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SENSORY QUALITY OF POTATO TUBERS IN CONDITIONS OF APPLICATION OF BIOSTIMULATORS AND HERBICIDE

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Summary. Field experiments were conducted in 2015–2017. The purpose of the study was to assess the impact of application of biostimulators and herbicide on the selected sensory quality feature of table potato tubers (color of tuber flesh, cooking type and darkening of raw and boiled tuber flesh). The experiment was established in three replications, using the randomized split-block system method, with the first factor being three early cultivars of edible potato: (Bellarosa, Owacja, Vineta), and the second one: five methods of use of growth biostimulators: GreenOK – Universal-PRO and Asahi SL, as well as their combination with the herbicide Avatar 293 ZC. On the basis of the obtained results, it was demonstrated that the color of tuber flesh depended substantially on the cultivars being grown. No significant impact of the experiment factors on the cooking type was proven. On the other hand, darkening of raw and boiled tuber flesh depended substantially on the cultivars being grown, methods of application of biostimulators and herbicide, as well as weather conditions during the vegetation period of potato plants.

Key words: *Solanum tuberosum* L., sensory quality, biostimulators, herbicides

INTRODUCTION

In the agriculture of the 21st century, the idea of protection of biodiversity, environment and consumers is becoming more and more popular and leads to searching for modern methods of cultivation, which reduce the pressure on the natural environment [Zarzyńska and Goliszewski 2006, Gajewski et al. 2013]. These trends are also visible in potato cultivation, and the growing interest of consumers in good-quality food forces pro

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ducers to improve the methods of cultivation of this plant and selection of potato cultivars that would meet the consumer expectations [Wichrowska and Rogozińska 2010, Baranowska et al. 2016]. An expression of the care for the natural environment and the quality of harvested crops is the introduction of various kinds of preparations classified as biostimulators to plant production, which are environmentally safe, stimulate life processes of plants and allow for obtaining high yields with good cooking quality [Maciejewski et al. 2007, Zarzecka and Gugała 2013, Kołodziejczyk 2016].

The cooking quality of potato is a set of features determining its use value. These features can be divided into external (morphological) and internal. Morphological features include, among others: regular shape of tubers, color and visual appearance of the peel. Internal characteristics of tubers affecting the quality include: chemical composition of tubers and organoleptic qualities (sensory, cooking qualities), such as: tastiness, color of flesh, cooking type, and darkening of raw and boiled tuber flesh [Hassanpanah et al. 2011, Zgórska and Grudzińska 2012].

The color of tuber flesh is a feature depending on the variety but can be slightly modified by habitat conditions [Wichrowska and Rogozińska 2010, Wichrowska et al. 2015]. The flesh may occur in shades of white, through creamy, to dark yellow. The flesh color is determined by the presence of pigments, e.g. a yellow tint is caused by carotenoids and flavonoids. A pink color is caused by the presence of anthocyans, first of all, glycosides: pelargonidin, petunidin and malvidin. The color of tuber flesh after peeling should be homogenous and flawless [Wroniak 2007, Mozolewski et al. 2014].

An important feature of cooking quality of tubers is the cooking type, also called the use and eating type. The cooking type is determined by five features of boiled potato tubers: level of overcooking of the surface, consistency, mealinesss, moistness, and flesh structure. On the basis of these features, we can distinguish the following cooking types of potato: salad, all-purpose, mealy, and very mealy. Selection preferences of the cooking type are regionally and personally diverse, depending on the needs of consumers [Lisińska et al. 2009, Zgórska 2013].

An important feature of sensory quality of potato tubers intended for direct consumption is: darkening of raw tuber flesh and darkening of boiled tuber flesh. Darkening of raw tuber flesh (enzymatic) is caused by the access of oxygen activating enzymes that oxidize phenol compounds contained in the flesh. Darkening of boiled tuber flesh (non-enzymatic) also depends on the access of oxygen but is caused by enzymes [Zgórska and Grudzińska 2012, Sawicka et al. 2015]. Quick and intensive darkening of flesh is an unwanted feature and lowers the eating value of tubers [Storey 2007, Kołodziejczyk 2013]. The flesh's susceptibility to darken is a complex genetic feature [Zimnoch-Guzowska and Flis 2006].

