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The Polyphenol Content in Three Edible Potato Cultivars Depending on the Biostimulants Used

Iwona Mystkowska [1,*], Krystyna Zarzecka [2], Marek Gugała [2] and Anna Sikorska [3]

[1] Department of Agriculture, Faculty of Technical Sciences, Pope John Paul II State School of Higher Education, ul. Sidorska 95/97, 21-500 Biała Podlaska, Poland
[2] Faculty of Agrobioengineering and Animal Husbandry, University of Natural Sciences and Humanities, ul. Prusa 14, 08-110 Siedlce, Poland; krystyna.zarzecka@uph.edu.pl (K.Z.); marek.gugala@uph.edu.pl (M.G.)
[3] Department of Agriculture, Vocational State School of Ignacy Mościcki, ul. Narutowicza 9, 06-400 Ciechanów, Poland; anna.sikorska@puzim.edu.pl
* Correspondence: imystkowska@op.pl; Tel.: +48-(83)-344-9900

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Abstract: The aim of the study was to assess the polyphenol content in tubers of three edible potato cultivars depending on the biostimulants used. Field research was carried out in the years 2016–2018 with an application of biostimulants in individual farm in Poland. The experiment was led by means of a split-plot method. The impact of two factors was tested. The first-order factor were the three cultivars of edible potato: Jelly, Honorata, Tajfun, while of the second–order four variants of applying biostimulants: Kelpak SL, Titanit, GreenOk, BrunatneBio Złoto. Potato plants were treated with biostimulators three times (beginning of flowering, full flowering and after plant flowering). The polyphenol content was determined by spectrophotometric method with Folin–Ciocâlteu reagent in fresh potato tuber mass. The content of polyphenols in tubers depended on the cultivars and biostimulants. Among the studied cultivars, Jelly accumulated the most polyphenols and Tajfun the least. Biostimulants increased the concentration of phenolic compounds compared to tubers from the control treatment.

Keywords: *Solanum tuberosum* L.; polyphenols; cultivars; biostimulants

1. Introduction

Potato tubers (*Solanum tuberosum* L.) contain polyphenols, which are desirable in the human diet because of their beneficial effects on health [1–3]. Polyphenols are one of the largest antioxidant groups and are considered the most numerous antioxidants in our diet [4–6]. They have a diverse structure, molecular weight, physical, biologic and chemical properties [7,8]. The potatoes are the most important source of polyphenols after apples and oranges [9–12], which contain on average–160 mg·100 g^{-1} of fresh weight [13]. Polyphenol content in studies by Hamouz et al. [14] was within the range of 62.6–1157.0 mg·kg^{-1} and Lemos et al. [15] 209.1 mg·kg^{-1} of fresh tuber weight. Many authors [14–17] have stated that the concentration of polyphenols in tubers depended on the variety. In addition, Hamouz et al. [14] showed that the concentration of these compounds was determined by the color of the genotype parenchyma and the location of the study. Grudzinska et al. [18] identified the effects of farming system, cooking method and flesh color on the contents of bioactive compounds in potato tubers.

Biostimulants work by stimulating and supplementing the deficiency of components during the vegetation period caused by, among others, drought, abiotic and biotic stress and agrotechnical errors [19–23]. Biostimulants enable more efficient uptake of nutrients from the substrate, and thus better supply of plants with nutrients [24]. Mikos-Bielak and Czeczko [25] stated that the biostimulant significantly increased the amount of polyphenols in tubers after both the single and double application, significantly increased the number of polyphenols in tubers in relation to the control treatment. In addition, climatic conditions during vegetation affected the accumulation of polyphenols [14]. Currently, there is little research on the impact of biostimulants on the content of polyphenols in potatoes. The research hypothesis that biostimulants may affect the polyphenol content of *Solanum tuberosum* L. tubers was adopted in the study, with the aim to determine the effect of using four biostimulants (Kelpak SL®, Green OK®, Tytanit®, BrunatneBio Złoto® on the content of polyphenols in tubers of three cultivars (Jelly, Honorata, Tajfun) of edible potato.

