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Original Research

Concentrations of Some Organic Acids in Potato Tubers Depending on Weed Control Method, Cultivar and Storage Conditions

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Abstract

Three-year-long field and storage experiments were carried out to evaluate changes in concentrations of some organic acids in 'Rywal' and 'Saturna' potato tubers as affected by herbicides used during the growing period. The tubers were stored for 3 and 6 months at 4ºC and 8ºC at relative humidity of 95%. The weed control method did not change acid concentrations in the tubers. However, significant differences between the cultivars were seen. 'Saturna' had a higher content of citric, tartaric and fumaric acids, while that of malic acid was lower than in the 'Rywal' cultivar. There was a negative correlation between organic acids under study and malic acid after the harvest. The storage period and a lower storage temperature promoted accumulation of malic acid in both cultivars. A reverse relationship was noted in the case of other acids under study. The highest decrease, up to 70%, was found for fumaric acid assessed after 6 months of storage of the 'Saturna' cultivar.

Keywords: organic acids, cultivars, herbicides

Introduction

Organic acids in potato tubers consist in total about 0.4-1.0% their fresh weight [1]. They are represented mainly by citric, malic, tartaric, oxalic, fumaric and succinic acids. Some of them play a catalytic role in the browning reactions. Organic acids are carbon compounds of high metabolic activity and numerous interrelations. Among other things, they participate in transformations of hydrocarbons. In plant tissues they normally occur as free compounds or as salts creating effective buffering systems. Usually they are concentrated in vacuoles, where to they are transported as energetic material. Some of them participate in the Crebs cycle, but there are organic acids that are not intermediate products of this cycle [2]. Together with free aminoacids, phenolic acids and others they are responsible for acidic reaction of the potato tuber cell sap, in which all the basic biochemical and physiological processes occur. The reaction of the sap ranges 5.6-6.2 and is negatively correlated with the concentration of reducing sugars [1]. According to the authors the content of citric acid in potato tubers is highest as compared with other acids. This acid plays an important role in oxidative processes as an antioxidant and synergent by inhibiting, together with ascorbic acid, the enzymatic browning process [3, 4]. Citric acid decreases, as well the tendency of the boiled tubers to darken.

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Table 1. Characteristics of the herbicides applied.

Weed control method	M-1-control – mechanical weed control before and after potato emergence			
	M-2 – mechanical weed control until emergence, and right before emergence the use of herbicide Afalon 50 WP (linuron) 2 kg·ha^{-1}	M-3 – mechanical weed control until emergence, and after emergence of herbicide Sencor 70 WG (metribuzin) 0.5 kg·ha^{-1} + adjuvant Olbras 88 EC 1.5 l·ha^{-1}	M-4 – mechanical weed control until emergence and a few days before emergence herbicide Azogard 50 WP (prometrin) 3 kg·ha^{-1}	M-5 – mechanical weed control until emergence, and after emergence spraying with herbicide Apyros 75 WG (sulphosulphuron) 26.5 g·ha^{-1} + adjuvant Atpolan 80 EC 1.5 l·ha^{-1},

Source: Czerniakowski Z, Czerniakowski Z.W., [23]; Praczyk T., Skrzypczak G. [14].

This phenomenon is the result of non-enzymatic processes of the oxidation (mainly by chlorogenic acid) of iron Fe (II) ions bound in colourless complexes with phenols to Fe (III), which causes them to become grey [5, 25]. Citric and other acids bind ferric ions, creating with them colourless complexes [1, 6-11]. Citric acid also has a positive effect on potato tuber tastiness, and it stimulates the excretion of gastric juices [12].

The important role played by organic acids in the potato was the main reason to undertake this study to evaluate their concentrations in the tubers of potatoes cultivated with different weed control methods after harvest and storage for 6 months.

Material and Methods

Potato tubers of two varieties were collected from the field experiment carried out in 2002-04 at the Mochelek Experimental Station of the University of Technology and Agriculture in Bydgoszcz. Two-factor trials settled on the soil of good rye complex in the system of triplicated randomized subblocks. The first factor was the ways of weed control system (Table 1), while the second was the medium-late potato cultivar 'Rywal' and 'Saturna'.

All the treatments were carried out according to the agrotechnological standards for potato cultivation. Plant protection toward diseases and pests were performed as indicated by the Plant Protection Institute, as well as the needs depending on the weather course.

