TOTAL CAROTENOIDS CONTENT OF SEVERAL POTATO VARIETIES DIFFERENT RESISTANTS TO POTATO VIRUS Y (BRAŞOV, 2023-2024)

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Abstract

As one of the most widely consumed vegetables globally, the potato represents a nutritionally valuable crop, providing an important source of essential bioactive compounds beneficial to human health. The present research aimed to assess the total carotenoids content (TCC) in both the skin and flesh of ten Romanian potato cultivars exhibiting varying degrees of resistance to Potato Virus Y (PVY), cultivated in Braşov over a two-year period. The analysis revealed significant varietal differences. Overall, the flesh of the tubers showed lower TCC levels compared to the skin. Among the examined cultivars, the Romanian variety Sevastia (resistant to PVY) recorded the highest concentrations of carotenoids in both tissues. The findings contribute valuable insights into the micronutrient composition of recently developed Romanian potato varieties, characterized by high nutritional value and diverse PVY resistance.

Key words**: **carotenoids, potato variety, potato virus Y

INTRODUCTION

Potato (*Solanum tuberosum* L.) tubers represent not only a significant source of starch but also contain various bioactive compounds with important functional roles, such as carotenoids (Al-Weshahy et al., 2009; Andre et al., 2006). These lipophilic organic pigments had two essential functions in plants in vegetation periode: they absorb light energy required for photosynthesis and protect chlorophyll molecules from photooxidative degradation (Young et al, 1991). Structurally, carotenoids are polyisoprenoid compounds composed of 40 carbon atoms arranged in a conjugated double-bond system, exhibiting molecular symmetry around the central double bond. Based on the presence of oxygen atoms in their molecular structure, carotenoids are divided into two major classes: xanthophylls (oxygen-containing carotenoids) and carotenes (hydrocarbon carotenoids) (Breithaupt and Bamedi, 2002, Young et al, 1991). Potatoes with yellow, orange, or red flesh are particularly rich in xanthophylls such as lutein, zeaxanthin, neoxanthin, and violaxanthin, along with trace amounts of β-carotene and additional minor carotenoids (Pryia and Saiprassad, 2023). The concentration of these carotenoids are different among the varieties (Morris et al, 2004).

Carotenoids exhibit multiple health-promoting effects; among these, lutein and zeaxanthin play a critical role in maintaining ocular health by reducing the risk of age-related macular degeneration (Andre et al., 2008; Camire et al., 2009). As the principal pigments located in the macular region of the human retina, lutein and zeaxanthin provide protection against damage induced

by blue light exposure and reactive oxygen species (Chucair et al., 2007). Although β-carotene is present only in small amounts—making potatoes a poor source of provitamin A — the relatively high concentrations of lutein and zeaxanthin confer functional properties to these vegetable (Pryia and Saiprassad, 2023)

Like another phytochemical compounds antioxidants, the carotenoids synthesized by plants could serve as defense mechanisms against various biotic and abiotic stressors. Environmental and physiological factors such as mechanical stress, pathogenic infection, microbial invasion, ultraviolet radiation, as well as water or nutrient deficiency, can stimulate the biosynthesis of these metabolites (Young et al, 1991).

Potato virus Y (PVY), classified within the genus *Potyvirus* and the family *Potyviridae*, is one of the most widespread and economically significant plant pathogens affecting solanaceous crops worldwide. (Cojocaru, 1978; Bădărău et al., 2018). In recent decades, PVY has become a major concern in potato production systems, particularly within the seed potato industry, due to its considerable impact on both yield and tuber quality. PVY infection frequently results in significant yield losses and physiological defects in tubers, leading to reduced marketability. High incidence levels of PVY commonly lead to the rejection of seed lots during certification processes, thereby generating substantial economic losses for producers. Furthermore, PVY outbreaks contribute to a decline in the overall commercial value of potato crops and exacerbate the shortage of certified seed material, particularly in cultivars exhibiting high susceptibility to PVY infection (Bădărău et al., 2018). The growing importance of PVY as a limiting factor in sustainable potato production underscores the necessity of developing resistant cultivars and implementing integrated management strategies to mitigate its impact. Consequently, the main objective of the present study was to determine the carotenoid content in several newly developed Romanian potato cultivars exhibiting variable resistance to Potato Virus Y (PVY), grown in Brasov over two years with different climatic conditions.