2. Materials and Methods

2.1. Experimental and Agronomic Management

The research materials were potato tubers (*Solanum tuberosum* L.) from 2016 to 2018. However, it is necessary to specify which are the years field experiment carried out on an individual farm in Międzyrzec Podlaski (51°59′ N and 22°47′ E) in Poland. The experiment was established in triplicate with the split-plot method) as two-factor. The first factor were three edible potato cultivars: Jelly, Honorata and Tajfun (Table 1) [26] and the second one four biostimulants: Kelpak®SL, Tytanit®, GreenOk®, BrunatneBio Złoto (Table 2) used in three dates beginning of flowering, fully flowering and after flowering of plants at doses of 0.2 dm^3 ha^{-1}. Biostimulants were used based on the permission of the Ministry of Agriculture and Rural Development [27]. The control treatment without biostimulators, comprised potato plants sprayed with distilled water.

Table 1. Factor I—Description of potato cultivars grown in the experiment [26].

Cultivar	Maturity	Color of Flesh	Color of Skin	Registration Year	Yeldt·ha^{-1}
Jelly	medium late	yellow	yellow	2005	50.2
Honorata	medium early	light yellow	light beige	2012	44.1
Tajfun	medium early	yellow	yellow	2004	49.8

Table 2. Factor II—Description of biostimulants applied in the experiment [27].

No.	Treatment	Active Substance/Composition
1	Kelpak®SL	extract from algae Ecklonia maxima-auxins 11 mg dm^3 and gibberellins 0.031 mg dm^3
2	Tytanit®	titanium
3	GreenOk®	humus substances 20 g·dm^{-1}
4	BrunatneBio Złoto®	plant hormones: auxin 0.06 mg·dm^{-1} and cytokinin 12 mg·dm^{-1}

The experiment was carried out on soil belonging to Haplic Luvisol (LV-ha), with sandy loam texture according to the World Reference Base for soil resources WRB FAO [28]. Soil parameters were determined before establishing the experiment: pH 5.40–6.5 in 1-M KCl, organic matter 14.0–18.7 g kg^{-1}, content of available mineral in mg kg^{-1} soil: P 73.4–120, K 95.6–135.4, Mg 49.0–55.0, Fe 445.0–560.5, Mn 78.8–81.4, Zn 7.4–7.8, Cu 2.6–2.8. The forecrop for potato was winter wheat. Potatoes were planted manually at a spacing of 67.5 × 37 cm, in the third decade of April (2016, 2017, 2018). Each plot with an area of 15 m^2 accounted of five ridges. During the growing season, observations of the most important phases of potato development were carried out on each growth stage: emergence, flowering buds, flowering, maturation of plants. Potato plants were treated three times with biostimulants. Cultivation and care treatments were carried out in accordance with the requirements of correct agrotechnical and methodological assumptions of the experiment (Table 3).

Table 3. Cultivation and care treatments.

Treatments	Specification	Dates
Fertilization	25 t ha^{-1} farmyard P 44.0 (100 P_2O_5·0.44) kg·ha^{-1} (lubofos for potatoes 7%) and K 124.5 (150 K_2O·0.83) kg·ha^{-1} (lubofos for potatoes 25%)	autumn
	N 100 kg/ha (nitro–chalk 27%)	spring—before planting
Insecticides	Actara 25 WG (thiamethoxam) at a dose of 0.08 kg·ha^{-1} and Calipso 480 S.C. (thiacloprid) at a dose of 0.1 dm·ha^{-1}	during vegetation
Fungicides	Ridomil Gold MZ 68 WG (metalaxyl-M+mancozeb) and Copper Max New 50 WP at a dose 2.0 g·kg^{-1} and Dithane at a dose 2.0 kg·ha^{-1}	during vegetation
Biostimulants	Kelpak SL, Titanit, GreenOk, BrunatneBio Złoto at a dose 0.2 kg·ha^{-1}	beginning of flowering, fully flowering and after flowering of plants

The harvest was carried out when tubers were fully ripened, in the first decade of September. Each year, just before the harvest, tubers from ten randomly selected plants was dug out (from two middle rows, excluding marginal plants). Potato tuber samples (50 tubers) were taken immediately after harvest for chemical analyses and stored at 10–12 °C, for 8–10 days.

