variance of these values. Our results additionally indicate that, given, its even greater variability, the viscosity at 50°C should also be considered a characteristic magnitude.

The results of reduced viscosity analysis remain on the level of the standards: one starch of the Commersoniana series (No. 1) is characterized by viscosity comparable to that of the Lenino standard, whereas the viscosity of the remaining starch samples is similar to that of the industrial starch standard from the Potato Industry Plant in Trzemeszno. The exceptions are starch No. 5 of the Commersoniana series and starch No. 7 of the wild Tuberosa series which were least viscuous.

The obtained results were analysed statistically to find whether there are dependences between the studied starch properties. The calculations demonstrated the significance of the following corelations (r — coefficient of corelation, the values in parentheses are corelation significances, t — error of corelation coefficient):

1) between reduced viscosity of starch paste ($\eta_{red.}$) and the total phosphorus content (P) in starch; the corelations here are negative: $r = -0.76$ (0.01) $t = 0.11$. This observation is in disagreement with the views held heretofore by Winkler and Pałasiński [10, 24]. This discrepancy observed by us in starches in uncultivated Solanum varieties may be due to genetical factors. The fact that in analysing this dependence we did not take into consideration factors such as cation content in the investigated starches and starch particle size, both of which have a decisive effect on the viscosity of starch gelatin, apparently also has a bearing on the result;

2) between reduced viscosity ($\eta_{red.}$) and the temperature of gelatinization beginning (t_o): $r = -0.71$ (0.01) $t = 0.13$;

3) between gelatinization characteristic points:

— viscosity maximum (R_{max}) and viscosity minimum ($R_{96°,20}$): $r = 0.73$ (0.01) $t = 0.12$;

— viscosity maximum (R_{max}) and viscosity at 50°C ($R_{50°}$): $r = 0.75$ (0.01) $t = 0.12$; and

— viscosity minimum ($R_{96°,20}$) and viscosity at 50°C ($R_{50°}$): $r = 0.68$ (0.01) $t = 0.14$.

This indicates that the gelatinization curves of the studied samples are all similar in nature, and that the absolute value of viscosity is responsible for the shift of the gelatinization curve with respect to the X-axis;

4) between the temperature of gelatinization beginning (t_o) and total phosphorus content (P): $r = 0.86$ (0.001) $t = 0.07$;

5) between gelatinization temperature (R_{tk}) determined viscosimetr-

ically (on a Rheotest 2 apparatus) and the total phosphorus content (P): $r = 0.82$ (0.001) $t = 0.09$;

6) between total phosphorus content (P) and amylose content (A): $r = 0.70$ (0.01) $t = 0.14$;

7) between amylose content (A) and temperature of gelatinization beginning (t_o): $r = -0.80$ (0.01) $t = 0.10$;

8) between amylose content (A) and gelatinization temperature (R_{tk}) determined viscosimetrically (on a Rheotest 2 apparatus): $r = -0.72$ (0.01) $t = 0.13$.

No dependence was observed between viscosity and graininess of grain both for viscosity measured with the Ostwald capillary viscosimeter and viscosity measured with the Rheotest 2 rotary viscosimeter. This is in agreement with literature [10] according to which this dependence is correct only for material segregated with regard to grain size.

CONCLUSIONS

1. The starches from the studied samples belonging to two Solanum series (Commersoniana and wild Tuberosa) and the Hybrid series Haploid Wulkan × S. Chacoense differed considerably as to physico-chemical properties. They were not, however, essentially different from starches of cultivated potatoes in properties such as total phosphorus content, gelitinization temperature and grain size range. The viscosity of paste and starch grain size is also not much different than in the Lenino standard. The only difference was a lower amylose content in some samples (*S. tarijense* No. 5, and *S. berthaultii* Nos 7 and 8). A part of the grains in uncultivated Solanum varieties are shapped irregularly (cylinder- or spindle-shaped, triangular).

