AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura
VOL. LXXIV (4) 2019

 http://dx.doi.org/10.24326/as.2019.4.7

[1] Experimental Station for Cultivar Assessment of Central Crop Research Center Uhnin, 21-211 Dębowa Kłoda, Poland
[2] University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland
[3] Department of Plant Production and Food Safety, Stanisław Pigoń State Higher Vocational School in Krosno, Dmochowskiego 12, 38-400 Krosno
e-mail: P.Pszczolkowski.inspektor@coboru.pl

PIOTR PSZCZÓŁKOWSKI[1], BARBARA SAWICKA[2], BARBARA KROCHMAL-MARCZAK[3]

Influence of cultivation technology on the color of raw potato tubers

Wpływ technologii uprawy na barwę miąższu surowych bulw ziemniaka

Summary. Results of the research were based on a field experiment carried out in 2014–2016 at the Experimental Station of Cultivar Assessment in Uhnin (51°34'N, 23°02'E), on podzolic slightly acidic soil. The experiment was carried out using random sub-blocks, in a dependent split-plot system, in triplicate. The first-order factor was potato cultivars (‘Vineta’ and ‘Satina’), and the second-order factor consisted of six cultivation technologies: A − using fungicides to control potato blight, technologies: B, C, D, E − with the application of effective microorganisms, and technology F − without the use of fungicides and effective microorganisms as a control object. The scope of the research included assessing the color of the raw tubers pulp. To determine the color of raw potato, the method of trichromatic colorimetry was used applying the Konica Minolta CM-5 spectrophotometer. The color measurement of raw tubers was carried out in the CIEL*a*b* system. Cultivation technology with fungicide application significantly contributed to the brightness change of the raw tuber flesh compared to the technology (D), where for the treatment, as in the growing season, effective microorganisms were used. Genetic properties of cultivars determined the color brightness, as well as its trichromatic coordinates.

Key words: effective microorganisms, plant extracts, fungicides, potato, color of tuber pulp

INTRODUCTION

Raw materials and products made without the use of chemicals are more and more valued by consumers. Plant cultivation systems and technologies can have a significant

impact on the biochemical composition and quality of potato tubers [Maggio et al. 2002, Janas 2009]. Biodynamic agriculture is a unique system of organic farming that contributes to the development of sustainable agriculture. Its main purpose is to use biological and physical means to strengthen the enzymatic activity of soil and biological diversity in the closed cycle in agriculture, as well as to produce safe food products with high nutritional value and high sensory and rheological properties [Ponzio et al. 2013, Vaitkevičienė 2016]. However, this system has not been extensively researched and is not yet widely used by farmers. In the use of potato for direct consumption and food processing (crisps, fries or potato dries), color of the raw tubers pulp plays a significant role. This rapid color of the raw potato tubers pulp creates serious problems in processing technology and can cause changes in the appearance and sensory properties of the products obtained. Undesirable coloring of a food product may cause a decrease in its market value or even disqualify it from the market [Kidmose and Hansen 1999, Vaitkevičienė 2016]. Changing the color of the flesh from its natural (from white to creamy, light yellow to yellow) to a dark color is not accepted by consumers. The browning process is an enzymatic reaction caused by the oxidation of phenolic compounds (tyrosine and chlorogenic acid). It is primarily related to the action of polyphenoloxidases, which catalyze the oxidation reactions of intracellular polyphenols in the presence of oxygen. Polyphenoloxidase, catalyzing the process of enzymatic browning, shows different activity, depending on the type of polyphenol compound and its occurrence place within the tuber [Frydecka-Mazurczyk and Zgórska 2003, Wang-Pruski and Nowak 2004, Sawicka and Skiba 2009, Mesquita and Queiroz 2013]. Conditions that can be created to obtain the variability of the color of the potato tuber flesh, determine the need to evaluate them. Currently, the most popular method of describing the color of plant and animal products is the CIELab system. It is the foundation of modern color management systems. The difference between two colors in the CIELab space is the usual Euclidean distance between two points in the three-dimensional space. Fungicides used in potato protection against *Phytopthora infestans* have a negative impact on the quality of potato tubers and the natural environment [Wszelaczyńska et al. 2004, 2007]. Substances that could partially replace fungicides in potato production are plant extracts [Wojcieszyńska and Wilczek 2006, Korzeniowska 2017] and microbiological preparations. The latter constitute a mixture of naturally occurring microorganisms (mainly lactic acid bacteria, yeasts, actinumines, photosynthetic bacteria and some fungi) [Kołodziejczyk 2014a, 2014b, Pszczółkowski and Sawicka 2018]. They create the possibility of using them to increase the resistance of crop plants to pathogens, improve the resistance of plants to enzymatic darkening, which is important for consumers and food processing of potato [Zgórska and Grudzińska 2012, Mesquita and Queiroz 2013, Korzeniowska 2017 Vaitkevičienė 2016]. The study assumes the hypothesis that biodynamic preparations improve the biological and agrochemical properties of the soil. In addition, the use of these preparations in cultivation technology have an impact on the accumulation of biologically active compounds and their antioxidant activity in potato tubers. Therefore, the studies evaluated the effect of biodynamic preparations on genotype properties and on enzymatic darkening of potato tubers.

MATERIAL AND METHODS

Field experiments were conducted in 2014–2016 at the Experimental Station of Cultivars Assessment in Uhnin (51°34'N, 23°02'E), on podzolic, slightly acidic soil. The experiment was made using randomized blocks, in a dependent split-plot system, in triplicate, in accordance with the methodology for studying the economic value of cultivated plant cultivars (WGO) at the COBORU stations [Lenartowicz 2013]. The first-order factor was potato cultivars ('Vineta' and 'Satina'), and the second-order factor consisted of 6 cultivation technologies: 5 technologies with the use of potato protection against potato blight and effective microorganisms (EM) and a standard object without the use of fungicides and effective microorganisms, with spraying of tubers potato with clean water before planting.

Cultivation technologies

The following technologies were used (Tab. 1):

Technology A (standard): three treatments with protection against potato blight. Their application, i.e. dates and doses were in accordance with the Institute of Plant Protection − National Research Institute (IOR-PIB) recommendations.

Technology B – tubers before planting were treated in an aqueous solution of EmFarma™ (1 dm^3 EmFarma™ · 10 dm^{-3} water) for 5 min. During the vegetation, 3 treatments with preparations were also used: EmFarma Plus™ (12 dm^3) + Ema5™ (2 dm^3) in 400 $dm^3 \cdot ha^{-1}$ water.

Technology C – tubers before planting were treated in aqueous solution of EmFarma™ with tansy and yarrow extract (1 dm^3 ·10 dm^{-3} water) for 5 min. During the vegetation, 3 treatments with preparations were also used: EmFarma Plus™ (12 l) + Ema5™ (2 dm^3) in 400 dm^3 water · ha^{-1}.

Technology D − tubers before planting were treated in aqueous solution of EmFarma™ (1 dm^3 ·10 dm^{-3} water) for 5 min. During potato vegetation, 8–10 treatments were performed depending on the cultivar and course of meteorological conditions during the growing season, with the preparations: EmFarma Plus™ (10 dm^3 each) and preparation Ema5™ (1 l) every third treatment, in 400 dm^3 water · ha^{-1}.

Technology E – tubers before planting were treated with an aqueous solution of EmFarma™ with tansy and yarrow extract (1 dm^3 ·10 dm^{-3}water) for 5 min. During potato vegetation, spraying with the following preparations was used: EmFarma Plus™ (10 dm^3) and Ema5™ (1 dm^3) every third treatment, in 400 dm^3 water · ha^{-1}. During potato vegetation, 8 to 10 treatments were performed, depending on the cultivar and meteorological conditions during the growing season.