The study results were statistically analyzed by means of the analysis of variance (ANOVA cultivars × treatments × years) for the two-way split-plot arrangement. The significance of sources of differences between the compared averages was verified using Tukey's test at the significance level $p \leq 0.05$. Calculations were performed in Excel using the authors' own algorithm based on the split-plot mathematical model.

2.2. Chemical Analysis of Seeds

Chemical analyses of fresh material were carried out 4–5 days after tuber harvest. The content of polyphenols in tubers was determined by a spectrophotometer with Folin–Ciocâlteu reagent [29]. 20 g of fresh potatoes were homogenized with 35 mL of 80% methanol. Appropriately diluted extract (0.5 mL) was added into a 50-mL volumetric flask and diluted with 7 mL distilled water. Folin–Ciocâlteu reagent (0.5 mL) was added to the mixture and mixed. After 3 min, 1 mL Na_2CO_3 solution was added. After 1 h at room temperature absorbance on the spectrophotometer at wave length 725 nm was measured against blanks. Results were expressed as gallic acid equivalents (in g·kg^{-1} FW).

2.3. Weather Conditions

Climatic conditions prevailing during potato growing periods are presented in Table 4 using the sum of precipitation, average air temperature and the Selyaninov hydrothermal coefficient. The division into 10 classes of the Selyaninov coefficient allowed to isolate extremely dry and extremely humid conditions. Extreme conditions were assumed as values of the hydrothermal coefficient that fall in the ranges lower than 0.7, i.e., extremely dry and very dry conditions and values over 2.5 very humid and extremely humid conditions [30]. The vegetative season 2016 was characterized by an average air temperature of 15.8 °C, 0.8 °C higher than the long-term average and the lowest amount of precipitation at the level of 200.9 mm, 134.5 mm lower than the long-term sum and their distribution was unfavorable for potato growth and development. The average value of the hydrothermal index was the lowest and amounted to 0.88. The highest amount of precipitation was recorded in the growing season 2017–325.4 mm and the lowest average air temperature −14.6 °C and the hydrothermal coefficient ranged from 0.28 to 3.19. In the last year of the study, the highest average air temperature of 17.6 °C and the annual rainfall of 295.7 mm were noted. The average value of the Selyaninov hydrothermal coefficient was 1.04 and it was rather a dry year.

Table 4. Weather conditions during of potato vegetation (Zawady Meteorological Station, (52°03′ N and 22°33′ E), Poland).

Years	Months						
	IV	V	VI	VII	VIII	IX	IV–IX
	Rainfall (mm)						Sum
2016	28.7	54.8	36.9	35.2	31.7	13.6	200.9
2017	59.6	49.5	57.9	23.6	54.7	80.1	325.4
2018	34.5	27.3	31.5	67.1	54.7	80.6	295.7
Multiyear sum (1996–2010)	33.6	58.3	59.6	57.5	59.9	42.3	335.4
	Air temperature (°C)						Mean
2016	9.1	15.1	18.4	19.1	18.0	14.9	15.8
2017	6.9	13.9	17.8	16.9	18.4	13.9	14.6
2018	13.1	17.0	18.3	20.4	20.6	15.9	17.6
Multiyear mean (1996–2010)	8.0	13.5	17.0	19.7	18.5	13.5	15.0
	Selyaninov hydrothermal coefficient *						Mean
2016	1.07	1.47	0.72	0.64	0.2	1.2	0.88
2017	3.19	1.52	1.06	0.47	0.61	0.28	1.18
2018	0.99	0.59	0.61	1.12	1.00	1.92	1.04

