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COMPARISON OF PROCESSING FRUIT QUALITY OF SEVERAL GRAPE VARIETIES CULTIVATED IN CLIMATIC CONDITIONS OF POLAND AND BULGARIA

PORÓWNANIE JAKOŚCI OWOCÓW PRZEROBOWYCH KILKU ODMIAN WINOROŚLI UPRAWIANYCH W WARUNKACH KLIMATYCZNYCH POLSKI I BUŁGARII

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Streszczenie. Na przestrzeni wielu lat doświadczeń selekcjonowano odpowiednie odmiany dla danych regionów i doskonalono technologię produkcji wina. Postępujące zmiany klimatu niosą ze sobą zmiany jakości winogron, które w przyszłości będą stanowiły duże wyzwanie dla prowadzenia winnicy (sposobu uprawy, terminów zbiorów i winifikacji). Celem pracy było porównanie jakości kilku odmian owoców winorośli uprawianych w odmiennych warunkach klimatycznych. Materiał doświadczalny pochodził z winnic zlokalizowanych na Nizinie Szczecińskiej w Polsce i z Plovdiv w Bułgarii. W doświadczeniu ujęto trzy odmiany winorośli: Cabernet Sauvignon, Cabernet Franc i Pinot Noir. Ocenie podlegały parametry fizyczne (masa owoców, masa i długość gron, jędrność) i skład chemiczny owoców (ekstrakt, kwasowość, pH, kwas askorbinowy, azotany, indeks antocyjanowy). Analizie poddano również wybarwienie zebranych owoców oraz zmiany barwy moszczu w trakcie maceracji. Warunki klimatyczne stanowiska uprawy miały istotny wpływ na skład chemiczny owoców. Wyższym poziomem ekstraktu i pH oraz niższą kwasowością cechowały się owoce uprawiane w Bułgarii. Niezależnie od miejsca uprawy owoce odmiany Cabernet Sauvignon miały najwyższą zawartość ekstraktu i kwasów organicznych. Sok z winogron zebranych w Bułgarii był ciemniejszy (L*) niż sok z owoców zebranych w Polsce. Natomiast sok z owoców uprawianych w Polsce miał więcej niebieskiego pigmentu (b*). Stwierdzono również, że parametry barwy owoców a* i b* są wysoce skorelowane z indeksem antocyjanowym.

Key words: colour, chemical composition, maceration, *Vitis*.
Słowa kluczowe: kolor, maceracja, skład chemiczny, *Vitis*.

INTRODUCTION

Vitis vinifera L. grape is one of the most widely cultivated vine types; it has great economic importance worldwide. Approximately 71% of this grape production is used by the wine industry, 27% is allocated for direct consumption and the remaining 2% is dried (Xiao-Ling Li et al. 2013).

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Each wine region can be described using a range of environmental factors basically describing climate and soil conditions. These factors have varying degrees of volatility and they impact vine plant functioning. This, in turn, leads to their indirect influence over the final characteristics of wine. Therefore, the vineyard owners need to learn about this natural diversity in order to be able to make the right decisions at key moments of running the vineyard, including choosing the best rootstocks and plant varieties as well as deciding on appropriate soil cultivation (Morlat and Bodin 2006; Van Leeuwen and Seguin 2006; Carey et al. 2008). Inevitable climate changes also affect grape quality, which in the future might become challenging during the vinification process and will influence the final wine quality. The characteristics which may be particularly affected by the climatic changes include grape expression through flavour, microbiological and chemical stability and sensory aspects (Mira de Orduña 2010). Wine quality is determined by four main factors: environmental conditions of production, grape variety, treatments carried out in the vineyard and wine production methods. These elements are factors in the French concept of terroir, which analyses the influence of climate and human activity (Goulet and Morlat 2011). Measurements of some quality parameters, including total soluble solids content (SSC), sugar content, acidity, pH value, tartaric and malic acids content, are essential in determining the optimal harvest date. They also allow to ensure the that produced wines are of high quality and remain chemically and biologically stable (Martínez-Toda 2007). The main harvesting indicators include high level of sugars, low level of acids, rich colour and 'fruity' flavour of the variety (Boulton et al. 1996). The production of red wines is based on grape maceration process in the presence of the grape skins. This process is carried out in order to extract the maximum amount of anthocyanins and obtaining the desired colour of wine. The highest level of anthocyanins extraction is observed during the first few days of maceration (Gómez-Plaza et al. 2001). The colour is one of the most important features which are assessed by red wine consumer during the tasting. Colour of the wine may reflect the product's age, represent its positive qualities and shortcomings. It can also indicate whether the wine has been subjected to a specific ageing process (Marquez et al. 2014).