Technology F – before planting, the potato tubers were soaked in clean water for 5 min. During the growing season, no protective measures or fertilization were applied. The combination was a control object. In technologies B and C, the first procedure was performed in phase 19 BBCH, the second − 2 weeks after the first one; third − in phase 65 BBCH (full flowering of the potato). However, in technologies D and E − the first treatment was applied in phase 19 BBCH, and the next one, every 7 days until the beginning of plant maturation.

Table 1. Dose and terms of application of fungicides in the standard technology, 2014–2016

Years	Application terms	Trade name of fungicide/active substance	Dose of fungicide (1 $dm^3 \cdot ha^{-1}$; $kg \cdot ha^{-1}$)
2014	16.06.2014	Infinito 687,5 SC – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$
	27.06.2014	Ridomil Gold MZ 67,8 WG – mankozeb, metalaksyl M	2.0 $kg \cdot ha^{-1}$
	11.07.2014	Infinito 687,5 SC – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$
2015	02.07.2015	Infinito 687,5 S.C. – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$
	15.07.2015	Ridomil Gold MZ 67,8 WG – mankozeb, metalaksyl M	2.0 $kg \cdot ha^{-1}$
	27.07.2015	Infinito 687,5 SC – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$
2016	22.06.2016	Infinito 687,5 SC – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$
	05.07.2016	Ridomil Gold MZ 67,8 WG – mankozeb, metalaksyl M	2.0 $kg \cdot ha^{-1}$
	20.07.2016	Infinito 687,5 S.C. – propamocarb hydrochloride, fluopicolide	1.6 $dm^3 \cdot ha^{-1}$

Extracts of herbs

Tansy leaf extract was made from above-ground parts of the plant (blooming herbs and flowers) − *Tanaceti herba* and *Tanaceti flos*. Tansy herb contains up to 0.6% volatile oil, and flowers from 1 to 1.5% of essential oil, the main component of which is toxic β-thujone (about 70%), camphor, borneol, α-pinene, 1.8-cineol, umbelloni, sabinene. Other components of this raw material are: a-amarine and β-amine, sesquiterpene lactones, mainly bitter tanacetin and arbuskulin-A, also germacren D and krispolid, steroids − β-sitosterol, campestrol, stigmasterol, cholesterol and flavonoids: derivatives of quercetin and luteolin and acacetin, coffees, tannins, ascorbic acid and mineral salts [Kurkina et al. 2011]. Tansy extracts have inhibitory properties against pathogenic and non-pathogenic strains [Derda et al. 2012].

Millefolii herbae extractum – Yarrow extract was made from above-ground parts (herb and flowers). The material contains essential oil, coumarins, flavonoids, sesquiterpene lactones, polyacetylenes, triterpenes, tannins, sterols and organic acids [Lakshmi et al. 2011, Vitalini et al. 2011]. The *A. millefolium* extract and its isolated components for the capture of free radicals against 2,2-diphenylpicrilhydrazyl represent complete antioxidant capacity (based on the reduction of Cu (++) to Cu (+)) and the ability to inhibit lipid peroxidation [Vitalini et al. 2011].

Soil analysis

Soil samples were taken each year at the beginning of vegetation of potato with Nekrasov auger from randomly chosen 5 places at the depths of 0–20 cm. Soil granulo-

metric composition was determined by means of the aerometric method by Prószyński[Ryżak et al. 2009]. The following soil quality indicators were determined: pH – 1 mol per dm^3 KCl in suspension according to ISO 10390 [2005]; the amounts of available phosphorus (P) and available potassium (K), by employing the Egner-Rhyming-Domingo (A-L) method [SWP 2011], amount of humus – by Thurin method [ISO 10694: 1995].

Agrotechnical treatments

The potato forecrop was winter triticale. Constant NPK fertilization in the amount of 90 kg N, 39.3 kg P, 112.0 kg K · ha^{-1} was used in the experiment. In addition, in autumn a green mass of mustard in the amount of 20 t · ha^{-1} was plowed. Tubers were planted in the end of April with a spacing of 67.5 × 37 cm. The seed potato material constituted tubers in the C/A health class. The area of plots for harvesting was 15 m^2. The agrotechnical and plant protection measures against potato beetle were carried out in accordance with good agricultural practice. The tubers were harvested in the 99 BBCH phase [Lenartowicz 2013]. During the harvest, representative samples were taken from each plot to determine the darkening of raw tubers pulp.

Evaluation of color of pulp of raw tubers

To determine the color of the raw potato samples tested, the method of trichromatic colorimetry was used using the Konica Minolta CM-5 spectrophotometer. The measurement of the color of raw tubers was carried out in the CIEL*a*b* system. The system consisted of determining the 3 parameters, which correspond to individual letters. The letter *L** determines the change in the brightness of the test sample on a scale of 0 to 100 (the higher the value of L, the sample is brighter), while a* and b* are the coordinates of color change. The letter a* shows the share of green and red in the analyzed color, where shades of green color have negative value, and shades of red − positive value, while the letter *b** shows the share of blue and yellow in the analyzed color, where shades of blue have negative and shades of yellow a positive value. The component a* representing the green-red axis and the component b* (blue-yellow axis) assume values in the range from –120 to 120 (Figure 1) [Marszałek 2011, Brainard et al. 2018].

The device was calibrated before the test on the white standard. Assuming that the white light is to be white, the reference has trichromatic components (x_w, y_w, z_w); the CIE XYZ coordinate transformation to CIEL*a*b* coordinates is described by the following equations:

(1) $$L^* = 116 \cdot f\left(\frac{y}{yw}\right) - 16,$$

(2) $$a^* = 500 \cdot \left[f\left(\frac{x}{xw}\right) - f\left(\frac{y}{yw}\right) \right],$$

(3) $$b^* = 200 \cdot \left[f\left(\frac{y}{yw}\right) - f\left(\frac{z}{zw}\right) \right],$$

where function $f(\frac{t}{tw})$ is defined by the formula:

$$f(\frac{t}{t_w}) = \begin{cases} (\frac{t}{t_w})1/3 & (\frac{t}{t_w}) > 0{,}008856 \\ \frac{\frac{t}{t_w}}{903{,}4} & \\ (\frac{116}{t_w}) + 16 & (\frac{t}{t_w}) < 0{,}008856 \end{cases} \tag{4}$$

All flesh color determinations were made 10 min after cutting of the tubers.

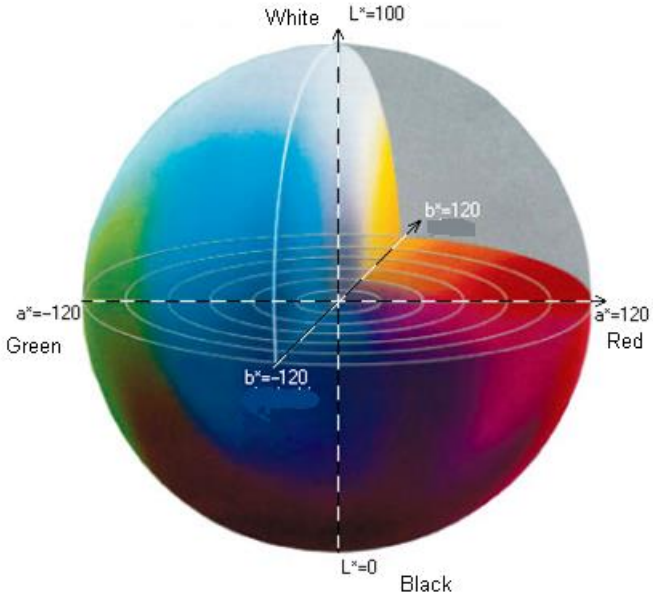

Fig. 1. The CIE Lab color model
Source: Marszałek [2011]

Soil conditions

Field experiments were carried out at the Department of Experimental Cultivar Assessment in Uhnin on podzolic soil with granulometric composition of sandy-loamy [WRB 2014]. The pH of soil was slightly acidic (5.8–6.4 pH in 1 n KCl). This soil was characterized by a very high content of available phosphorus, average potassium content and low to very high content of available magnesium, depending on the year of research (Tab. 2).