The aforementioned sensory characteristics of potato tubers are affected by many genetic, agrotechnical and environmental factors [Krochmal-Marczak et al. 2016]. It should be emphasized that, despite many years of evaluation conducted at the stage of potato cultivation, assessment of some features is verified no sooner than in production conditions [Zimoch-Guzowska and Flis 2006]. Therefore, the study aimed at identifying the impact of the application of growth biostimulators and herbicide on significant culinary characteristics of three table potato cultivars.

MATERIAL AND METHODS

Experiment and plant material. The research results come from a field experiment conducted in 2015–2017 in the area of eastern Poland, in the Biała Podlaska commune, in the Lubelskie Voivodship. The experiment was conducted on acidic light soil. The experiment was established as two-factor in the split-plot system, in three replications. Two factors were examined in the experiment: I. factor – potato cultivars: Bellarosa, Owacja, Vineta, II. factor – methods of application of biostimulators and herbicide: 1. Standard object – mechanical treatment (without biostimulators and herbicide), 2. From sprouting of potato plants – mechanical treatment and after sprouting – GreenOK Universal-PRO bioactivator, three times to leaves: at a dose of 0.10 $dm^3 \cdot ha^{-1}$ – peak-end of sprouting + 0.15 $dm^3 \cdot ha^{-1}$ – covering of interrows + 0.15 $dm^3 \cdot ha^{-1}$ – flower bud break, 3. From sprouting of potato plants – mechanical treatment, and after sprouting – Asahi SL bioactivator, three times to leaves at a dose of 0.50 $dm^3 \cdot ha^{-1}$ – peak-end of sprouting + 0.50 $dm^3 \cdot ha^{-1}$ – covering of interrows + 0.50 $dm^3 \cdot ha^{-1}$ – flower bud break, 4. From sprouting – mechanical treatment, and after the final shaping of ridges and just before sprouting Avatar 293 ZC herbicide at a dose of 1.5 $dm^3 \cdot ha^{-1}$. After sprouting – three applications of GreenOK Universal-PRO bioactivator at a dose of 0.10 $dm^3 \cdot ha^{-1}$ – peak-end of sprouting + 0.15 $dm^3 \cdot ha^{-1}$ – covering of interrows + 0.15 $dm^3 \cdot ha^{-1}$ – flower bud break, 5. From sprouting – mechanical treatment, and after the final shaping of ridges before sprouting of potato plants – Avatar 293 ZC herbicide at a dose of 1.5 $dm^3 \cdot ha^{-1}$.

Each year in autumn, before establishment of the experiment, natural fertilization was used at a dose of 25 $t \cdot ha^{-1}$, as well as mineral fertilization with phosphorus 44.0 kg $P \cdot ha^{-1}$ (triple superphosphate 46%) and potassium 124.5 kg $K \cdot ha^{-1}$ (potassium salt 60%), and during spring – nitrogen fertilization (ammonium nitrate 34%) at a dose of 100 kg N per 1 ha. Potato tubers were planted in the second decade of April (in 2015 and 2016) and in the third decade of April (in 2017). Harvest was performed in the phase of full technological maturity of tubers. Sensory evaluation of tubers was performed after 8–10 days following the harvest. Evaluation of the color of potato flesh was made on the basis of a six-point scale, where: 1 – means white flesh, 2 – white flesh with gray tint, 3 – creamy flesh, 4 – light–yellow flesh, 5 – yellow, 6 – dark yellow flesh. When assessing the cooking type (consistency of tuber flesh after boiling), bonitation was used in the scale of 1–4, where 1 means type A – salad (waxy), 2 – type B – all-purpose (slightly waxy), 3 – type C – mealy, 4 – type D – very mealy. Darkening of raw and boiled tuber flesh was evaluated after 10 minutes in the longitudinal section, using a 9-point reversed Danish scale, where 9 – means no darkening, and 1 – the strongest darkening [Roztropowicz et al., 1999; Domański, 2001].

The statistical methods. The results were subjected to the statistical analysis with the method of the analysis of variance. Significance of variability sources was tested with the Fisher-Snedecor F test, and rating significance of differences at P = 0.05 between the compared means using Tukey's test.

Weather conditions. Weather conditions during the study were diverse. The largest sum of rainfall was recorded in the vegetation period of 2017. It amounted to 425 mm and was higher than the average sum from the period long-term by 64 mm. On the other hand, in the vegetation period of 2015, the sum of rainfall was the smallest and amounted to 288 mm; a slight drought was recorded in this season. When analyzing the distribution of temperatures in particular vegetation seasons, it should be stated that the warmest vegetation season was in 2016, and the average air temperature amounted to 16.1°C and was higher than the average from the long-term period by 1.2°C.