Manure was applied in autumn in a dose of 25 t·ha^{-1}. All the mineral fertilizers were used in spring before potato planting in amounts that considered the nutritional needs of plants based on soil resources:

- nitrogen – 120 kg N·ha^{-1} as ammonium nitrate (34%),
- phosphorus – 110 kg P_2O_5·ha^{-1} as triple superphosphate (46%),
- potassium – 120 kg K_2O·ha^{-1} as potassium sulphate (50%).

Cereals constituted the potato forecrop. After harvesting fully matured tubers, according to the actual norm, 5 kg * five samples were collected from every experimental plot and than put in storage chambers at 8ºC and 4ºC and relative air humidity of 95%. The concentration of organic acids was assayed with HPLC immediately after the harvest and after 3 and 6 months of storage.

Table 2. Correlation coefficients of chosen organic acids after harvest.

Components	
Fumaric acid vs. tartaric acid	0.971**
Tartaric acid vs. citric acid	0.979**
Citric acid vs. malic acid	-0.915**
Malic acid vs. fumaric acid	-0.897**
Fumaric acid vs. citric acid	0.997**
Tartaric acid vs. malic acid	-0,959**

** = significant at P<0.01

The results were evaluated statistically with variation analysis according to the experimental scheme. The significance of the differences were assessed with Tukey test at the α=0.05. Standard deviations were calculated for means from plots (repetitions) of years of cultivation 2002, 2003, 2004. Comparison of the interrelationship among concentrations of organic acids in potato tubers was done by calculating the Pearson correlation coefficient.

Results

The use of herbicides over plant vegetation did not have any considerable effect on accumulation of the substances under study in the tubers, but some significant cultivar differences were noted. Tartaric, citric and fumaric acids were more abundant in the tubers of 'Saturna' than 'Rywal' cultivar, respectively about 37.7%, 14.9%, 29% and content 95.4 mg·100g^{-1} of fresh weight, 522.6 mg·100g^{-1} of fresh weight and 2.01 mg·100g^{-1} of fresh weight (mean from plots). However, 'Rywal' content included more malic acid (13.8%) mean from plots- 123.4 mg·100g^{-1} of fresh weight (Fig. 1a-d). A negative correlation between concentrations of malic and the other acids was shown (Table 2). The years of research had an impact on the concentration of the acids, which the exception of citric acid, which was demonstrated as high standard deviations (Fig. 1a-d).

After 3 and 6 months of storing the tubers, an increase of citric acid was shown for both cultivars (by 11.4% and 4.4% after 3 months, and 15.8% and 11.5% after 6 months, for 'Rywal' and 'Saturna', respectively) (Fig. 2c).

The content of the other acids decreased over the storage period. After 3 months the decrease reached 12.8% and 37.3% of malic acid, 9.1% and 52.5% of fumaric acid, and 10.3% and 16.5% of tartaric acid for 'Rywal' and 'Saturna', respectively, while after 6 months the concentrations dropped by 46.6% and 39.8% of malic acid, 66.4% and 73.5% of fumaric acid, and 30.4% and 39.2% of tartaric acid for 'Rywal' and 'Saturna', respectively (Fig. 2 a, b, d).

While comparing concentrations of organic acids in potato tubers stored in chambers set at two different temperatures (8ºC and 4ºC), their higher content was shown for the tubers stored at lower temperatures. Somewhat different was the pattern of malic acid concentration, because tuber samples of both cultivars coming from the chamber set at 8ºC analyzed after the first term (after 3 months of storage) contained more of this acid (Fig. 2b).