Table 2. Content in the soil available forms of phosphorus, potassium magnesium and humus and pH in KCl (2014–2016)

Years	The content of available forms of macronutrients (mg · kg^{-1} in dry mass of soil)			pH (1 mol · dm^{-3} KCL)	Humus content (%)
	P	K	Mg		
2014	99.5	132	34	6.4	1.03
2015	87.7	108.8	78	5.9	0.94
2016	82.5	90.5	70	5.8	1.06
Mean	89.9	110.4	60.7	6.0	1.01

Meteorological conditions

Meteorological conditions in the years of study varied. The year 2014 can be classified as wet, 2015 was one of the least favorable, in which there was a large shortage of precipitation in June-August, which determined the yields, while 2016 was average, both in terms of temperature and precipitation [Skowera et al. 2014] (Tab. 3).

Table 3. Rainfall, air temperature and the hydrothermal coefficient of Sielianinov, during the growing season of potato, according to the meteorological station in Uhnin 2014–2016

Year	Month	Rainfall (mm)				Air temperature (°C)				Hydrothermal coefficient of Sielianinov*
		decade			month	decade			mean	
		1	2	3		1	2	3		
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
2014	IV	1.6	20.7	20.7	43.0	9.3	9.5	14.3	11.1	1.3
	V	20.3	62.0	59.1	141.4	11.0	13.2	19.2	14.7	3.1
	VI	32.5	3.7	49	85.2	16.4	15.9	15.2	15.9	1.8
	VII	4.0	54.2	11.5	69.7	19.9	20.7	22.5	21.1	1.1
	VIII	21.7	44.1	30.0	95.8	23.2	19.2	15.6	19.2	1.6
	IX	1.9	5.0	12.7	19.6	16.3	15.6	12.0	14.6	0.5
	Total				454.7					
2015	IV	14.6	5.9	41.3	61.8	5.4	8.6	12.4	8.8	2.3
	V	23.4	13.9	83.0	120.3	12.6	12.0	13.7	12.8	3.0
	VI	5.4	16.5	24.8	46.7	17.7	16.3	16.1	16.7	0.9
	VII	10.5	21.6	13.1	45.2	19.6	18.7	19.9	19.4	0.8
	VIII	0.4	0	5.7	6.1	23.4	20.6	20.3	21.4	0.1
	IX	32.4	32.6	65.2	130.2	16.0	17.7	12.8	15.5	2.8
	Total				410.3					

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
2016	IV	11.5	22.2	13.4	47.1	10.9	10.1	9.0	10.0	1.6
	V	4.9	2.8	38.6	46.3	14.4	17.8	12.9	15.3	1.0
	VI	10.1	43.2	34.0	87.3	16.6	17.5	23.0	19.1	1.5
	VII	22.4	30.8	60.9	114.1	19.5	20.1	21.9	20.5	1.8
	VIII	22.8	17.7	0.5	41.0	20.7	17.1	20.4	19.5	0.7
	IX	7.6	0.1	4.1	11.8	19.5	15.5	11.5	15.5	0.3
	Total				347.6					

* Coefficient was calculated according to the formula:

$$k = \frac{10P}{\sum t}$$

where: P – the sum of the monthly precipitation in mm, Σt – monthly total air temperature > 0°C [Skowera et al. 2014].

Ranges of values of this index were classified as follows: extremely dry − $k \leq 0.4$; very dry − $0.7 \leq k < 0.4$; dry − $1.0 \leq k < 0.7$; rather dry − $1.3 \leq k < 1.0$; optimal − $1.6 \leq k < 1.3$; rather humid − $2.0 \leq k < 1.6$; wet − $2.5 \leq k < 2.0$; very humid − $3.0 \leq k < 2.5$; extremely humid − $3.0 > k$.

Statistical calculations

The statistical calculations were based on the three-factor analysis of variance [ANOVA] model and multiple t-Tukey tests, with the $p_{0.05}$ significance level. Multiple comparison tests enabled detailed analyses of medium comparisons, by isolating statistically homogeneous medium groups (homogeneous groups) and determining so-called the least significant mean differences, which in the Tukey tests are marked as HSD (Tukey's Honest Significant Difference) [SAS 9.2 2008].

RESULTS

Three applications of fungicides in standard technology (A) resulted in significant color of raw tuber pulp hue in relation to technology (D), where tubers were treated with EmFarma™ aqueous solution before planting, and during 8–10 treatments with the following preparations: EmFarma Plus™ and Ema5™ every third treatment. In other technologies, the differences within this parameter proved to be insignificant. Technologies B, C, D, E and F and A and F proved to be homogeneous due to the value of this feature (Table 4).

Among the tested cultivars, ‘Vineta’ was characterized by significantly brighter color of the flesh. In turn, ‘Satina’ was characterized by significantly higher saturation and darker shade of the flesh color. Conditions of the growing season did not have any significant impact on the value of L* parameter (Tab. 4).

The effect of cultivation technology on the brightness of the flesh (L*) was dependent on the reaction of potato cultivars. Among the tested cultivars, ‘Vineta’ reacted with a significant change of the pulp to the application of effective microorganisms. Application before planting tuber treatment with aqueous EmFarma™ solution, and during potato vegetation – 8–10 treatments with EmFarma Plus™ and Ema5™ preparations every third treatment, contributed to a significant brightening of the raw tubers pulp, in com-

parison with object (A), where fungicide protection against *Phytopthora infestans* was applied (Fig. 2).

Table 4. Parameters of color of raw tubers of potato in the CIELab system

Specification		L*	a*	b*
Cultivation technologies**	A	74.1 ±1.4	3.32 ±0.25	40.3 ±2.8
	B	78.3 ±1.7	3.26 ±0.19	42.8 ±2.6
	C	77.6 ±1.1	2.59 ±0.13	42.0 ±2.2
	D	79.5 ±0.8	2.86 ±0.14	43.0 ±2.3
	E	78.3 ±1.0	2.80 ±0.20	40.4 ±2.8
	F	75.3 ±1.3	2.35 ±0.21	40.4 ±2.7
	$HSD_{0.05}$	5.2	0.44	n.s.
Cultivars	'Vineta'	78.0 ±1.2	2.55 ±0.16	40.4 ±2.4
	'Satina'	76.3 ±1.5	3.18 ±0.19	42.6 ±2.6
	$HSD_{0.05}$	1.7	0.15	2.1
Years	2014	77.3 ±1.6	2.79 ±0.15	40.5 ±2.2
	2015	75.3 ±1.3	3.42 ±0.21	42.7 ±2.5
	2016	76.3 ±1.8	3.32 ±0.19	44.4 ±2.6
	$HSD_{0.05}$	n.s.***	0.22	3.2