The vine has been cultivated in Szczecin area from the thirteenth century. The wine from the vineyards located around the Szczecin's castle was appreciated by Pomeranian dukes in Szczecin and by the Mecklenburg princes in Schwerin, Stargard and Gustrow (Chełpiński et al. 2009).

The aim of this paper is to compare the quality of several grapevine varieties cultivated in Poland and Bulgaria. The colour change occurring during must maceration was also evaluated.

MATERIAL AND METHODS

The research was conducted as a result of close collaboration between the Viticulture Department of Agricultural University in Plovdiv along with the Horticulture Department of West Pomeranian University of Technology, Szczecin. The research station is located in the north-western part of Poland in the Szczecin Lowland at a distance of approx. 65 km from the Baltic Sea. In this area, there are numerous hills of 20–60 m ASL, the remnants of the frontal moraine. This affects the distribution of rainfall intensity, number of sunlight hours,

temperature and wind speed. The climate of this area is also significantly affected by the presence of big water basins (Szczecin Lagoon, Dąbie Lake, the Odra River), which provide additional moisture in the period of plant vegetation. The majority of the West Pomeranian Province belong to the zone 7A on the Heinz and Schreiber's "Map of zones of plant resistance to frost" (Snowarski 2012). Minimal temperatures range from –15ºC to –17ºC here. However, in the area of Szczecin and in the nearby northern region, minimal temperatures range from –12ºC to –15ºC, which corresponds to values typical of zone 7B. The vines were planted in the clay soil, are of III valuation class, of wheat and beet type, and at a pH of 6.9–7.1. The soil was rich in nutrients and water.

In the Agricultural Research Station of the University of Plovdiv fruits were harvested in the third decade of September. Plants were grown in a cinnamon-brown soil with a pH 7.1. – (richness of the soil, fertilizing). Plants were planted in 2003. The annual sum of active temperatures (>10ºC) for the station was about 3900 h, and the average total precipitation was 515 mm.

The research focused on three grapevine cultivars: Cabernet Sauvignon, Cabernet Franc, Pinot Noir. The experiment consisted in the comparison of: yield, the size of clusters and fruit, their chemical composition and colour. The bins in pulp during maceration were placed in a heater room at 18º–20ºC. During fermentation, the pulp was mixed every 12 hours to remove carbon dioxide. Titratable acidity and pH were determined by titration of a water extract of fruits homogenate with 0.1 N NaOH to an end point of pH 8.1 (measured with an multimeter Elmetron CX-732) according to PN-90/A-75101/04. Soluble solids content was determined with a digital refractometer PAL-1 (Atago, Japan). Nitrates content were measured with a RQflex 10 reflectometer (Merck). Fruit colour were measured in a transmitted mode through Konica Minolta CM-700d spectrophotometer in 1 cm-thick glass trays. Measurements were conducted in CIE L*a*b* system [L* white (100) black (0), a* green (–100) red (+100), b* blue (–100) yellow (+100)], through a 10º observer type and D65 illuminant. CP Pigment Analyzer PA1101 (Produced by Control in Applied Physiology GbR., Germany) was used for non-destructive measurement of quality parameters. Spectra collected from CP PA1101 were used for calculating Normalized Anthocyanin Index – NAI = (*I780-I570*)/(*I780+I570*). The firmness was expressed as a gram-force causing fruit surface to bend 1 mm.