* Coefficient value [30]: extremely dry (ss) $k \leq 0.4$; very dry (bs) 0.4–0.7; dry (s) 0.7–1.0; rather dry (ds) $1.0 < k \leq 1.3$; optimal (o) $1.3 < k \leq 1.6$; rather wet (dw) $1.6 < k \leq 2.0$; wet (w) $2.0 < k \leq 2.5$; very wet (bw) $2.5 < k \leq 3.0$; extremely wet (sw) $k > 3.0$.

3. Results and Discussion

Gheribi (2013) [31] noted that the content of phenolic compounds in food products is very different and depends on a number of factors, including cultivation methods, technological processing and storage time. The content of polyphenolic compounds in potato has made it extremely important in the daily diet [13]. Polyphenols in potato tubers are varied and depend on many factors. Their content ranges from 53.0 to 1098.0 mg·kg^{-1} of fresh matter [14–16].

3.1. Polyphenol Content Depending on Cultivated Cultivars

In the conducted research, the content of polyphenols in potato tubers was in the range of 153.1–179.6 mg·kg^{-1} of fresh mass and depended significantly on the cultivated cultivars, treatments of biostimulants used and atmospheric conditions in the years of research (Tables 5 and 6). Of the grown cultivars, the largest amount of polyphenols was accumulated by the late cultivar Jelly (on average 176.3 mg·kg^{-1} fresh mass), followed by medium early cultivars: Honorata and Tajfun. Tubers of the Tajfun cultivar contained the least of these compounds (on average 155.0 mg·kg^{-1} fresh mass) (Table 5). In the conducted research Lombardo et al. [32] the organic cultivation system produced tubers of higher nutritional value, specifically exhibiting a higher total phenolics content. The polyphenol content was differentiated by genotype. The concentration of polyphenols in tubers was similar to the values obtained by other authors [15–17]. Lombardo et al. [32] and Brazinskiene et al. [33] found that the differences in polyphenols in tubers depend on the cultivar and year of the study.

The influence of the cultivars factor on the value of the discussed feature was conditioned by the color of the flesh, the origin of the cultivar and the tuber maturity proved by many authors [8,14,16,34]. The authors [7,8] studying potatoes with different flesh skin colors showed that cultivars with white and yellow color contain from two to three times less polyphenols than those with white-red and red-purple flesh. Moreover, it depended significantly on the cultivated cultivar. Different content of polyphenols depending on the cultivar was shown by other authors [7,8,34–36]. Lombardo et al. [37] have shown, the cultivation system significantly affected the chemical variables under study, with the effect being season and cultivar dependent.

Table 5. Content of polyphenols in the fresh mass of potato tubers (mg·kg^{-1}).

Table 2016.	Cultivars (I)			Years			Mean
	Jelly	Honorata	Tajfun	2016	2017	2018	
	Polyphenol content (mg kg^{-1})						
1. Control Treatment	171.2 ^{A}	160.2 ^{A}	153.1 ^{A}	172.6 ^{D}	153.8 ^{C}	158.0 ^{C}	161.5 ^{d}
2. Kelpak SL®	178.3 ^{A}	162.4 ^{A}	154.2 ^{A}	176.8 ^{C}	157.0 ^{B}	161.2 ^{B}	165.0 ^{c}
3. Tytanit®	175.9 ^{A}	165.7 ^{A}	154.9 ^{A}	177.0 ^{B,C}	157.0 ^{B}	162.5 ^{A,B}	165.5 ^{b,c}
4. GreenOk®	176.5 ^{A}	168.7 ^{A}	155.6 ^{A}	179.7 ^{A,B}	158.1 ^{A}	162.8 ^{A,B}	166.9 ^{b}
5. BrunatneBio Złoto®	179.6 ^{A}	170.2 ^{A}	157.2 ^{A}	181.6 ^{A}	161.0 ^{A}	164.3 ^{A}	169.0 ^{a}
Mean	176.3 ^{a}	165.4 ^{b}	155.0 ^{c}	177.5 ^{a}	157.4 ^{c}	161.8 ^{b}	

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

Table 6. Ccontent of polyphenols in the fresh mass of potato tubers depending on the cultivars (I) in the years of research (III) (mg·kg^{-1}).