L* – brightness (luminance), a* – green to magenta color, b* – blue to yellow color, ***ns – not significant at $p_{0,05}$
**A – technology standard: 3 treatments with protection against potato late blight; B – pre-planting tubers were treated with EmFarmaTM + Ema5TM in aqueous solution during vegetation 3 treatments; C – the tubers for the planting was treatments in EmFarmaTM aqueous solution with a vetiver and yarrow extract and while vegetation period of potato applied 3 treatments: EmFarma PlusTM and Ema5TM; D – the tubers were treated with aqueous solution of EmFarmaTM before planting, and during the vegetation of potato, 8–10 treatments were made: EmFarma PlusTM and Ema5TM, every third treatment; E – the tubers were treated with aqueous solution of EmFarmaTM with vetiver and yarrow extract and during potato vegetation 8–10 treatments were applied: EmFarma PlusTM and Ema5TM, every third treatment; F – potato tubers prior to planting soaked in clean water (control object);

The value of parameter a* depended significantly on the cultivation technology used. The change of potato tuber flesh color towards red was observed in the technology using fungicides against potato blight, compared to the object (F) and object (C), where tubers were treated with aqueous solution of EmFarma^{TM} with tansy and yarrow extract before planting, and during the growing season, three treatments were used: EmFarma Plus^{TM} and Ema5^{TM}; (D), where tubers before planting were treated with an aqueous solution of EmFarma^{TM}, and during the potato vegetation, 8–10 treatments were performed with preparations: EmFarma Plus^{TM} and Ema5^{TM}, every third treatment; (E) – tubers were treated with an aqueous solution of EmFarma^{TM} with tansy and yarrow extract and during potato vegetation, 8–10 treatments were used with the following preparations: EmFarma Plus^{TM} and Ema5^{TM} every third treatment. Technologies A and B and C, D and E turned out to be homogeneous in terms of the value of this feature (Fig. 3).

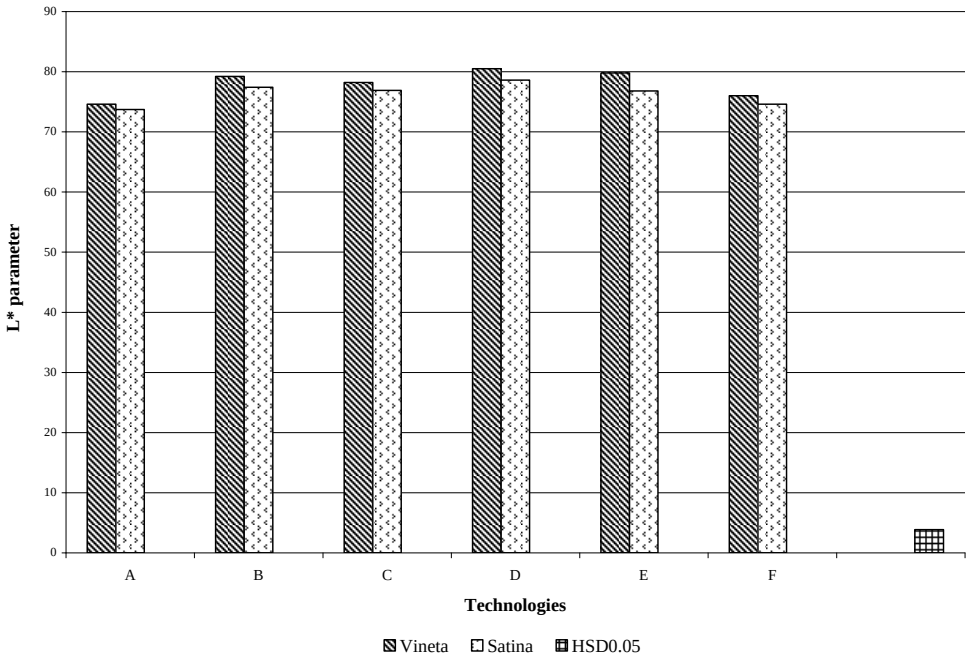

Fig. 2. Effect of cultivation technology and cultivars on brightness of potato tuber flesh (L *) (scale 0–100)

A – technology standard: 3 treatments with protection against potato late blight; B – pre-planting tubers were treated with EmFarmaTM + Ema5TM in aqueous solution during vegetation 3 treatments; C – the tubers for the planting was treatments in EmFarmaTM aqueous solution with a vetiver and yarrow extract and while vegetation period of potato applied 3 treatments: EmFarma PlusTM and Ema5TM; D – the tubers were treated with aqueous solution of EmFarmaTM before planting, and during the vegetation of potato, 8–10 treatments were made: EmFarma PlusTM and Ema5TM, every third treatment; E – the tubers were treated with aqueous solution of EmFarmaTM with vetiver and yarrow extract and during potato vegetation 8–10 treatments were applied: EmFarma PlusTM and Ema5TM, every third treatment; F – potato tubers prior to planting soaked in clean water (control object)

A cultivar of potato more prone to change the hue of the color in red, turned out to be an average mid early 'Satina', than the early 'Vineta'. Applied fungicides as well as effective microorganisms (EM) and herbal extracts had no significant effect on color saturation of the flesh (parameter b*). Cultivar significantly more prone to a change in color in the yellow direction turned out to be 'Satina' (Tab. 4).

Conditions during the study years significantly determined the value of a* parameter. The largest changes in the shade of the flesh in the red direction were observed in 2015, which was the dry year, whereas the smallest saturation of the flesh with red color was observed in the year with excessive precipitation, in 2014 year (Tab. 4).

The examined cultivars also showed a different response to meteorological conditions during the growing season (Tab. 5). Only in 2016, the average in terms of precipitation and temperature, the tested cultivars differed significantly in terms of the brightness of the flesh color. 'Vineta' was characterized by a significantly lighter pulp than 'Satina'. In the remaining years, tested cultivars proved to be homogeneous due to the values of this characteristics.

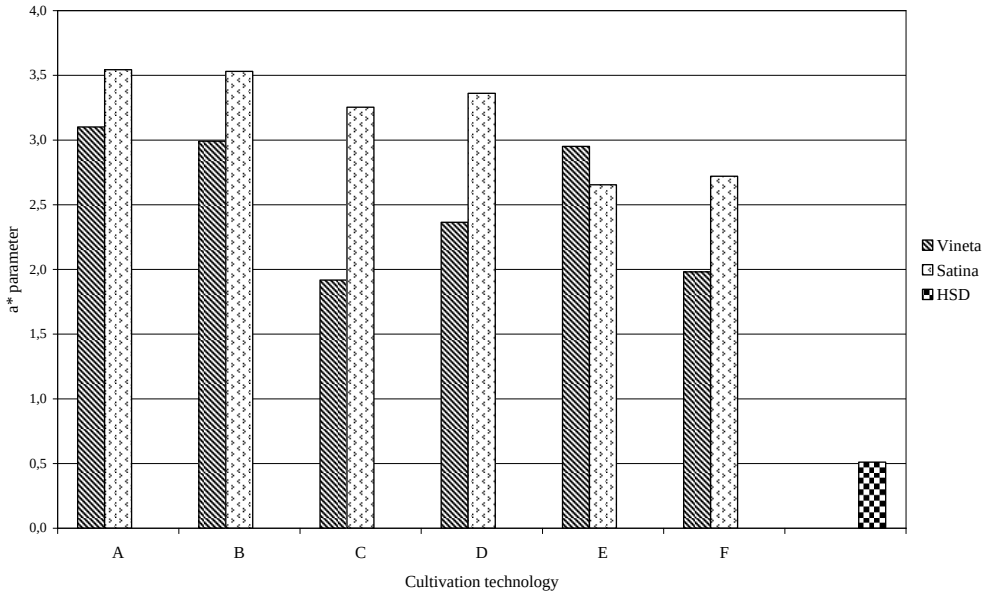

Fig. 3. Influence of cultivation technology and cultivars on the value of a* parametr of flesh raw tubers