RESULTS AND DISCUSSION

As a result of the conducted study, it was diagnosed that treatments with the use of biostimulators and herbicide as well as weather conditions in the study period did not have any effect on the color of potato tuber flesh. In turn, the value of the concerned characteristic was differentiated by the potato cultivars being grown (Table 1). The Bellarosa and Vineta cultivars were characterized by a yellow hue of tuber flesh, and the Owacja cultivar – light-yellow hue (Table 1). In the opinion of Wichrowska and Rogozińska [2010], Zarzecka et al. [2017], the color of tuber flesh is a feature depending on the cultivar, which is modified by habitat factors only to a small extent. When evaluating the eating quality of tubers, it is desired for the flesh color to be stable and for the tendency to change to be as low as possible. In the opinion of Wroniak [2007], the flesh color does not affect the consistency and nutritional value of tubers and is the distinguishing mark of potato cultivars.

An important feature of sensory quality of potato tubers is the cooking type, also called the use and eating type. In the conducted experiment, the Bellarosa and Owacja varieties were qualified as the cooking type B (all-purpose) – tubers were slightly mealy, slightly moist, with quite a dense consistency and a delicate flesh structure (Table 2). On the other hand, the Vineta cultivar was qualified as the mixed cooking type AB (salad/all-purpose). The cooking type A was joined by tubers with dense flesh that do not fall apart after boiling and that can be sliced quite easily (Table 2). No significant impact of experiment factors on the value of the concerned characteristic was reported. Assessment of the cooking type was close to the values included in the Characteristics of the National Register of Potato Cultivars, where the Bellarosa cultivar was classified into the cooking type B (all-purpose), Owacja to type B/BC (all-purpose, mealy), and Vineta to the cooking type B/AB (all-pur-

Table 1. Flesh color of potato tubers (scale 1–6)

Tabela 1. Barwa miąższu bulw ziemniaka (w skali 1–6)

Objects Objekty	Cultivars / Odmiana			Years / Lata			Mean Średnio
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	5.0	4.0	5.0	4.7	4.7	4.7	4.7
2	5.0	4.0	5.0	4.7	4.7	4.7	4.7
3	5.0	4.0	5.0	4.7	4.7	4.7	4.7
4	4.9	4.0	4.9	4.6	4.6	4.6	4.6
5	5.0	4.0	5.0	4.6	4.7	4.7	4.7
Mean / Średnio	5.0	4.0	5.0	4.7	4.7	4.7	4.7

**$LSD_{0.05}$ for: cultivars – 0.02; objects – n.s.; years – n.s.; interaction – n.s.
**$LSD_{0.05}$ dla: odmian – 0.02; obiektów – n.s.; lat – n.s.; interakcji – n.s.

* – as in the experiment's methodology; ** LSD – least significant difference; n.s. – not significant.

* – jak w metodologii eksperymentu; ** LSD – najmniej znacząca różnica; n.s. – nieistotne

pose, salad) [Plant Breeding..., 2015]. The research of Wichrowska and Rogozińska [2010] also indicates that the use and eating type of tubers is a feature determined genetically. On the other hand, the results of Zgórska and Grudzińska [2012], as well as Thybo et al. [2006], indicate the relation between denseness of tuber flesh after boiling (the cooking type) and the content of starch and dry matter in tubers. In the opinion of the authors, tubers with smaller content of dry matter and starch usually belong to the salad type, and those with greater content of these components – to the medium dense or mealy type.

The feature of determining the quality of potato tubers intended for direct consumption and processing is darkening of raw tuber flesh (enzymatic darkening) and after boiling (non-enzymatic darkening) [Zgórska and Grudzińska, 2012]. Quick darkening of tuber flesh is an unwanted feature. It is the cause of an ugly color of frozen or dried products, French fries, chips, as well as dishes prepared using potatoes [Frydecka-Mazurczyk and Zgórska 2003, Grudzińska 2009]. According to Zgórska [2013], slight darkening covers darkening of raw flesh below 6.5 point on a 9-point scale.