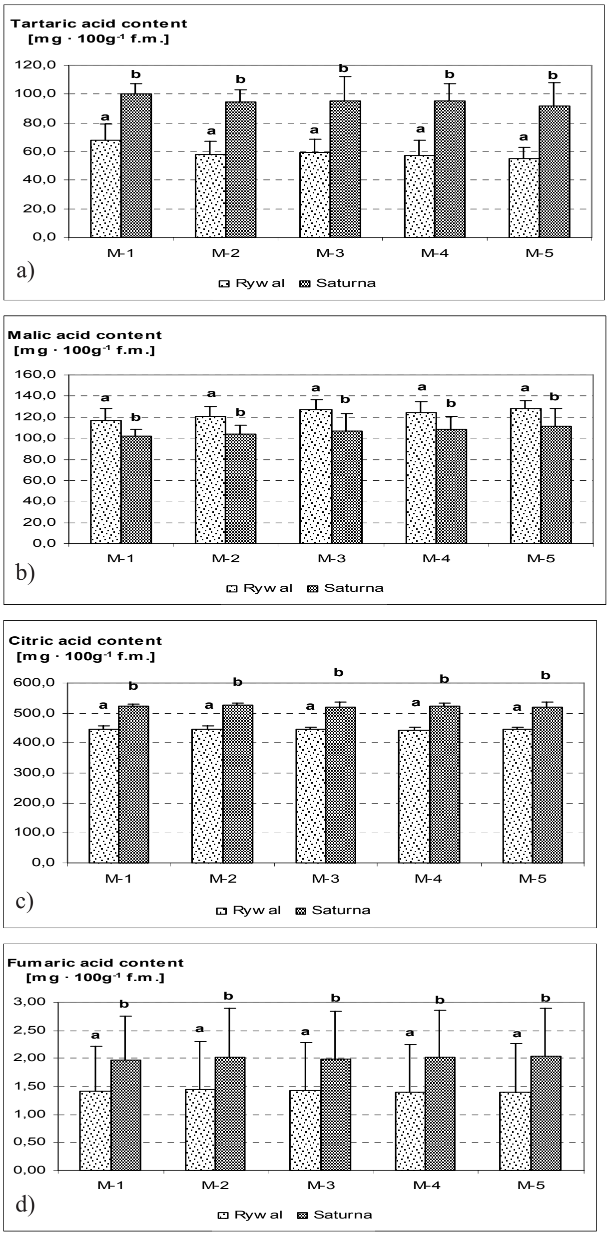

Fig. 1a, b, c, d. Chosen organic acid contents after harvest depends on weed control methods during the vegetation period in two cultivars of potato tubers (mean from 2002-04).
Explanation:
M-1 – without herbicides (control); M-2 – with herbicide Afalon 50 WP, M-3 – with herbicide Sencor 70 WG +adjuvant Olbras 88 EC 1.5 $l \cdot ha^{-1}$, M-4 – with herbicide Azogard 50 WP; M-5 – with herbicide Apyros 75 WG +adjuvant Atpolan 80 EC 1.5 $l \cdot ha^{-1}$, a, b – no significant difference between the same group at the α=0.05.

Discussion

Despite the basic role played by organic acids naturally present in potato tubers, especially citric acid, there is little data on changes of concentration of these acids during tuber storage. It is known that the tubers must respond to a specific norm, depending on the method of their use, however, independent from their destination the darkening tendency is probably the most important property. The intensity of the darkening of tuber flesh is limited mainly by citric acid [4, 5, 13].

The question of the impact of herbicides used over vegetation on the content of organic acids in the tubers has not been recognized in full, and the results of this study do not show such a relationship. According to Zgórska and Frydecka- Mazurczyk [14], Rogozińska, Pińska [15], Wojdyła [16] and Pobereżny [17], concentrations of citric acid depend mainly on genetics, which has been supported in this study. However, the time and conditions of storage can also change concentrations of the acids under study. Suliman [18] and Pobereżny [17] found a higher content of citric acid after the 6-month-long storage than after harvest. As reported by Shekhar, Iritani [19], and Hyde and Morrison [20], a lower storage temperature results in a lower pH of the cell sap and in the same way in higher concentrations of organic acids. Sweeney et al., who measured increasing concentration of citric acid and decreasing one of malic acid over the storage, described similar results [21]. This corroborates well with our findings even if potato cultivars and their vegetation conditions were different. Malic acid is a by-product of sugar metabolism. It has been speculated that it has a crucial role in acid turnover being a precursor of a number other organic acids. It is processed to citric acid particularly easy [22]. Changes in the inter-ratios of the organic acids under study could be caused by such transformations. Other acids occurring in potato tubers have triggered very little attention up to date. It is probably because of their low concentrations in potato tubers as well as not well-recognised activity in the tuber. A deeper knowledge on the effects of natural conditions over vegetation, as well as storage on the biochemical reactions occurring in the tuber cell sap, should be interesting, not only because of scientific curiosity but also for practical reasons. According to Rogozińska [13], Griffiths, Bain [5], Komorowska-Jędrys [8], Grzesiuk, Górecki [7] and Gabriel [6] an increase in pH of cellular juice of tuber, on which the influence has the content of studied organic acids, and chlorogenic acid, causes more susceptibility for darkening of flesh cooked. Exchanged authors report that the rate of