In order to determine the significance of differences in the change of pulp colour, a one--factor analysis of variance was carried out, using Statistica 10 software. The significance of differences was determined using Tukey's test at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

In order to compare the quality of fruit from the Polish and Bulgarian vineyards immediately after the harvest, single berries and fruit bunches were weighed and measured, then their firmness (Table 1), chemical composition (Table 2) and colour (Table 3 and 4) were assessed. In many parts of Europe with well-established wine production traditions, the value of maximum fruit production per unit area is strictly determined. This allows to create the best quality wines. The weight of grape bunches helps to determine fruit quantity on individual vines, which in turn helps to obtain assumed yield and not exceed the limits.

Table 1. Physical parameters of the fruit obtained from the studied vine varieties depending on crop location
Tabela 1. Parametry fizyczne owoców badanych odmian winorośli w zależności od miejsca uprawy

Crop location Miejsce uprawy	Cultivar – Odmiana			
	Cabernet Sauvignon	Cabernet Franc	Pinot Noir	Mean – Średnia
	Mass of 100 fruits – Masa 100 owoców [g]			
Poland – Polska	158b*	102a	144b	**135a**
Bulgaria – Bułgaria	149b	108a	163b	**140a**
Mean – Średnia	**154b**	**105a**	**154b**	
	Mass of clusters – Masa grona [g]			
Poland – Polska	136a	215c	172b	**175a**
Bulgaria – Bułgaria	154b	223c	159b	**179a**
Mean – Średnia	**145a**	**219b**	**166a**	
	Length of clusters – Długość grona [cm]			
Poland – Polska	12.8a	17.5c	15.0b	**15.1a**
Bulgaria – Bułgaria	14.1a	16.3bc	14.6ab	**15.0a**
Mean – Średnia	**13.5a**	**16.9b**	**14.8ab**	
	Firmness – Jędrność [G · mm^{-1}]			
Poland – Polska	274b	271b	359d	**301a**
Bulgaria – Bułgaria	332c	247a	312c	**297a**
Mean – Średnia	**303b**	**259a**	**336b**	

*Means followed by the same letter do not differ significantly at P = 0.05 according to Tukey multiple range test.
*Oznaczenia tą samą literą nie wykazują istotnych różnic na poziomie α = 0,05 według wielowymiarowego testu Tukeya.

Table 2. Chemical composition of the fruit obtained from the studied vine varieties depending on crop location
Tabela 2. Skład chemiczny owoców badanych odmian winorośli w zależności od miejsca uprawy

Crop location Miejsce uprawy	Cultivar – Odmiana			
	Cabernet Sauvignon	Cabernet Franc	Pinot Noir	Mean – Średnia
	Soluble solids – Ekstrakt [%]			
Poland – Polska	21.4b*	17.2a	17.8a	**18.8a**
Bulgaria – Bułgaria	25.2c	22.9b	24.6c	**24.2b**
Mean – Średnia	**23.3b**	**20.1a**	**21.2a**	
	Titratable acidity – Kwasowość [g · 100 mL^{-1}]			
Poland – Polska	0.73b	0.79b	0.65b	**0.72b**
Bulgaria – Bułgaria	0.64b	0.46a	0.42a	**0.51a**
Mean – Średnia	**0.69b**	**0.63ab**	**0.54a**	
	Juice pH – pH soku			
Poland – Polska	3.42a	3.49ab	3.53abc	**3.48a**
Bulgaria – Bułgaria	3.56abc	3.63bc	3.70c	**3.63b**
Mean – Średnia	**3.49a**	**3.56ab**	**3.62b**	
	L-ascorbic acid – Kwas L-askorbinowy [mg · 1000 g^{-1}]			
Poland – Polska	53.6ab	64.7bc	55.8ab	**58.0a**
Bulgaria – Bułgaria	76.3c	56.5ab	44.2a	**59.0a**
Mean – Średnia	**65.0b**	**60.6b**	**50.0a**	
	Nitrates – Azotany NO_3 [mg · 1000 g^{-1}]			
Poland – Polska	45.7c	34.3b	51.5c	**43.8b**
Bulgaria – Bułgaria	19.7a	14.6a	18.4a	**17.6a**
Mean – Średnia	**32.7ab**	**24.5a**	**35.0b**	
	Normalized Anthocyanin Index – Indeks Antocjanowy NAI			
Poland – Polska	0.668c	0.729d	0.634b	**0.677b**
Bulgaria – Bułgaria	0.642b	0.656bc	0.576a	**0.625a**
Mean – Średnia	**0.655b**	**0.693c**	**0.605a**	

* For explanation, see Table 1 – objaśnienia jak w Tabeli 1.