In the original study, darkening of raw flesh, evaluated after 10 minutes from slicing of tubers, depended upon the cultivar, methods of use of biostimulators and herbicide, and weather conditions during the study period (Table 3). The smallest degree of darkening was observed in tuber flesh of potatoes of the Bellarosa cultivar – on average, 8.8 on the 9-point scale, and the largest degree of darkening in the Owacja cultivar – on average, 8.4 on the 9-point scale (Table 3). The research of Urbanowicz [2010], Wichrowska and Rogozińska [2010] also indicated that the intensity of darkening of raw tuber flesh depended on the cultivar.

In the conducted experiment, greater darkening of tuber flesh was observed in the case of objects, on which the biostimulant was applied together with the herbicide (objects 4) or the herbicide alone (objects 5) – Table 3. This is consistent with the research Sawicka et al. [2006]. On the other hand, Urbanowicz [2010] did not ascertain any significant impact of metribuzin on darkening of raw flesh.

Table 2. Cooking type (scale 1–4)

Tabela 2. Typ kulinarny (skala 1–4)

Objects Objekty	Cultivars / Odmiana			Years / Lata			Mean Średnio
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	2–B***	2–B	1.4–A	1.8– AB	1.8–AB	1.7–AB	1.8–AB
2	2–B	2–B	1.5–AB	1.8–AB	1.8– AB	2–B	1.9–AB
3	2–B	2–B	2–B	2–B	2–B	2–B	2–B
4	2–B	2–B	2–B	2–B	2–B	2–B	2–B
5	2–B	2–B	2–B	2–B	2–B	2–B	2–B
Mean	2–B	2–B	1.8–AB	1.9–AB	1.9–AB	1.9–AB	1.9–AB

**$LSD_{0.05}$ for: cultivars – 0.02; objects – n.s.; years – n.s.; interaction – n.s.
**$LSD_{0.05}$ dla: odmian – 0.02; obiektów – n.s.; lat – n.s.; interakcji – n.s.

* – as in the experiment's methodology; ** LSD – least significant difference; n.s. – not significant; *** A – salad cooking type; B – all-purpose cooking type.

* – jak w metodologii experymentu; LSD – najmniej znacząca różnica; n.s. – nieistotne; *** A – typ sałatkowy; B – typ wszechstronny

Table 3. Darkening of raw tuber flesh after 10 minutes (scale 1–9)

Tabela 3. Ciemnienie miąższu bulw surowych po 10 minutach (skala 1–9)

Objects Objekty	Cultivars / Odmiana			Years / Lata			Mean Średnio
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	8.9	8.5	8.7	8.8	8.7	8.5	8.7
2	8.9	8.5	8.7	8.8	8.7	8.5	8.7
3	8.9	8.5	8.7	8.8	8.7	8.5	8.7
4	8.7	8.3	8.3	8.7	8.5	8.0	8.4
5	8.7	8.3	8.2	8.7	8.4	8.0	8.4
Mean / Średnio	8.8	8.4	8.5	8.8	8.6	8.3	8.6
**$LSD_{0.05}$ for: cultivars – 0.02; objects – n.s.; years – n.s.; interaction – n.s.							
**$LSD_{0.05}$ dla: odmian – 0.02; obiektów – n.s.; lat – n.s.; interakcji – n.s.							

* – as in the experiment's methodology; ** LSD – least significant difference; n.s. – non-significant differences.

* – jak w metodologii eksperymentu; ** LSD – najmniej znacząca różnica; n.s. – nieistotne.

The presented results indicate that the application of biostimulators (objects 2 and 3) does not deepen the darkening of raw tuber flesh (Table 3). Kołodziejczyk [2016] also did not ascertain the impact of the UGmax preparation on the intensity of darkening of raw tuber flesh.

In the conducted research, the darkening of boiled tuber flesh after 10 minutes depended upon the cultivar, methods of use of biostimulators and herbicide, as well as years of testing (Table 4). The lowest tendency of boiled tubers to darken was observed in the Bellarosa cultivar, while the greatest tendency – in the Owacja cultivar tubers, where greater darkening of flesh occurred also after application of the GreenOK Universal-PRO (object 2) and Asahi SL biostimulator (object 3) – Table 4. Greater darkening of boiled flesh (as compared to the control object) was observed after application of the Avatar 293 ZC herbicide together with the GreenOK biostimulator (object 4) and on objects, on which only the Avatar 293 ZC herbicide was applied (object 5). The research of Wichrowska and Rogozińska [2010] also indicated that tubers from plots sprayed with herbicides darkened more than those harvested from control plots.