Years (III)	Cultivars (I)			Mean
	Jelly	Honorata	Tajfun	
	Polyphenol content (mg kg^{-1})			
2016	179.9 ^{A}	177.4 ^{A}	175.1 ^{A}	177.5 ^{a}
2017	170.9 ^{C}	157.3 ^{C}	143.8 ^{C}	157.4 ^{c}
2018	178.1 ^{B}	161.5 ^{B}	145.7 ^{B}	161.8 ^{b}
Mean	176.3 ^{a}	165.4 ^{b}	155.0 ^{c}	165.6

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for cultivars and years.

3.2. Polyphenol Content Depending on the Treatments of Biostimulants Used

The biostimulants used in the study significantly affected the concentration of polyphenols in tubers, causing them to increase compared to the control treatment sprayed with distilled water. In all cultivars, the BrunatneBio Złoto biostimulant increased the concentration of polyphenols to the greatest extent in the Jelly cultivar 179.6 mg·kg^{-1} compared to plants from the control variant sprayed with distilled water (Table 5). The authors [15] obtained equivocal results in the content of polyphenols by cultivating potatoes using the ecological and conventional methods. In some varieties, they observed an increase, in others a decrease in the amount of polyphenols, which could be associated with a reaction to various stress factors (Colorado potato beetles destroying potato leaves, infection by *Phytophthora infestans*). Whereas Chauhan et al. (2013) after the application of the imidacloprid insecticide in potatoes noted a decrease in polyphenol content and an increase in total protein in tubers. Beneficial effects of biostimulants on the content of polyphenols in potato were found [24,38,39].

3.3. Polyphenol Content Depending on Climatic Conditions in the Years of Research

The concentration of polyphenols in potato tubers was determined by the weather conditions of the growing season (Table 6). The highest amounts of these compounds were found in 2016, an average of 177.5 mg·kg^{-1}. This year was characterized by the smallest amount of precipitation that was unevenly distributed and the average air temperature 0.8 °C higher than the long-term average. In contrast, the lowest polyphenols were found in the 2017 season, an average of 157.4 mg·kg^{-1}, which turned out to be the most humid and coolest. The interaction of biostimulants used during the years of research has been demonstrated, which proves that phenol accumulation is a resultant of interaction of many factors. The influence of weather conditions on the level of polyphenols was observed by other authors [14,40]. Lombardo et al. [32] found that polyphenols show an effect of environment. The environment × cultivar interaction is very important, because it shows that the cultivars responded differently to the environmental conditions. The contents of polyphenols of potatoes can be modified by growing conditions farming system and nutrient supply [18,41,42].

4. Conclusions

Tubers of plants treated with biostimulants contained larger amounts polyphenols than potatoes from control treatments, whereas the BrunatneBio Złoto preparation produced the largest accumulation of these components. A differentiated reaction of varieties to the applied biostimulants was observed. The BrunatneBio Złoto preparation increased the concentration of polyphenols to the largest extent in the cultivar Jelly, which is confirmed by the proven interaction of varieties with biostimulants. The polyphenol content in potato tubers was significantly differentiated by the genotype of the cultivar. The obtained results indicate that the choice of the cultivar and biostimulants is important with respect to the polyphenol accumulation capacity in potato tubers. Weather conditions, especially the small amount of rainfall in 2016, contributed to the increase in polyphenols. Thus, the presence of polyphenols in potatoes is important and highly desirable in the human diet, as it can reduce the risk of numerous human diseases.

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