Explanations as in Fig. 2

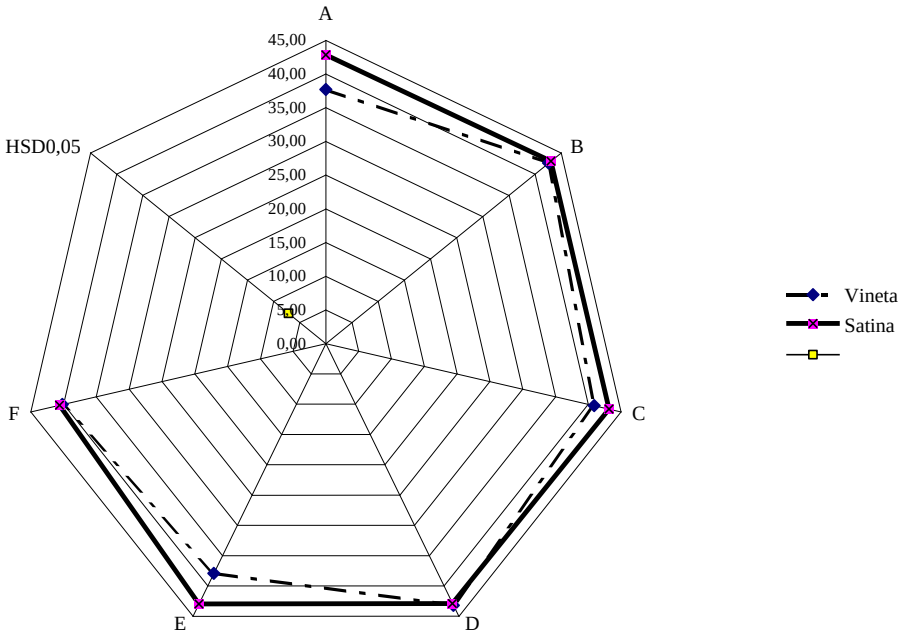

Fig. 4. Influence of cultivation technology and cultivars on the value of b* parameter of flesh raw tubers

Explanations as in Fig. 2

Table 5. Influence of cultivation technology, cultivars and years on the on L* parameter of flesh raw tubers

Experimental factors		2014	2015	2016
Cultivation technologies**	A	75.1	71.5	75.8
	B	77.4	77.5	80.1
	C	77.6	75.8	79.3
	D	79.6	77.7	81.3
	E	77.8	77.1	80.1
	F	77.6	71.3	77.0
$HSD_{0,05}$			ns***	
Cultivars	'Vineta'	77.7	74.9	81.5
	'Satina'	77.3	75.3	76.3
$HSD_{0,05}$			5.3	

* brightness (luminance), ** explanations as in Tab. 4, ***ns – not significant at $p_{0.05}$

The applied cultivation technologies significantly modified the value of the *a** parameter in both cultivars. In the case of 'Vineta' cv., the highest saturation of the red color was recorded in the pulp of tubers grown in technology (A) using fungicides, and the lowest – in technology C, where the tubers were treated with aqueous solution of EmFarma™ with tansy and yarrow extract before planting and during the growing season 3 treatments were applied: EmFarma Plus™ and Ema5™. Homogeneous objects were: (C) and (F) as well as (A) and (B). In the case of 'Satina' cv., only objects (A) and (E) differed significantly in terms of this feature, while objects (A) and (B), (C) and (D) as well as (D) and (F) were homogenous (Fig. 3).

Table 6. Influence of cultivation technology, cultivars and years on the a* parameter of flesh raw tubers

Experimental factors		2014	2015	2016
Cultivation technologies**	A	3.00	3.50	3.47
	B	2.91	3.47	3.41
	C	2.22	2.83	2.70
	D	2.53	3.07	2.99
	E	2.42	3.06	2.93
	F	2.21	2.39	2.45
$HSD_{0,05}$			ns***	
Cultivars	'Vineta'	2.30	2.69	2.66
	'Satina'	2.79	3.42	3.32
$HSD_{0,05}$			0.44	

*a – green to magenta color, ** explanations as in Tab. 4, ***ns – not significant at $p_{0,05}$

Table 7. Influence of cultivation technology, cultivars and years on the b* parameter

Experimental factors		2014	2015	2016	Mean
Cultivation technologies**	A	38.7	40.1	42.0	40.3
	B	41.2	42.4	44.7	42.8
	C	40.2	42.0	43.9	42.0
	D	40.5	43.7	44.9	43.0
	E	39.9	39.2	42.2	40.4
	F	39.4	39.6	42.1	40.4
$HSD_{0,05}$			ns***		ns
Cultivars	'Vineta'	39.4	39.6	42.2	40.4
	'Satina'	40.6	42.7	44.5	42.6
$HSD_{0,05}$			ns		2.1
Mean		40.0	41.2	43.3	41.5
$HSD_{0,05}$			3.2		

*b – blue to yellow color; ** explanations as in Tab. 4; ***ns – not significant at $p_{0,05}$

The theoretical color model created by the CIE (Commission Internationale d'Eclairage) contains all the colors recognized by a human eye. Figures 5 and 6 show the trichromatic coordinates of the color of the raw tuber pulp characteristic for the tested potato cultivars and cultivation technology. They characterize: the ratio of red to green (a*), yellow to blue (b*) and brightness ratio (L*).

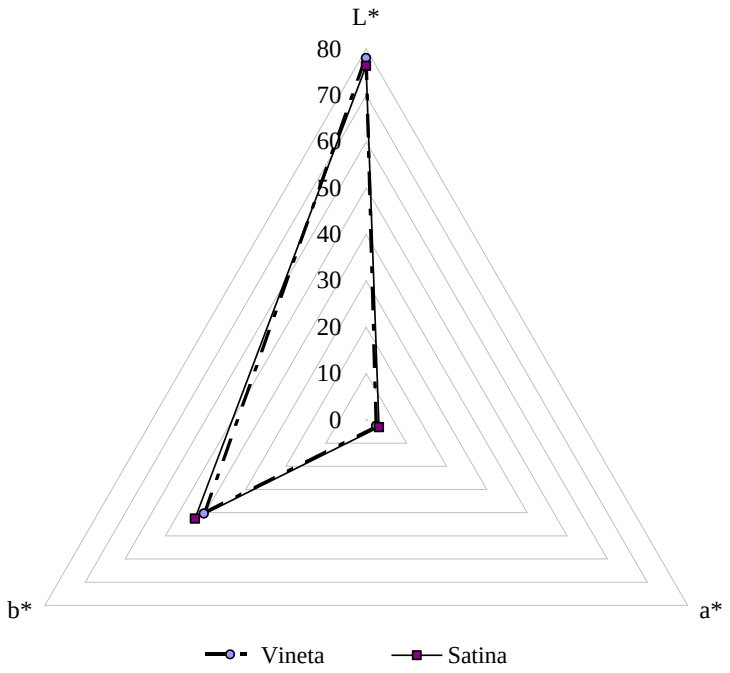

Fig. 5. Three chromatic coordinates of the color of the cross section of raw tubers for cultivars

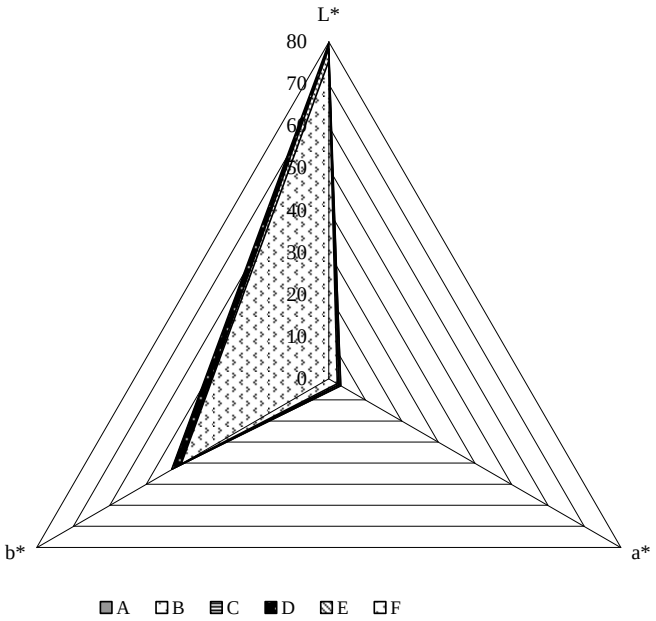

Fig. 6. Three chromatic coordinates of the color of the cross section of raw tubers for technologies

Explanations as in Fig. 2.