MATERIALS AND METHODS

Biological material

The potato varieties tested were:

-Darilena, Foresta, Christian, Cezarina, Sevastia, Marvis, Castrum, Brasovia, Cosiana (new Romanian varieties)

- Albastru Violet de Galanesti (Blue Purple of Galanesti) (with strong pigmentation in the flesh).

The climatic conditions in the experimental years are presented in Table 1.

Table 1. Climatic conditions years 2023-2024

Month	Year	Mean temperature (° C)	Rainfall (mm)
Avril	2023	7.3	83.1
	2024	12.2	43.5
May	2023	13.8	77.5
	2024	13.6	42.7
June	2023	17.6	111.1
	2024	21.1	54.5
July	2023	20.5	59.1
	2024	22.2	79.4
August	2023	20.9	77.5
	2024	21.2	65.0
September	2023	16.9	11.0
	2024	15.9	48.7
Average / Sum	**2023**	**16.2/ 97.0**	**69.9/ 419.3**
	2024	**17.7/ 106.2**	**55.6/ 333.8**

Seed tubers were planted in May in Brasov in 2023 and 2024, with three replicates. Similar fertilizer chemical inputs were applied in both years. Mature tubers were harvested 160 days after planting in Brasov in 2023 and 148 days in Brasov in 2024. After harvest, marketable tubers (medium size and free of damage and defects) were selected, washed, stored at 4°C until the sample preparation.

The level of PVY resistance for the cultivars analyzed is presented in table 2 (Soiuri noi de cartof create la INCDCSZ Brașov, 2023)

Sample preparation
Composite samples (4 to 10 tubers from each cultivars, depending of their size) were prepared by pooling tubers. Tubers were peeled with a potato peeler, the flesh of each tuber quartered from stem to bud and one of the quarters sliced. The tissues were freeze-dried (ScanVacCoolSafe 55-9 Pro Freeze Dryer, Denmark), ground to a fine powder (using a coffee grinder) and stored to -20^{o}C until analysis

Total carotenoids content (TCC) analysis
Total carotenoids content was determined according to Burgos et al. (2009) without alkaline hydrolysis. Extraction of TCC from 0.5g of powdered skin or 2g of powdered flesh was sequentially carried out in triplicate with acetone, shaking in 50 ml tubes at 10 000 rot/min for 15 minutes. The supernatants were combined and 5 ml of petroleum ether and 20 ml of ultra-pure water added. The tubes were shaken vigorously by hand and centrifuged at 10 000 rot/min for 1 minute. The top organic phase was removed and washed with pure water, separating both phases as described above. The top organic phase was again removed and the absorbance of an aliquot was measured at 450 nm against petroleum ether using a UV VIS spectrophotometer SpectronicGenesys 5 (Milton Roy).

Detection of PVY infection. The analysis was performed following the protocol described by Clark and Adams (1977) and using ELISA specific products from Bioreba (Shwitzerland). The rinsed microplates filled with substrate solution (p-nitro phenyl phosphate) were incubated 1 hour and the absorbance values determined at 405 nm (A_{405}) using a Tecan SunRise reader (software Magellan). The samples having A_{405} values exceeding the cut-off (two times the average of healthy controls) were considered virus infected (Bădărău et al., 2018).

Statistical interpretation
Analysis of variance (ANOVA) and Duncans multiple range test were used.

RESULTS AND DISCUSSIONS

In this study, there were analyzed several new Romanian varieties with strong color in the flesh and skin tissue, having different resistance to potato virus Y. The data regarding the PVY resistance of the biological material depend on the percentage of infection identified in the material tested (unpublish data).
The experiments conducted in Brasov show that variety Sevastia had the highest mean TCC value in both skin and flesh. Genotypes with the lowest quantified values were Darilena, Marvis and AVG in 2023 and 2024 for both tissues, flesh and skin respectively (table 2).
The levels of TCC ranged from negligible quantities to 10.02 and 4.91 mg kg-1 DW in the skin and flesh, respectively, with flesh and skin contents showing a significant difference for both years (table 2). The results presented in table 2 revealed higher TCC in skin compared with the flesh tissue. On average, the skin of the potatoes analysed contained more TCC than in the flesh (1.9 times in 2023, 2.09 times in 2024). These data are in agreement with other studies: it has been reported (Breithaupt and Bamedi, 2002) that the total quantity of the four main carotenoids in eight commercial potato varieties was between 0.38 and 1.75 mg Kg-1, which would be equivalent to 1.90-8.75mg kg-1 DW assuming 80% of water in the fresh samples. Other authors (Morris et al., 2004, Lu et al., 2001) found that for varieties Pentland Javelin (white flesh) TCC was 1.60 mg kg^{-1} DW and for variety Yukon Gold (yellow flesh) and Superior (white flesh) were 1.11. and 0.64 mg kg^{-1} FW, respectively (equivalent to approximately 5.55 and 3.20 mg kg^{-1} DW). Other studies reported values of total caroteins content of white and yellow potatoes ranging from 50-100 and 100-350 micrograms per 100 g FW whereas in dark yellow cultivars it was estimated to be up to 2690 micrograms per 100 g FW (Brown et al., 2008).
In our experiments, excepting the cultivars Sevastia, Cezarina, Azaria and Foresta, the majority of the varieties included in this work had relatively low content of TCC in the