Table 3. Colour components of studied vine varieties
Tabela 3. Składowe barwy badanych odmian winorośli

Crop location Miejsce Uprawy	Cultivar – Odmiana											
	Cabernet Sauvignon			Cabernet Franc			Pinot Noir			Mean – Średnia		
	Skin colour with wax coating – Kolor skóry z powłoką woskową											
	L*	a*	b*	L*	a*	b*	L*	a*	b*	**L***	**a***	**b***
Poland Polska	41.31	1.33	–9.45	44.67	–2.31	–11.23	37.12	–3.46	–9.04	**41.03**	**–1.48**	**–9.91**
Bulgaria Bułgaria	39.43	–1.48	–8.19	39.22	–1.76	–7.17	39.50	–1.29	–6.97	**39.38**	**–1.51**	**–7.44**
Mean Średnia	**40.37**	**–0.08**	**–8.82**	**41.95**	**–2.04**	**–9.20**	**38.31**	**–2.38**	**–8.01**			
	Skin colour without wax coating – Kolor skóry bez powłoki woskowej											
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Poland Polska	21.59	2.32	–1.34	25.03	3.46	–6.49	27.89	2.24	–3.52	**24.84**	**2.67**	**–3.78**
Bulgaria Bułgaria	23.36	–0.04	-0.91	25.46	–0.35	–1.58	23.57	0.13	–0.36	**24.13**	**–0.09**	**–0.95**
Mean Średnia	**22.48**	**1.14**	**–1.13**	**25.25**	**1.56**	**–4.04**	**25.73**	**1.19**	**–1.94**			
	Colour of flesz – Barwa miąższu											
	L*	a*	b*	L*	a*	b*	L*	a*	b*	**L***	**a***	**b***
Poland Polska	31.24	3.74	11.42	31.47	5.67	2.33	32.41	11.48	5.46	**31.71**	**6.96**	**6.40**
Bulgaria Bułgaria	29.49	0.45	8.28	35.03	2.33	4.38	33.45	6.19	10.49	**32.66**	**2.99**	**7.72**
Mean Średnia	**30.37**	**2.10**	**9.85**	**33.25**	**4.00**	**3.36**	**32.93**	**8.84**	**7.98**			

Regardless of plant variety, no significant differences in the physical parameters of fruit cultivated in Poland and Bulgaria were recorded (Table 1). Laboratory examination which followed, however, indicated significant differences between the studied grape varieties. Regardless of where grapes were cultivated, the Cabernet Franc variety had the lowest mass per unit of fruit (100 berries weighed 105 g) with the largest size bunches weighing 219 g and measuring 16.9 cm. Ryona et al. (2008) recorded the average weight of one berry of this variety at 1.45 g. Moreover, the Cabernet Franc berries were the least firm (259 G · mm^{-1}). The weight of the Cabernet Sauvignon and Pinot Noir fruit was similar, 100 berries weighed 154 g. The size of the berries was almost identical, regardless of where they were cultivated. On the other hand, the bunches of the Cabernet Sauvignon variety harvested in Bulgaria were significantly heavier (154 g) then the grapes harvested in Poland (136 g). Scientific publications on the subject state that these parameters can vary between 160 g and 241 g (Bergqvist et al. 2001; Ryan and Revilla 2003). The least firm fruits were found on the Cabernet Franc varieties grown in Bulgaria (247 G · mm^{-1}); the firmest on the Pinot Noir variety harvested in Poland (359 G · mm^{-1}).