Cultivation technologies have not had any significant impact on the value of parameter b*. The pulp of 'Satina' was characterized by a significantly higher saturation of the yellow color than the flesh of 'Vineta' (Tab. 4). Meteorological conditions during the study years significantly modified the value of parameter b*. The highest saturation of the flesh color in the yellow direction was observed in 2016, which was optimal in terms of rainfall, and the smallest in humid, in 2014 year (Tab. 4).

A different reaction of cultivars was shown in terms of color saturation of the raw tubers pulp, on meteorological conditions in the years of research (Tab. 6). In the average 2016, both cultivars were characterized by higher tendency of the flesh to change the color saturation in the yellow direction, compared to 2014, which was a wet year. In dry 2015, only 'Satina' showed a greater tendency to the saturation of the color in the yellow direction than in the moist one, 2014 (Tab. 6).

The value of the b* parameter, in the CIELab system, was independent of both the technology of potato production and the interactions of years x technologies and years × cultivars (Tab. 7).

DISCUSSION

Genetic properties of tested potato cultivars had the greatest impact on the analyzed characteristics of the raw tuber pulp color, which is confirmed by research of Frydecka-Mazurczyk and Zgórska [2003], Jakubowski and Wrona [2012], Hussein et al. [2014],

Krochmal-Marczak et al. [2016]. The growing demand for biodynamic farms around the world has triggered the need for scientific research aimed at multi-faceted scientific verification of the impact of biodynamic preparations on the quality of vegetable raw materials. However, there is very little data in the literature describing the effects of biodynamic preparations on qualitative characteristics of potato tubers [Vaitkevičienė 2016]. The use of pesticides in potato cultivation still plays a large role, but their impact on the quality characteristics of the crop is ambiguous [Wszelaczyńska et al. 2007, Rahman et al. 2012, Zarzecka and Gugała 2013]. The three-fold use of fungicides in the conducted tests, in standard technology, contributed to a significant deterioration of the brightness of raw tuber pulp (L*) as compared to technology where the tubers were treated with aqueous EmFarma™ solution before planting, and when during the potato season, 8–10 treatments were performed applying preparation EmFarma Plus™ and every third treatment with Ema5™. Also, the value of parameter a* depended significantly on the cultivation technology used. The change of tuber flesh color towards red was found in technology with fungicides application against potato blight, compared with the control combination, and with objects where tubers were treated with aqueous solution of EmFarma™ with tansy and yarrow extract, containing the natural phenolic compounds, before planting and during the growing season 3 treatments using EmFarma Plus™ and Ema5™ were applied and where tubers before planting were treated with an aqueous solution of EmFarma™, and during the season 8–10 treatments were performed with the following preparations: EmFarma Plus™ and every third treatment with Ema5™; as well as in the object where tubers were treated with aqueous solution of EmFarma™ with tansy and yarrow extract and during potato vegetation, 8–10 treatments were used with the preparations EmFarma Plus™ and every third treatment – Ema5™. Wojcieszyńska and Wilczek [2006] report that in a potato infected with spores of *Phytopthora infestans*, between healthy and infected tissue creates a blue fluorescent zone, which is a barrier between two types of tissues. The comparison of phenolic components in healthy tissue and the fluorescent zone indicates that in this area there is an intense synthesis of two phenolic compounds – fluorescing scopoline and chlorogenic acid. Thus, the use of herbal extracts may help to create such a barrier for spores *Phytopthora infestans*. The saturation of the flesh color did not depend significantly on the fungicides, herbal extracts or microbiological preparations applied. In the available literature, there are no studies confirming directly the effect of effective microorganisms on the color of tuber pulp. Janas [2009], Pszczółkowski and Sawicka [2018] argue that effective microorganisms (EM) support the growth and activity of roots, as well as increase the efficiency and photosynthetic capacity of plants. According to Kaczmarek et al. [2008] and Khayatnezhad et al. [2011], this is probably due to higher availability of nutrients that facilitate EM application over time.

In opinion of Wszelaczyńska [2004], Sawicka and Skiba [2009], Krochmal-Marczak et al. [2017], the change in the raw tuber flesh color is influenced by the melanin resulting from the oxidation of tyrosine along with the catalytic activity of the enzyme tyrosinase. Reduction of tyrosine content and nitrogenous components in tubers is influenced by potassium fertilization, which may cause a reduction in color of the pulp. Zgórska and Grudzinska [2012] claim, that this process can be caused by both enzymatic and non-enzymatic reactions. Enzymatic reactions are caused by the activity of oxidase enzymes, and non-enzymatic − by external factors (temperature, oxygen, pH, presence of catalytic

metals, such as Fe or Cu) [Wszelaczyńska 2004, Wszelaczyńska et al. 2007]. The process of enzymatic darkening of raw tubers, according to Wang-Pruski and Nowak [2004], Sawicka and Dolatowski [2007], Mesquita and Queiroz [2013], is related to the action of polyphenol oxidases [PPO], which catalyze the oxidation reactions inside cellular polyphenols in the presence of oxygen. However, polyphenoloxidase, catalyzing the enzymatic browning process, shows variable activity depending on the polyphenol compound and the place of occurrence in the raw material Mesquita and Queiroz [2013]. According to Yoshi [2007], the color is an impression induced in our brain by electromagnetic radiation in the 380–780 nm range acting on the eye. The impression of the color brightness can be combined with the physical parameter of light intensity. These stimuli cause the impression of saturation and shade of color and constitute fuzzy sets, but the affiliation of stimuli to the sets does not yet give a clear description of the color [Shyam 2010, Hussein et al. 2014]. To process this information, different models are used, that are based on neural networks, stimulating brain functions, and they are not stimuli from trichromatic methods. According to Hussein et al. [2014], the psychophysiological ability to identify colors is based on distinguishing three attributes of color: hue, saturation and brightness (vividness), which are understood as characteristic properties of a color impression, constituting the basis for describing one of three attributes. According to Yoshi [2007], all colors can be divided into achromatic and chromatic. The first ones are from white through neutral gray to black. They have only one color attribute: brightness against secondary light sources, and brightness – with primary light sources. The remaining colors are chromatic ones with three attributes. Three-dimensional Schanda space [2007] is required to determine them. All chromatic and achromatic colors are characterized by brightness (vividness), thus they were assumed to be the main, hence vertical in solids of colors. Therefore, the chromatic color can be presented as a mixture of white and monochromatic light and can be described by means of brightness, shade and color saturation, which was achieved in our own research.

From the point of view of physics, color saturation can also be determined based on the spectral composition of the color. The higher the saturation of the color, the smaller the share of its wave radiation spectrum with different lengths than the dominant wave, which binds the saturation with the shade of color. The amount of saturation of the flesh color was also associated with its brightness (vividness), which is confirmed by the studies of Frydecka-Mazurczyk and Zgórska [2003]. Wszelaczyńska et al. [2007] proved highly significant correlation between subjective methods for assessing darkening of raw tuber pulp and parameters of the CIELab system as well as a*/b* ratio.

