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Differences in the Properties of Potato Starch as an Effect of the Application of Herbicides in Potato Cultivation

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ABSTRACT

Triazine herbicides (Sencor, Bladex and Topogard) and urea preparations (Afalon, Patoran and Monorotox), used in the cultivation of four potato varieties, influenced both chemical composition and physical properties of the subsequent starch. All herbicides except Sencor caused changes in the starch granularity. Bladex increased the number of granules larger than 35 μm and the average diameter of the granules. Topogard increased the number of granules less than 10 μm and 20 μm in diameter and decreased the number of 20–35 μm granules and the average diameter of the granules. Urea preparations resulted in a decreased number of granules smaller than 20 μm, while Afalon decreased the number of granules larger than 35 μm and increased the 20–35 μm granules; Monorotox increased the number of granules larger than 35 μm and the average diameter of the granules. All herbicides decreased the viscosity of 0·25% starch pastes and Topogard decreased the amylose content of the starch.

INTRODUCTION

Herbicides, applied in potato cultivation in order to control the growth of weeds, also affect the main yield. Penetrating the tissues, they promote

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disorders in the metabolism of potato plants and, consequently, they can change the chemical composition of the tubers, affecting, among other things, the starch content (Roth, 1968; Leszczyński & Lisińska, 1983).

Earlier studies, on starch separated from the potato tubers treated with herbicides during cultivation, have indicated that the herbicides could affect the properties of the resulting starch. Various herbicides used in these studies, mainly in the Silesian region, affected the content of amylose, the mineral components of starch, viscosity in 0·25% starch pastes and the size of starch granules (Leszczyński, 1977; Leszczyński & Kierat, 1984). Increasingly frequent use of herbicides in potato cultivation requires comprehensive studies on the effects of their application, including properties of the starch obtained from the tubers treated with the herbicides.

The purpose of the present study was to examine the influence of several triazine and urea herbicides, applied in potato cultivation, on the chemical composition and several physical properties of the starch separated from the tubers.

MATERIALS AND METHODS

Materials

The experimental material comprised starch separated from potato tubers treated with herbicides during cultivation, obtained from the Institute of Potato in Bonin, near Koszalin. Experiments were carried out for two years on four potato varieties—Narew, Sokół, Sowa and Pola—treated with the following herbicides:

From the group of triazines:		
Sencor	70% metribuzin	2·25 kg/ha
Bladex	50% cyanazin	6·00 kg/ha
Topogard	35% terbutrin + 15% terbulazin	4·5 kg/ha
From the group of urea preparations:		
Afalon	50% linuron	3 kg/ha
Patoran	50% metobromuron	4·5 kg/ha
Monorotox	50% monolinuron	3 kg/ha

The herbicide doses used in the experiments were 50% greater than optimal.

The samples were analysed after about 6 weeks' storage at 10–12°C. The tubers (2–3 kg) were crushed on a mechanical rasp and then in a kitchen mixer at 10 000 rpm for 1 min. Starch was rinsed with distilled water, in a fourfold amount in relation to pulp weight, on starch gauze. After sedimentation of the starch, the supernatant was decanted and the sediment was added to distilled water (25–30 times the weight of the starch). After resedimentation, the supernatant was decanted again and this process was repeated. Starch, thus purified, was dried at 20–25°C; small clods were crushed in a mortar and stored for 3 months at about 20°C. Subsequently, starch was sieved (0·108 mm mesh) and then sampled for the analysis.

Methods

The following determinations were carried out.

The content of matter by drying at 60°C and then at 105°C.
Amylose content—gravimetrically after electrodialytic separation of 1% starch paste (Sroczyński, 1954).
Phosphorus content—after wet mineralization by the colorimetrically modified vanado-molybdate method (Turyna & Tyszkiewicz, 1964).
Potassium content—by means of a flame photometer.
Relative viscosity of 0·25% starch pastes on an Ostwald viscosimeter (Sroczyński, 1954).
Viscosity of 7% starch pastes, measured at 80°C, on a rotary viscosimeter (Rotowisko RV3, Haake), with a pinwheel (Winkler *et al.*, 1971).
Granularity on a sedimentation balance (Sartorius), using methanol in the liquid phase. The average diameter of the starch granules was calculated as the mean of granules of 10–60 μm.

The results of the determination were statistically analysed, which was the basis for determining the significance of the differences resulting from the use of herbicides. These are shown, with their least significant differences, in the accompanying tables

RESULTS

Table 1 shows average results for the determinations of starch chemical composition and viscosity of pastes obtained from the starch.