2. The following are interesting from the point of view of starch industry as cross-breeding components:

— samples of *S. chacoense* (schickii) of the Commersoniana series thanks to large grain size of the starch, good phosporus content, and viscosity of starch paste;

— the Hybrids in view of high phosphorus content and advantageous grain size and paste viscosity.

3. Interesting from the theoretical viewpoint are the *S. berthaultii samples* (wild Tuberosa series) with their properties visibly different from those of cultivated varieties: their paste are marked by low viscosity, the grain size is good, and the phosphorus content is high.

4. Statistical calculations demonstrated significant corelations between the following properties of starch:

— reduced viscosity of paste and total phosphorus content,

— reduced viscosity of paste and gelatinization temperature,

— total phosphorus content and gelatinization temperature,
— total phosphorus content and amylose content.

LITERATURE

1. Birecki M.: Ziemniaki. PWRiL, Warszawa 1964, 9.
2. Blinc M., Cimerman A., Pertot E., Stucin D.: Die Stärke 1971, **23**, 395.
3. Göring K. J., Fritts D. H.: Cereal Chemistry 1974, **51**, 764.
4. Kameraz A. J.: Vestnik Socjalisticeskogo Rastieniovodstva 1940, 4, 13.
5. Koubek I.: Die Stärke 1974, **26**, 81.
6. Leach H. W.. Cereal Chemistry 1963, **40**, 593.
7. Łukovnikowa G. A., Samorodova-Bianki G. B.: Vestnik Sielskochozjajstviennoj Nauki 1964, **9**, 40.
8. Marsh B. B.: Biochimica et Biophisica Acta 1959, **32**, 357.
9. Nowotny F. et al: Skrobia. WNT, Warszawa 1969, 26, **28**, 117, 155.
10. Pałasiński M.: Acta Agraria et Silvestra, Seria Rol., 1964, **4**, 151.
11. Pałasiński M., Sochocka J., Warchoł M.: Zeszyty Problemowe Postępów Nauk Rolniczych 1977, **191**, 137.
12. Prokosev S. M., Mattison N. J.: Vestnik Socjalisticeskogo Rastieniovodstva 1940, 4, 61.
13. Richter M., Augustat S., Schierbaum F.: Ausgewählte Methoden der Stärkechemie, VEB Fachbuchverlag, Leipzig 1968, 104.
14. Roguski K.: Hodowla Ziemniaka. PWRiL, Warszawa 1966, 7.
15. Rothacker D.: Sortiment wider und kultivierter Kartoffelspecies des Institutes für Pflanzenzüchtung, Gross-Lüsewitz, Teil II Untersuchungsergebnisse. DAL Institut für Pflanzenzüchtung Gross-Lüsewitz 1968.
16. Rothacker D., Effmert E.: Theoretical and Applied Genetics 1968, **38**, 309.
17. Samotus B., Pałasiński M.: Zeszyty Naukowe WSR w Krakowie, Rolnictwo 1958, 5, 119.
18. Sawicka E.: Zeszyty Problemowe Postępów Nauk Rolniczych 1971, **118**, 67.
19. Sawicka E., Lipski A., Milej-Pietkiewicz M.: Genetyka i Hodowla Ziemniaka. VIII Sesja Naukowa w Koszalinie. Instytut Ziemniaka, Bonin 1975, 58.
20. Schierbaum F.: Die Stärke 1965, **17**, 324.
21. Sochocka J., Federowicz T., Pałasiński M., Warchoł M.: Roczniki Technologii i Chemii Żywności 1974, **24**, 297.
22. Świeżyński M. K.. Postępy Nauk Rolniczych 1972, **19/24**, 95.
23. Ulman M., Augustat S.: Zeitschrift für Analytische Chemie 1958, **162**, 337.
24. Winkler S.: Die Stärke 1961, **9**, 319.
25. Winkler S., Luckow G., Donie H.: Die Stärke 1971, **23**, 235.

Manuscript received: August 1980.
Authors address: 30-059 Kraków, Mickiewicza 24/28.