The fruits used for the production of wine must meet specific quality standards. The extract content and acidity are one of the most significant parameters determining grape quality and, consequently, the quality of produced wines. Analysing the chemical composition of the grapes (Table 2) significant differences were observed in the parameters of berries, depending on the place of cultivation and the studied variety. Higher levels of extract and the pH were recorded in fruits grown in Bulgaria (24.2% extract and pH 3.63). These fruits also had a significantly lower organic acids content, averaging 0.51 g · 100 mL^{-1}, compared to fruit harvested in Poland, with the average content of 0.72 g · 100 m^{-1}. Regardless of

where they were grown the Cabernet Sauvignon variety had the highest level of extract (on average 23.3%) and acidity (on average 0.69 g · 100 mL^{-1}). Other fruit of Cabernet Sauvignon variety had similar acidity levels and amounted to 0.57–0.72 g · 100 mL^{-1}, depending on the rootstocks (Lee and Steenwerth 2011). The lowest level of extract was recorded in the Cabernet Franc variety, 17.2% in Poland and 22.9% in Bulgaria. Ryona et al. (2008) obtained similar extract levels in Bulgarian fruit (21.5%). The fruit of the Cabernet Sauvignon variety used in the experiments conducted by Lee and Steenwerth (2013) had the extract level of 23.3%. This value was higher than the one measured in fruits grown in Poland (21.4%), but lower than in fruits grown in Bulgaria (25.2%). The study showed that the average acidity of the Pinot Noir variety grapes was the lowest (0.54 g · 100 mL^{-1}). In Polish conditions, the level of this parameter was recorded at 0.65 g · 100 mL^{-1}, and in Bulgaria 0.42 g · 100 mL^{-1}. Lee and Skinkis (2013) in their research obtained a much higher level of acidity in the Pinot Noir variety fruit, ranging between 0.79–1.10 g per 100 g.

Ascorbic acid is a reduced form of vitamin C and the main biologically active form of this vitamin; it is also a powerful antioxidant (Jacob and Sotoudeh 2002). Its content in grapes from different locations was recorded at a similar level. The Pinot Noir variety fruit had a significantly lower level of ascorbic acid, as compared to the other two varieties (50.0 mg · 1000 g^{-1}). Major differences were also recorded in the nitrates levels; they were relatively low regardless of where the crop was obtained. Polish standards do not determine their content, but in the special purpose products their levels should not exceed 200 mg · 1000 g^{-1}. The vine fruit cultivated in Poland, nitrate content was recorded at the level of 43.8 mg · 1000 g^{-1}; in Bulgaria 17.6 mg · 1000 g^{-1}. Anthocyanin index in the grape must is a parameter related to the level of polyphenols in fruits, namely anthocyanins responsible for the juice colour. In the experiment it was observed that the anthocyanin index was significantly higher in the fruits grown in Poland (0.677) as compared to the fruits grown in Bulgaria (0.625). The differences between studied varieties were also significant. The lowest anthocyanin index was determined in the Pinot Noir variety (mean 0.605), especially in the fruits harvested in Bulgaria (0.576). Ochmian et al. (2013) in their research obtained an even lower rate of anthocyanin index (0.512) in Pinot Noir variety fruit. The highest value of this parameter was recorded for the Cabernet Franc variety especially in the fruits harvested in Poland (0.729).

Anthocyanin index was highly correlated with the a* colour parameter (0.76), and the b* colour parameter (0.81). The higher this index, the higher intensity of extraction of the red and blue pigments, as the mentioned parameters are the colour indicators (Table 3). However, no relationship between the anthocyanin index and the must colour on the 7th day maceration was observed. CIE L*a*b* parameters showed that the fruit colour with waxy coating may be misleading to the human eye. The Pinot Noir variety fruit with waxy coating harvested in Poland seemed to be the darkest (L* 37.12). It was then found that after removing the coating the L* parameter was observed at 27.89. It was the highest value among the studied varieties, which means that they were actually the lightest (Table 3). Parameters describing the colour of the flesh had the highest value in the Pinot Noir variety fruit; they indicate a yellow-red colour.