flesh, with values below 0.29 and 1.47 mg kg-1 DW (table 2).

Results regarding the carotenoids content (TCC) according to the color of the skin and flesh color of the tubers are presented in Figure 1. The higher values were observed in the dark yellow and yellow flesh tissue of the tubers, and in the yellow and red skin tissue, respectively (Fig. 1).

Table 2. Total carotenoids content (mg /Kg DW) of potato samples (Brasov, 2023-2024)

Cultivars /resistance to PVY	Flesh / Skin colour	Year 2023		Year 2024	
		Flesh	Skin	Flesh	Skin
Darilena /mr	W / LY	0.29±0.114 (h)	1.26±0.101 (f)	0.41±0.101(g)	1.59±0.207(g)
Foresta / r	DY / R	1.21±0.064 (d)	2.12±0.204(d)	1.47±0.204(de)	3.05±0.231(e)
AVG/ nr	B/B	1.11±0.163(d)	2.44±0.207(c)	1.25±0.207(de)	1.60±0.113(f)
Brasovia/mr	WY / Y	0.43±0.171(g)	1.51±0.131(e)	0.42±0.131(g)	1.86±0.225(ef)
Castrum/mr	LY / Y	0.93±0.276(e)	1.51±0.191(e)	1.37±0.191(de)	3.02±0.217(ef)
Azaria/mr	Y / R	1.53±0.259(c)	2.54±0.186(c)	2.27±0.186(c)	4.70±0.259(c)
Cosiana/mr	WY / R	0.68±0.155(ef)	1.40±0.134(ef)	1.78±0.134(d)	3.69±0.204(d)
Marvis/mr	WY / Y	0.45±0.166(g)	1.46±0.200(e)	0.86±0.200(f)	1.61±0.189(f)
Cezarina/r	DY / Y	3.27±0.234(b)	5.37±0.356(b)	3.57±0.356(b)	8.11±0.239(b)
Sevastia/r	DY / Y	4.91±0.325(a)	7.96±0.275(a)	4.99±0.275(a)	10.02±0.212(a)
		1.38	2.76	1.82	3.81

*Means with different letters are significantly different at p<0.05 in each column. Values reported for the two Romanian trials are the mean of three filed replicates. Abbreviations: DW dry weight; AVG Albastru Violet de Galanesti (Blue Purple of Galanesti);W white; WY white yellow; LY light yellow; Y yellow; DY dark yellow; R red; B blue. Abbreviations for the type of PVY resistance of the varieties: r resistant; mr medium resistant; nr no resistant.

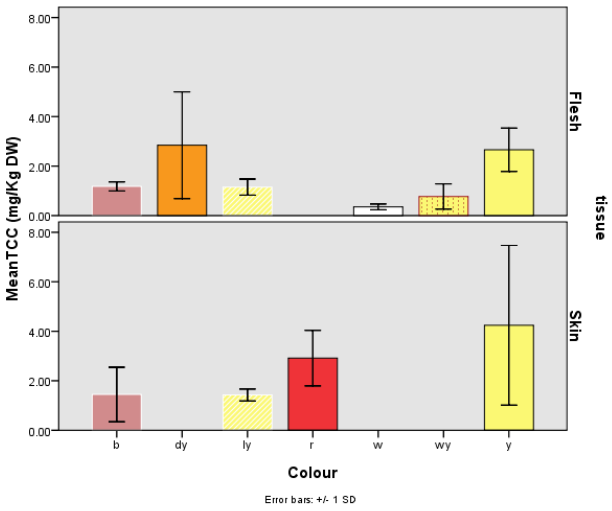

Figure 1. Mean total carotenoids content (TCC) according to the color of the skin and flesh color of the tubers (mean values of samples collected in 2023 and 2024, tubers with different skin and flesh color from varieties resistant , medium resistant and no resistant to Potato Virus Y). Abbreviations: TCC-total carotenoids content; DW-dry weight.