Changes in the tuber flesh color often precede changes in their other organoleptic characteristics, which may be useful in the analysis of product quality and be an indicator of the correctness of technological processes and during the storage of tubers [Krochmal-Marczak et al. 2016, 2017]. Color of tested potato cultivars was measured in the CIELab system using three basic parameters L*a*b*, that best describe the changes in the color of products. Thus, all three parameters affect the color perceived by the observer at the same time, which is why a coefficient that combines three measured parameters is sought.

According to Wang-Pruski and Nowak [2004], Sawicka and Dolatowski [2007], Sawicka and Skiba [2009], Krochmal-Marczak et al. [2017] color of the raw tubers flesh also depends on the impact of various environmental factors occurring during vegetation.

Nourian et al. [2003], Jakubowski and Wrona [2012] mention the following causes that affect the color of potato tuber pulp: interference of pathogens and pests, mineral deficiencies during the growing season, mechanical damage during tuber harvesting and transport, rapid changes in microclimate conditions during tuber storage and improper preparation of the raw material for processing (peeling, cutting, etc.). In opinion of Krochmal-Marczak et al. [2017], the shortage of rainfall as well as high air temperatures during potato vegetation favor preserving the bright color of raw tuber flesh. Our own research proved that in the average year, in terms of rainfall and air temperature, there were significant differences between cultivars related to the brightness of raw tubers. Due to the adverse effect of excessive chemistry on the quality of raw materials, alternative solutions in agriculture are sought [Rahman et al. 2012, Kołodziejczyk 2014a, b]. Here presented results require further research on the use of microbiological formulations and herbal extracts in the protection of potatoes against fungal diseases and studies of their impact on the yield quality, both in organic crops, integrated crops, and intended for food processing.

CONCLUSIONS

1. The use of effective microorganisms and herbal extracts has contributed to improving brightening of tuber pulp in technology with tuber treatment before planting with EmFarma™ solution and application of 8–10 treatments with EmFarma Plus™ and Ema5™ preparations every third treatment, compared with a 3-fold application of fungicides.

2. Under influence of effective microorganisms and herbal extracts color change of potato tuber flesh in the yellow direction, in technologies where the tubers before treatment were treated with EmFarma™ solution with tansy and yarrow extract and application of three EmFarma Plus™ and Ema5™ treatments as well as technology where tubers were treated with EmFarma™ solution and during potato vegetation 8–10 treatments were performed using preparations: EmFarma Plus™ and Ema5™ every third treatment, as compared with traditional technology with 3 fungicide treatments.

3. Genetic properties of studied cultivars significantly determined the color characteristics of the raw tubers pulp as well as its trichromatic coordinates. The ‘Vineta’ was characterized by a lighter color of the flesh than the ‘Satina’ The latter was characterized by significantly higher saturation and shade of the flesh color in the yellow direction.

4. Examined cultivars showed different reaction expressed in the brightness of tuber pulp (L*) to cultivation technologies. Only ‘Vineta’ reacted with a significant change of the pulp to the application of effective microorganisms. Application of aqueous EmFarma™ solution as a tuber treatment before planting, and during potato vegetation, 8–10 treatments with preparations: EmFarma Plus™ and every third treatment with Ema5™, contributed to significant brightening of raw tubers pulp, compared with traditional technology, where fungicide protection against *Phytopthora infestans* was used.

5. The optimum humidity and thermal conditions were favorable for obtaining tubers with lighter color of the flesh and better saturation than tubers collected in years with unfavorable weather conditions for potato vegetation. Conditions during the study years had significant effect on the saturation of yellow tuber flesh in the case of ‘Satina’.

REFERENCES

Brainard D.H., Cottaris N.P., Radonji A., 2018. The perception of color and material in naturalistic tasks, http://dx.doi.org/10.1101/288662 [access 01.04.2018].

Derda M., Hadaś E., Thiem B., Wojt W.J., Wojtkowiak-Giera A., Cholewiński M., Skrzypczak L., 2012. *Tanacetum vulgare* L. jako roślina o potencjalnych właściwościach leczniczych w *Acanthamoeba keratitis* [*Tanacetum vulgare* L. as a plant with potential medicinal properties for *Acanthamoeba keratitis*]. Now. Lek. 81(6), 620–625.

Frydecka-Mazurczyk A., Zgórska K., 2003. Optical colour measurement of potato products. Acta Hortic. 600, 717–722.

Hussein S.M., Jaswir I., Jamal P., Othman R., 2014. Carotenoid Stability and Quantity of Different Sweet Potato Flesh Colour over Postharvest Storage Time. Adv. Environ. Biol. 8(3), 667–671.

ISO 10694: 1995. Soil quality – Determination of organic and total carbon after dry combustion (elemental analysis).

ISO 10390: 2005. Soil quality – Determination of pH. https://www.sis.se/api/document/preview/905787/

Jakubowski T., Wrona P., 2012. Wpływ promieniowania mikrofalowego na ciemnienie miąższu bulw ziemniaka [Influence of microwave radiation on flesh potato]. Acta Sci. Pol., Technica Agraria 11(3–4), 55–63.

Janas R., 2009. Possibilities of using effective microorganisms in organic crop production systems. Probl. Agric. Eng. 3, 111–119.

Kaczmarek Z., Jakubus M., Grzelak M., Mrugalska L., 2008. Impact of the addition of various doses of Effective Microorganisms to arable-humus horizons of mineral soils on their physical and water properties. J. Res. Applic. Agric. Eng. 53, 118–121.

Khayatnezhad M., Shahriari R., Gholamin R., Jamaati-e-Somarin S., Zabihi-e-Mahmoodabad R., 2011. Correlation and path analysis between yield and yield components in potato (*Solanum tuberosum* L.). Middle-East J. Sci. Res. 7, 17–21.

Kidmose U., Hansen M., 1999. The influence of postharvest storage, temperature and duration on quality of cooked broccoli florets. J. Food Qual. 22, 135–146.

Kołodziejczyk M., 2014a. Effectiveness of nitrogen fertilization and application of microbial preparations in potato cultivation. Turk. J. Agric. For. 38, 299–310.

Kołodziejczyk M., 2014b. Effect of nitrogen fertilization and microbial preparations on potato yielding. Plant Soil Environ. 60(8), 379–386.

Korzeniowska K., 2017. Możliwości zastosowania ekstraktów roślinnych zawierających związki fenolowe w rolnictwie ekologicznym [Possibilities of using plant extracts containing phenolic compounds in organic farming]. Przem. Chem. 1(7), 100–104, http://dx.doi.org/10.15199/62.2017.7.15

Krochmal-Marczak B., Sawicka B., Kiełtyka-Dadasiewicz A., 2017. Culinary properties of selected potato cultivars in relation to storage. Pol. J. Commodity Sci. 4 (53), 72–81.

Krochmal-Marczak B., Sawicka B., Kiełtyka-Dadasiewicz A., Bienia B., 2016. Influence of storage and climatic conditions on the quality tuber flesh potato cultivated in the organic system. Fragm. Agron. 33(2), 44–54.

Kurkina A.V., Khusainova A.I., Daeva E.D., Kadentsev V.I., 2011. Flavonoids from *Tanacetum vulgare* flowers. Chem. Nat. Comp. 47(2), 284–285.

Lakshmi T., Goetha R.V., Roy A., Kumar A., 2011. Yarrow (*Achillea millefolium* Linn.) a herbal medicinal plant with broad therapeutic use – A review. Int. J. Pharm. Sci. Rev. Res. 9(2), 136–141.