Maceration is a process of the highest importance during the vinification of red wine; it enables obtaining the required colour. During this process the colouring compounds are leached, mainly from the peel. Analysing the maceration process diagrams (Fig. 1) it could be noticed that the largest extraction of pigments took place during the first 48 hours of the process.

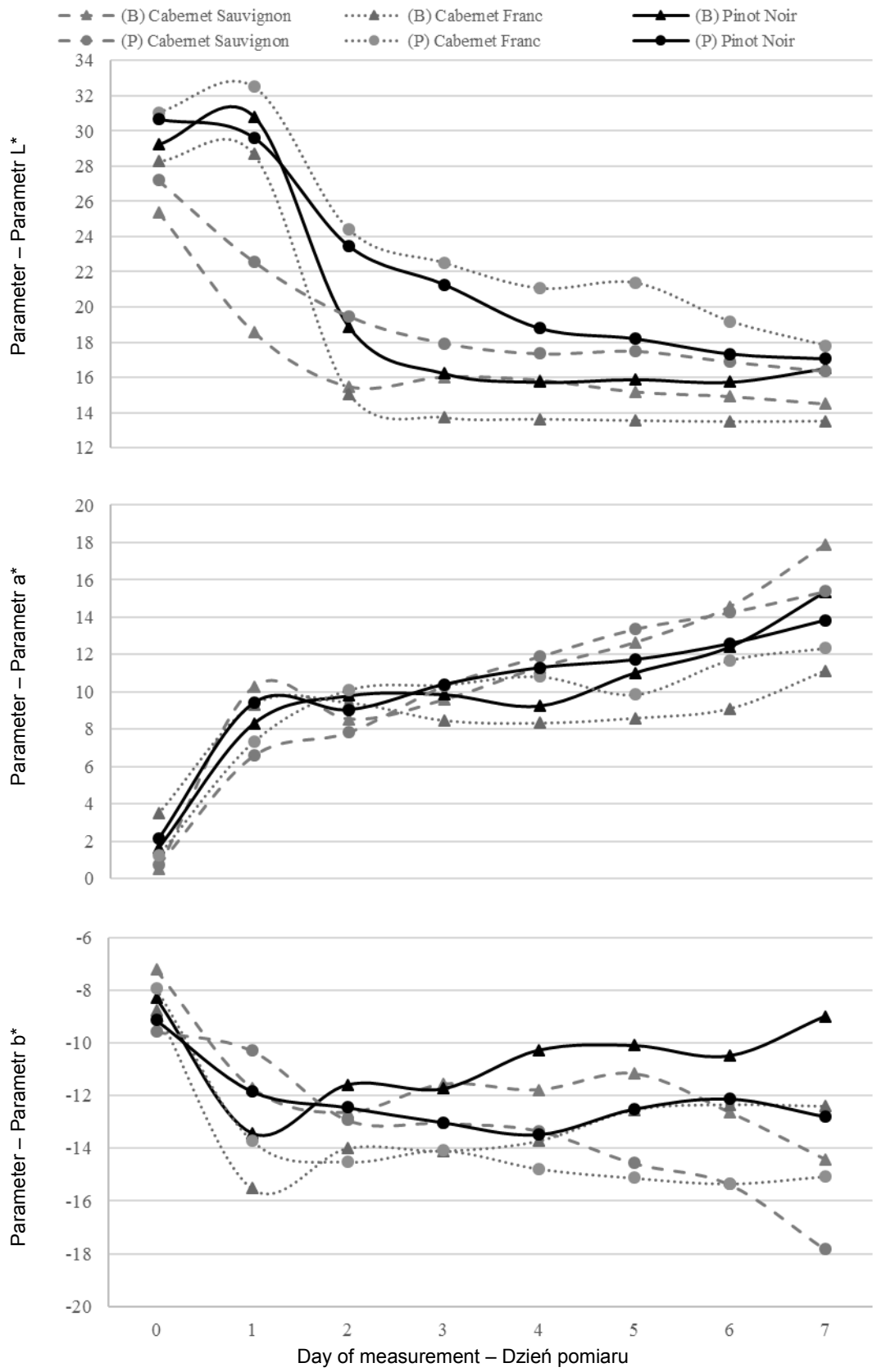

Fig. 1. Grape must colour changes during maceration
Rys. 1. Zmiany barwy moszczu w trakcie maceracji

Explanation: (B) Bulgaria, (P) Poland – Objaśnienia: (B) Bułgaria, (P) Polska.