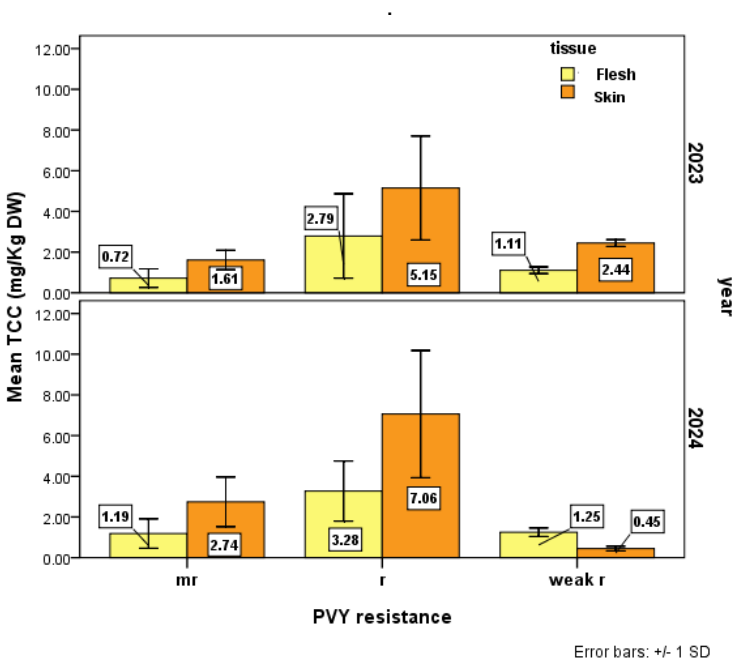

Figure 2. Mean total carotenoids content (TCC) according to the PVY resistance estimated for the cultivars tested. Abbreviations: PVY - Potato Virus Y; mr-PVY medium resistant; r-PVY resistant; weak r - non PVY resistant.

As seeing in table 2, tubers grown in 2024 had an average higher TCC content than those grown in 2023. TCC content seems to be higher in early developing tubers, so these climatic conditions during the summer months could contribute to difference observed. The cultivars Sevastia, Cezarina, Azaria and Foresta with strong yellow colour in flesh had in our experiment high level of carotenoid content and these varieties are considered resistant to potato virus Y, the other varieties (Cosiana, Darilena, Brasovia, Marvis, Castrum) are considered medium resistant to this virus, respectively non resistant us the cultivar AVG (Table 2). The mean values of TCC for flesh and skin tissue were higher in case of varieties resistant to PVY (Fig 2).

Climate data for the growing season in Brasov (table 1) show that average temperatures in 2024 were slightly higher than in 2023. This difference was accentuated in June, July and August and was accompanied also by increased rainfall. TCC content seems to be higher in early developing tubers (Morris et al., 2004) so these climatic conditions during the summer months could contributed to difference observed. Reddivari et al., 2007 reported that tubers planted in the location with higher average temperature and increased rainfall contained higher levels of carotenoids.

Significant interactions between variety and year and variety and tissue were also found (table 3).

Table 3. Effects of same variables on TCC*

Variables /interactions between variables	**ANOVA p values**
Year	< 0.01
Variety	0.169
Tissue	0.205
PVY resistance	0.269
Year x variety	< 0.01
Year x tissue	0. 504
Variety x tissue	< 0.01

** TCC = total carotenoids content*

This suggests that evaluation of TCC across years may be more important than evaluation across PVY resistance of the variety, which should be confirmed by further filed trials considering a wider variety of cultivars and over more than 2 years. A variety of factors can influence variation of TCC between the structure to

climatic conditions or pressure from pests or pathogens.

CONCLUSIONS

Ten Romanian potato genotypes with different colour of the skin and flesh tissue (grown in Brasov two years) were analysed for estimation their total carotenoids content. The results obtained were in the range of values reported in the literature.

Significant differences between the different cultivars tested were observed, higher contents of carotenoids being found in intense coloured fleshed tubers than in white counterparts, which should allow visual selection of varieties with enhanced levels of these compounds. So, the cultivar Sevastia (with a dark yellow colour of the flesh) had the highest values of total carotenoids content.

Potato consumption has a great importance in population food and this study offer preliminary information to researchers and producers on the level of some phytochemicals such carotenoids, antioxidants with functional properties.

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