Table 4. Darkening of boiled tuber flesh after 10 minutes (scale 1–9)

Tabela 4. Ciemnienie miąższu bulw ugotowanych po 10 minutach (skala 1–9)

Objects Objekty	Cultivars / Odmiana			Years / Lata			Mean Średnio
	Bellarosa	Owacja	Vineta	2015	2016	2017	
1*	8.9	8.8	8.8	9.0	8.8	8.8	8.9
2	8.9	8.6	8.8	8.9	8.7	8.6	8.7
3	8.9	8.6	8.8	8.9	8.7	8.6	8.7
4	8.7	8.5	8.6	8.8	8.6	8.4	8.6
5	8.7	8.5	8.7	8.8	8.6	8.5	8.6
Mean / Średnio	8.8	8.6	8.7	8.9	8.7	8.6	8.7
**$LSD_{0.05}$ for: cultivars – 0.02; objects – n.s.; years – n.s.; interaction – n.s.							
**$LSD_{0.05}$ dla: odmian – 0.02; obiektów – n.s.; lat – n.s.; interakcji – n.s.							

* – as in the experiment's methodology ; ** LSD – least significant difference; n.s. – non-significant differences.

* – jak w metodologii eksperymentu; ** LSD – najmniej znacząca różnica; n.s. – nieistotne.

The impact of weather conditions on flesh color of tubers as well as on the cooking type was not proven. On the other hand, more intense darkening of raw and boiled tuber flesh was observed in conditions prevailing in 2017, which was the most humid year. The research of Kołodziejczyk et al. [2005] proves that dry and warm years foster preservation of a light color of tuber flesh.

CONCLUSIONS

1. The GreenOK Universal-PRO and Asahi SL biostimulators, as well as the Avatar 293 ZC herbicide did not change the flesh color of potato tubers and the cooking type.
2. Increased darkening of raw and boiled flesh was observed after application of the Avatar 293 ZC herbicide and the GreenOK Universal-PRO bioactivator (object 4) and after application of the Avatar 293 ZC herbicide (object 5). The smallest darkening tendency was observed in the Bellarosa cultivar, and the greatest – in the Owacja cultivar.
3. The impact of meteorological conditions on flesh color of potato tubers as well as the cooking type was not proven. On the other hand, more intense darkening of raw and boiled tuber flesh was observed in conditions prevailing in 2017, which was the most humid year.
4. In connection with introduction of new cultivars of potatoes to cultivation as well as improvement of agrotechnics of this plant, the qualitative characteristics of potato tubers should be systematically assessed.

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JAKOŚĆ SENSORYCZNA BULW ZIEMNIAKA W WARUNKACH STOSOWANIA BIOSTYMULATORÓW I HERBICYDU

Streszczenie. Celem badań była ocena wpływu stosowania biostymulatorów i herbicydu na wybrane cechy jakości sensorycznej bulw ziemniaka jadalnego (barwę miąższu bulw, typ kulinarny oraz ciemnienie miąższu bulw surowych i ugotowanych po 10 minutach). Badania polowe przeprowadzono w latach 2015–2017 w rejonie Polski wschodniej. Doświadczenie założono w trzech powtórzeniach, metodą losowanych podbloków w układzie split-plot, gdzie czynnikiem pierwszym były trzy wczesne odmiany ziemniaka jadalnego: Bellarosa, Owacja, Vineta, a drugim – pięć sposobów stosowania biostymulatorów wzrostu: GreenOK Uniwersal-PRO i Asahi SL oraz ich kombinacja z herbicydem Avatar 293 ZC. W prowadzonym eksperymencie nie udowodniono wpływu biostymulatorów i herbicydu na barwę miąższu i typ kulinarny bulw ziemniaka. Wykazano, że ciemnienie miąższu bulw surowych i ugotowanych było większe po zastosowaniu biostymulatora łącznie z herbicydem, lub tylko samego herbicydu (obiekty 4. i 5.). Największą skłonnością do ciemnienia miąższu surowego i gotowanego po 10 minutach charakteryzowały się bulwy odmiany Owacja, a najmniejszą Bellarosa. Nie stwierdzono wpływu warunków meteorologicznych na barwę miąższu bulw ziemniaka oraz typ kulinarny. Pogłębienie ciemnienia miąższu bulw surowych i gotowanych zaobserwowano w sezonie wegetacyjnym 2017 roku, który był najbardziej wilgotny.

Słowa kluczowe: *Solanum tuberosum* L., jakość sensoryczna, biostymulatory, herbicydy