Lenartowicz T., 2013. Methodology of economic value analysis of cultivars (WGO). Potato. COBORU, Słupia Wielka, Poland, pp. 34.

Maggio A., Miyazaki S., Veronese P., Fujita T., Ibeas J.I., Damsz B., Narasimhan M.L., Hasegawa P.M., Joly R.J., Bressan R.A., 2002. Does proline accumulation play an active role in stress-induced growth reduction. Plant J. 31, 699–712.

Marszałek K., 2011. Badanie współrzędnych barw filtrów optycznych z pomocą programu MCalc Multilayer Calculation (wersja 4.0.6) [The study of coordinates of optical filter colors with the help of the MCalc Multilayer Calculation program (version 4.0.6)]. AGH, Laboratorium Technologii Cienkowarstwowej, Kraków, 1–10.

Mesquita V., Queiroz C., 2013. Enzymatic Browning. Biochem. Foods, 387–418.

Nourian F., Ramaswamy H.S., Kushalappa A.C., 2003. Kinetics of quality change associated with potatoes stored at different temperatures. LWT – Food Sci. Technol. 36(1), 49–65.

Ponzio C., Gols R., Pieterse M.J.C., Dicke M., 2013. Plant-microbe-insect interactions. Ecological and phytohormonal aspects of plant volatile emission in response to single and dual infestations with herbivores and phytopathogens. Funct. Ecol., 27, 587–598.

Pszczółkowski P., Sawicka B., 2018. Effect of the fungicides, microbiological preparations and extracts with herbs on the yield of potato. Fragm. Agron. 35(1), 81–93, http://dx.doi.org/10.26374/fa.2018.35.08

Rahman M.M., Khan A.A, Ali M.E., Mian I.H., Akanda A.M., Abd Hamid S.B., 2012. Botanicals to Control Soft Rot Bacteria of Potato. Sci World J., article 796472, http://dx.doi.org/10.1100/2012/796472

Ryżak M., Bartmiński P., Bieganowski A., 2009. Metody wyznaczania rozkładu granulometrycznego gleb mineralnych [Methods for determination of particle size distribution of mineral soils]. Acta Agrophys. 175, 48–51.

SAS Institute Inc. 2008. SAS/STAT®9.2 User's Guide. Cary, NC Institute Inc, SAS.

Sawicka B., Dolatowski Z., 2007. Variability of the flesh darkening in tubers of new potato cultivars under the influence of ultrasounds. Probl. Prog. Agric. Sci. 517, 639–649.

Sawicka B., Skiba D., 2009. Fluctuation of flesh darkening of raw and cooking tubers *Helianthus tuberosus* L. Annales UMCS, E, Agricultura, 64(2), 15–22.

Schanda J., 2007. CIE colorimetry. (in:) J. Schanda (ed.), Colorimetry: Understanding the CIE System. Wiley – Interscience. John Wiley & Sons, pp. 459, http://dx.doi.org/10.1002/9780470175637

Shyam N.J., 2010. Colour measurements and modeling. In: N.J. Shyam (ed.), Nondestructive evaluation of food quality – theory and practice. Springer, London–New York, 17–40, http://dx.doi.org/10.1007/978-3-642-15796-7

Skowera B., Kopcińska J., Kopeć B., 2014. Changes in thermal and precipitation conditions in Poland in 1971–2010. Ann. Wars. Univ. Life Sci.-SGGW, Land Reclam. 46(2), 153–162.

SWP, 2011. Financial Econometrics Series. https://www.swpberlin.org/fileadmin/contents /products/comments/2011C38_mlg_ks.pdf

Vaitkevičienė N., 2016. The effect of biodynamic preparations on the accumulation of biologically active compounds in the tubers of different genotypes of ware potatoes. Doctoral dissertation. Agricultural Sciences, Agronomy (01A), ASU, Akademija, Kaunas, Lithuania.

Vitalini S., Beretta G., Iriti M., Orsenigo S., Basilico N., Dall'Acqua S., Iorizzi M., Fico G., 2011. Phenolic compounds from *Achillea millefolium* L. and their bioactivity. Acta Biochim. Pol. 58(2), 203–207.

Wang-Pruski G., Nowak J., 2004. Potato after-cooking darkening. Am. J. Potato Res. 81, 7–17. http://www.findarticles.com/p/articles/mi_qa4069/is_200401/ai_n9402757 [Acess 10.04.2018].

WRB, 2014. World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports 106, Food And Agriculture Organization of The United Nations, Rome, 2015, http://www.fao.org/3/i3794en/I3794en.pdf

Wojcieszyńska D., Wilczek A., 2006. Phenolic compounds of natural origin. Sci. Technol. 6, 6–12. https://www.kiosk24.pl/download.html [access 11.04.2018].

Wszelaczyńska E., 2004. Effect of magnesium fertilisation on the content of organic acids and 'Mila' potato tuber blackening. Acta Sci. Pol. Agricultura 3(1), 175–186.

Wszelaczyńska E., Wichrowska D., Pińska M., Rogozińska I., 2007. Evaluation of enzymatic browning degree of edible potato tubers induced by herbicides, mechanical damages and storage by means of instrumental and sensory methods. Pol. J. Food Nutrit. Sci. 57(3A), 163–166.

Yoshi O., 2007. Spectral color measurement. In: Colorimetry: Understanding the CIE System. Ed. by J. Schanda. Wiley – Interscience. A. John Wiley & Sons Inc., 101–132.

Zarzecka K., Gugała M., 2013. Wpływ użyźniacza glebowego UGmax na plon ziemniaka i jego strukturę [The effects of soil fertilizer UGmax on yield of potato tubers and its structure]. Bull. IHAR 267, 107–112.

Zgórska K., Grudzińska M., 2012. Changes in selected quality parameters of potato tubers during storage. Acta Agrophys. 19(1), 203–214.

Financing source: Author's own funds.

Streszczenie. Wyniki badań oparto na doświadczeniu polowym przeprowadzonym w latach 2014–2016 w Zakładzie Doświadczalnym Oceny Odmian w Uhninie (51°34', 23°02'E), na glebie płowej, lekko kwaśnej. Eksperyment wykonano metodą podbloków losowanych, w układzie zależnym, split-plot, w trzech powtórzeniach. Czynnikiem I rzędu były odmiany ziemniaka ('Vineta' i 'Satina'), zaś czynnik II rzędu stanowiło sześć technologii uprawy: A – z zastosowaniem fungicydów do zwalczania zarazy ziemniaka, technologie: B, C, D, E – z aplikacją efektywnych mikroorganizmów oraz technologia F – bez stosowania fungicydów i efektywnych mikroorganizmów, jako obiekt kontrolny. Zakres badań obejmował ocenę barwy miąższu bulw surowych. Do oznaczenia barwy ziemniaka surowego zastosowano metodę kolorymetrii trójchromatycznej z wykorzystaniem spektrofotometru Konica Minolta CM–5. Pomiar barwy bulw surowych przeprowadzono w systemie CIEL*a*b*. Technologia uprawy z aplikacją fungicydów przyczyniła się istotnie do zmiany jasności barwy miąższu bulw surowych, w stosunku do technologii (D), gdzie do zaprawiania, a także w czasie wegetacji stosowano efektywne mikroorganizmy. Właściwości genetyczne badanych odmian determinowały zarówno jasność barwy, jak i jej współrzędne trójchromatyczne.

Słowa kluczowe: efektywne mikroorganizmy, wyciągi roślinne, fungicydy, ziemniak, ciemnienie miąższu bulw

Received: 30.08.2019
Accepted: 13.12.2019