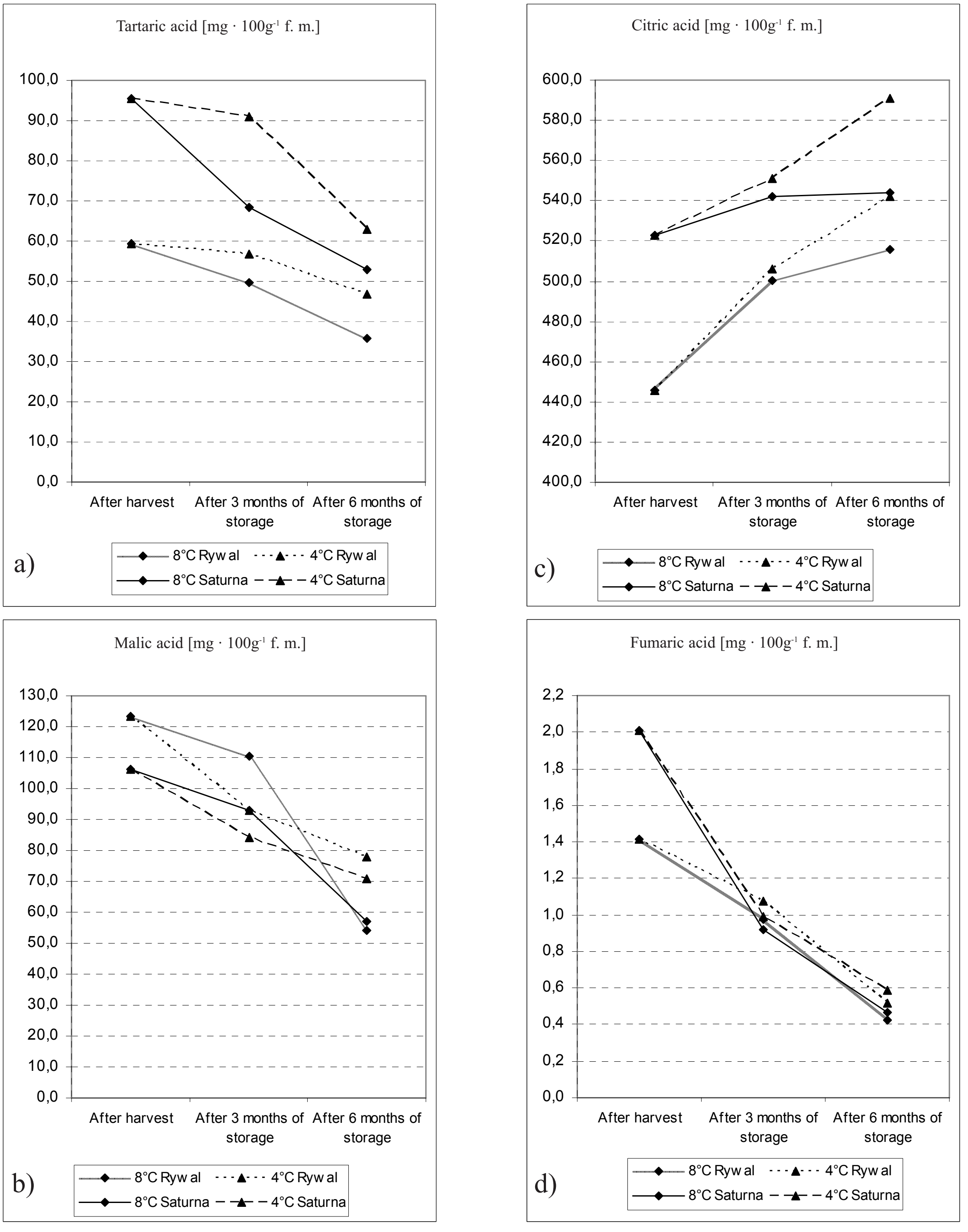

Fig. 2 a, b, c, d. Change of organic acid content during 3 and 6 months of storage in two different temperatures (mean from storage period 2002-05).

this reaction depends mostly on the content of citric acid, which can react with iron, unlike chlorogenic acid, into a form of colorless complexes. This affirming can be the basis for investigations on subjects about interaction of acids on the degree of tuber darkening.

Conclusions

1. Used herbicides did not significantly change acid concentrations in the tubers.
2. Cultivar 'Saturna' had a higher content of citric, tartaric and fumaric acids, while that of malic acid was lower than in the 'Rywal' variety.
3. The content of malic, tartaric and fumaric acids decreased during storage in tubers from chambers with temperatures of 8ºC and 4ºC. The highest decrease, even up to 70%, was found for fumaric acid assessed after 6 months of storage of the 'Saturna' cultivar.
4. Storage time and lower temperature favoured the biochemical transformations on accumulation of citric acid in both varieties.

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