TABLE 1
Influence of Herbicides Applied in Potato Cultivation on Chemical Composition of Potato Starch and Viscosity of Starch Pastes

Herbicide	*Water* (%)	*Amylose* % *of dry matter*	P_2O_5 10^{-3}% *of dry matter*	K_2O 10^{-3}% *of dry matter*	*Viscosity of starch pastes*	
					0·25% t/t_0	*7%* *Pa s*
Control	12·97	17·45	179	77	6·07	1·65
Sencor	12·73	17·96	173	76	4·50[b]	1·62
Bladex	13·08	17·11	168	80	5·04[b]	1·64
Topogard	13·05	16·44[b]	172	79	4·68[b]	1·80
Afalon	12·90	17·30	170	81	5·09[b]	1·76
Patoran	12·38	17·19	166	80	4·34[b]	1·66
Monorotox	12·86	17·23	164[b]	77	5·10[b]	1·74
Least significant difference	[a]	0·73	(14)[a]	[a]	0·74	[a]

[a] No significant difference.
[b] Significant differences from the control samples.

As can be seen in the table, only Topogard affected amylose content, causing a decrease. The amount of phosphorus in the starch did not undergo significant changes after application of the herbicides. However, the calculated least significant difference was lower than the difference between the phosphorus content in the starch from the tubers of the control samples and starch from the tubers treated in cultivation with Monorotox. This indicates a tendency to decrease the content of phosphorus in the starch affected by this herbicide. 0·25% pastes, made from the tubers treated with herbicides, had lower viscosities than pastes from the starch of control samples. On the other hand, no effects of herbicides on the viscosities of 7% starch pastes or the contents of potassium and water in the starch were observed.

Table 2 presents the granularity analysis of starch from the potato tubers treated with herbicides during cultivation. The results, for the samples treated with herbicides and significantly different from the control samples, are presented in Fig. 1. They are presented as deviations of the contents of several fractions of the granules from the control samples, in per cent.

As can be seen in Fig. 1, almost all herbicides used in the experiment

TABLE 2
Influence of Herbicides Applied in Potato Cultivation on Granularity of Potato Starch

Herbicide	*Contents (%) of starch granules of diameter*					*Average diameter of granules*
	> 35 μm	*20–35 μm*	*< 20 μm*	*10–20 μm*	*< 10 μm*	*(μm)*
Control	30·43	57·81	11·76	6·16	5·60	32·79
Sencor	31·63	58·45	9·92	5·40	4·52	33·23
Bladex	40·23[a]	49·67[a]	10·10	5·06	5·04	35·11[a]
Topogard	30·73	52·45[a]	16·82[a]	7·25[a]	9·07[a]	31·48[a]
Afalon	25·66[a]	65·19[a]	9·15[a]	4·70[a]	4·45	32·29
Patoran	31·94	59·34	8·72[a]	4·17[a]	4·55	33·73
Monorotox	36·58[a]	53·84	9·58[a]	5·37	4·21	34·90[a]
Least significant difference	3·62	4·24	1·87	1·42	1·52	1·00

[a] Significant differences from the control samples.

affected the starch granularity. Two triazine preparations, i.e. Bladex and Topogard, decreased the fractions of average granules (20–35 μm) by 16% and 9%, respectively, in relation to the control samples. In the samples treated with Bladex, a 32% increase of large granules (larger than 35 μm) was observed whereas the samples treated with Topogard had a remarkable increase in amounts of small granules, i.e. a 63%

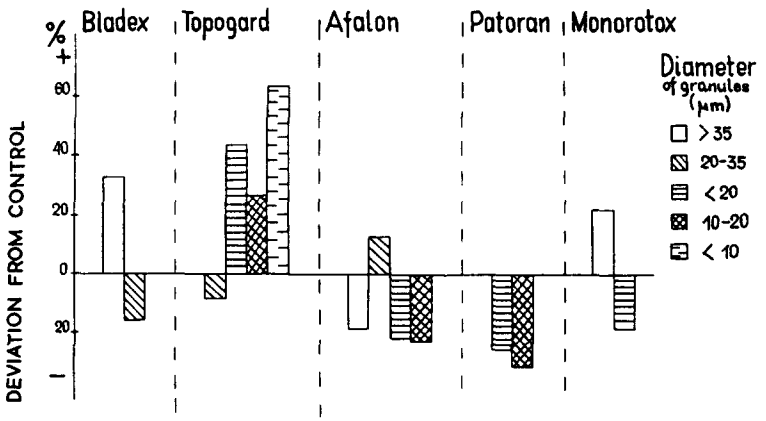

Fig. 1. Effect of herbicides on content of granules of different diameters in potato starch in relation to control.

increase of granules smaller than 10 μm, a 26% increase of granules 10–20 μm in diameter and a 43% increase of granules smaller than 20 μm.