Similar observations of the colour change rate occurring during the initial must fermentation was presented by Gómez-Míguez et al. (2007); Extending the maceration time for a few days allows to further increase the pigment content in the grape must, as well as to leach tannins and aromatic compounds. Numerous studies indicate that the maximum colour intensity can be obtained after a 7–10 day long maceration; after that period intensity is reduced and further extending of the process does not affect the pigment concentration (Bautista-Ortín et al. 2005; Budić-Leto et al. 2006). Similar conclusion was reached by Ochmian et al. (2013), the must of all grape varieties darkened (L*) during the maceration process. The juice from grapes harvested in Bulgaria was darker than the juice of the Polish grapes. The biggest L* indicator reduction was observed for the Cabernet Franc variety. The juice of this variety grown in Bulgaria produced the darkest juice. On the other hand, must produced from the Cabernet Franc variety grown in Poland was the lightest of all the studied varieties. As the process of maceration continued the levels of the red pigments increased (a*). In case of this parameter the differences between the studied varieties were recorded. The highest levels of red pigment on the last day of maceration were observed for the Cabernet Sauvignon variety, the lowest for the Cabernet Franc grapes. The greatest fluctuations during maceration were recorded for indicator b*. The blue content increased rapidly in the first 24 hours of the process, and then the extraction stabilised. In the last two days of maceration, there was a noticeable increase of the blue colour in the Cabernet Sauvignon juice; that signified the highest levels of the pigment. The juice obtained from varieties grown in Poland, after maceration, had a higher content of blue pigments which indicates higher levels of anthocyanins in the fruit.

CONCLUSIONS

1. Different climatic conditions of Poland and Bulgaria do not affect the physical parameters of grapes, but have a significant impact on their chemical composition. Significantly higher levels of extract and significantly lower levels of acidity were recorded for the fruit grown in Bulgaria. The highest levels of extract and organic acids were observed in the berries of the Cabernet Sauvignon variety, regardless of the place of cultivation.
2. The most intense extraction of pigments occurs in the first two days of maceration; after this period further changes are less intense. After the maceration process, the juice from grapes harvested in Bulgaria is darker (L*), while the juice from Polish fruit has more blue pigment (b*).
3. Anthocyanin index is highly correlated with the a* and b* colour parameters. This may be a useful indicator for quick assessment of the polyphenolic compounds content in fruits. The anthocyanin index is significantly higher in grapes cultivated in Poland.

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Abstract. Wine producers have been working on selecting the most suitable grape variety for specific regions and therefore improving wine production technology for numerous years. Climate changes lead to change in grape quality; in the future these changes will have to be considered by the vineyard owners as they will affect cultivation methods, harvest dates and vinification process. The aim of this paper is to compare the quality of several grape varieties cultivated in different climatic conditions. Research material was collected from vineyards situated in the Szczecin Lowlands (Poland) and Plovdiv (Bulgaria). The study focused on three grape varieties: Cabernet Sauvignon, Cabernet Franc and Pinot Noir. Measured characteristics included contained physical parameters: ruit weight, bunch weight and length and firmness as well as chemical composition: soluble solids, acidity, pH, ascorbic acid and nitrates levels, anthocyanin index. Analysed fruit was also examined in terms of colouration and must colour changes during maceration. Climatic conditions of the crop location had significant influence on the chemical composition of fruits, for example Bulgarian fruit featured higher levels of extract and pH combined with lower acidity. The Cabernet Sauvignon variety, regardless of crop location, had the highest levels of extract and organic acids. The juice obtained from Bulgarian grapes was darker (L*) than the juice from the fruit harvested in Poland. On the other hand, the juice of Polish fruit had more blue pigment (b*). It was also found that a* and b* fruit colour parameters are highly correlated with the anthocyanin index.