All three urea preparations used in the experiment reduced the amounts of small granules (fractions of the granules smaller than 20 μm) by 19%–26% and Afalon and Patoran resulted in 23% and 32% decreases in the fractions of 10–20 μm diameter granules, in relation to the control. Moreover, Afalon reduced the amount of large granules (>35 μm) by 20% and increased the 20–35 μm granules by 12%, while Monorotox caused a 20% increase in the large granules.

Table 2 also shows that the use of herbicides in potato cultivation affected the average diameter of starch granules. The starch samples from the tubers treated with Bladex and Monorotox were composed of granules 2 μm larger than those of the control samples, while the granules of the samples treated with Topogard were 1 μm smaller than those of the control samples.

TABLE 3

Influence of Herbicides Applied in Cultivation of Different Potato Varieties on the Content of Large Starch Granules (>35 μm). (%)

Potato variety	*Control*	*Sencor*	*Bladex*	*Topogard*	*Afalon*	*Patoran*	*Monorotox*	*Least significant difference*
Narew	26·09	32·77	35·33[a]	22·46	26·92	23·52	21·72	7·23
Sokół	25·89	28·51	39·92[a]	32·74	23·74	27·80	33·29[a]	7·23
Sowa	35·86	30·67	39·51	33·69	20·53[a]	31·88	45·18[a]	7·23
Pola	33·90	34·56	46·16	34·02	31·46	44·55[a]	46·13[a]	7·23
Mean	30·43	31·63	40·23[a]	30·73	25·66[a]	31·94	36·58[a]	3·62

[a] Results significantly different from the control.

In most cases, the effect of the herbicides on starch properties depended on the variety of potato. Table 3 gives examples of the most important (from a technological point of view) fraction of the granules, larger than 35 μm in diameter. The potato varieties examined showed various responses to the herbicides, both in direction and magnitude. Only in the case of the Bladex application did all the potato varieties show the same response, i.e. an increased amount of large starch granules. For the other herbicides, changes in the contents of these granules were different and depended on potato variety (Table 3).

DISCUSSION

The greatest changes in starch quality resulted from the use of Topogard followed by Afalon; these changes were unfavourable, especially in the case of Topogard.

Only a slight effect on potato starch was observed after the application of Sencor; this preparation did not result in any significant changes in starch granularity.

It is difficult to compare the results of the present experiment with those found in contemporary literature, as we can find very few studies by other authors on this subject. Several data obtained in the present study have been confirmed by our own earlier results. As in the present paper, a tendency to decrease the average diameter of starch granules was observed after the application of Topogard in potato cultivation (Leszczyński, 1977). According to the experimental results, Afalon reduced the number of larger than 35 μm granules and increased that of 20–35 μm granules. Similar results have been obtained in earlier studies (Leszczyński, 1977; Leszczyński & Kierat, 1984).

Also in earlier studies, diverse responses of various potato varieties to the herbicides were reported, together with subsequent changes in the properties of potato starch (Leszczyński, 1977). This can account for the lack of total agreement of the results obtained in this study with those obtained earlier.

The differences observed between the properties of starches separated from the tubers of the potato treated with herbicides during cultivation and control samples, are probably due to various growth processes during the plant's vegetation.

The herbicides applied are absorbed by the inner parts of plants and affect biochemical processes, enzymes and the processes connected with starch biosynthesis, thus changing the conditions of the formation of starch granules in the potato tubers. According to several authors, triazine herbicides increase phosphorylase activity in the plants (Singh & Salunkhe, 1970; Wu *et al.*, 1971) and Topogard is one of the herbicides restraining the activity of acid phosphate (Leszczyński & Golachowski, 1975). According to other authors, urea herbicides, i.e. linuron and monolinuron, active substances of Afalon and Monorotox, affect oxidative phosphorylation in the mitochondria of potato tubers (Ducruet & Gauvrit, 1978) and linuron inhibits the process of photosynthesis (Timofejev, 1978) and increases the phosphorus content, including the phosphorus of sugar esters (Sosnovaja *et al.*, 1978), in potato leaves.

Disturbances in enzymatic processes can be influenced by herbicides and their decay in a plant. Disturbances can also result from the activity of products of herbicide decay. A number of different herbicide metabolites (of varying toxicity) were found and their quantities in the potato plants, in relation to the residues of preparations such as Sencor (Callihan *et al.*, 1976) and Bladex (Beynon *et al.*, 1972) were considered significant.

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