

Article

Assessment of Selected Parameters for Determining the Internal Quality of White Grape Cultivars Grown in Cold Climates

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Abstract: Viticulture in a cool climate is more challenging than in traditional wine regions. Due to the weather conditions, the berries may not achieve their full maturation composition. Therefore, suitable grape cultivars should be selected for cultivation in cool climate regions. The aim of this research was to compare selected grape cultivars grown under the same climatic conditions in terms of their antioxidant activity, chemical composition, and macronutrient contents. Their dry matter content, total soluble solids, pH, total acidity, and vitamin C were also analyzed. This research confirmed the existence of differences between the cultivars regarding their antioxidant activity, total soluble solids and polyphenols, and content of vitamin C and macronutrients.

Keywords: grape; viticulture; antioxidants; mineral composition



Citation: Czaplicka, M.; Parypa, K.; Szewczuk, A.; Gudarowska, E.; Rowińska, M.; Zubaidi, M.A.; Nawirska-Olszańska, A. Assessment of Selected Parameters for Determining the Internal Quality of White Grape Cultivars Grown in Cold Climates. *Appl. Sci.* **2022**, *12*, 5534. <https://doi.org/10.3390/app12115534>

Academic Editor: Silvia Guidoni

Received: 13 April 2022

Accepted: 27 May 2022

Published: 30 May 2022

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1. Introduction

Of the 60 *Vitis* species, which naturally grow almost exclusively in the Northern Hemisphere, only the *Vitis vinifera* L. (Vitaceae) vine is widely used in the global wine industry [1]. Grapes are a source of antioxidants such as phenolic compounds [1]. It is believed that the antioxidant activity of the polyphenols present in grapes is much higher than that of essential vitamins and contributes to the dietary benefits of grapes [1]. In addition, phenolic compounds are the most important plant secondary metabolites that affect the quality parameters of wines. Cultivars that are selected for cool climate regions should be fully mature before the first autumn frosts. By doing so, success can be achieved in cultivation. The common grapevine (*Vitis vinifera* L.) is a species of worldwide economic importance. In 2018, it was cultivated on a global scale of approximately 7.5 million hectares, and 77.8 million tons of grapes were harvested, of which 57% were wine grapes, 36% were table grapes, and 7% were used to produce raisins [2]. Newly established vineyards located in cool climates to the north of the traditional grape-growing regions are increasing in importance [3]. The new northern regions are understood as being areas within Poland or Denmark. An alternative to traditional production is the introduction of hybrid cultivars—interspecies hybrids with increased resistance to fungal diseases [4,5]. Because of the high sugar content of wine grapes (<20%), the berries are characterized by a high caloric content [6]. This allows for the production of wine, where during alcoholic fermentation, an average of 17 g of sugar per liter are used to produce 1% ethyl alcohol by volume. One kilogram of grapes used for wine production contains between 700 and 1200 kcal, whereas the caloric content of apples and plums does not exceed 550 and 580 kcal, respectively, per kilogram of fruit. The caloric content of table grapes is lower than of wine grapes due to the lower sugar content (up to 15%). This caloric content is lower in white grapes (on average, 33 kcal·100 g^{−1}) than in black grapes (79 kcal·100 g^{−1}). Table grapes

consist mainly of water (65–75%) and sugars (glucose and fructose) (20–25%). Organic acids amount to 0.5–1.4%, and among them, tartaric acid is the most abundant, followed by malic acid. Citric acid is present in low concentrations [7]. The contents of proteins and mineral salt are within the range of 0.15–0.9%, and that of pectin is within the range of 0.3–1%. Table and wine grape cultivars are rich in potassium, phosphorus, magnesium, sodium, iron, manganese, and copper salts [7]. The presence of the vitamins A, B1, B2, B6, B12, H, PP, and C has also been reported [6,7].

It has been reported that phenolic compounds have many biological properties, including cardioprotective, anti-inflammatory, anti-carcinogenic, antiviral, and antibacterial properties, which are mainly attributed to their antioxidant effects [8]. Grapes, compared to other types of fruit, are distinguished by their high antioxidant potential [8,9]. Czaplicki et al. [10] demonstrated that grape juice and wine contain increased concentrations of bioactive compounds, and in particular, phenolic compounds. Their results showed that the polyphenol content was significantly lower in white grape juice than in red grape juice. A similar correlation was found in a study on antioxidant activity. A higher activity was reported in red grape juice. Leja et al. [11] confirm that dark grapes have higher nutritional qualities than green or white grapes.

The aim of the study was to assess the basic chemical composition, antioxidant activity, and macronutrient content of six grape cultivars grown under temperate climate conditions. The information can serve as a reference for the selection of a suitable variety for the production of the selected type of wine.

2. Materials and Methods

2.1. Plant Material

All grape samples were obtained from the Research and Teaching Station of the Department of Horticulture of the University of Environmental and Life Sciences in Wrocław, in the village of Samotwór, Lower Silesia province, Kąty Wrocławskie municipality, Poland. The following white grape cultivars were used as experimental material: ‘Bacchus’, ‘Chardonnay’, ‘Johanniter’, ‘Muscaris’, ‘Solaris’, and ‘Sovignier gris’. The Lower Silesia region is characterized by a temperate climate. The experiment was set up on luvisol soil, made of medium sandy clay (25% clay particles). According to the valuation class, this soil belongs to Class IIIa. The grape collection was performed from September 16 through to October 15 at 21–23 °Brix ripeness level (i.e., according to the term of maturity). The grapes of the ‘Chardonnay’ and ‘Bacchus’ cultivars were harvested on 15 October to avoid the first autumn frost, even though they were not yet fully ripe. The climatic parameters of the experimental site over the last 30 years (1991–2020) are shown in Table 1.

Table 1. Climatic conditions of the experimental site.

Climatic Parameters	Value
Average growing season length	220–228 days
Average temperature of the growing season	+8.3 °C
Average highest multi-year temperature	July, +17.9 °C
Average lowest average temperature:	January, −1.9 °C
Average first autumn frosts	October, 22
Average last spring frosts	April, 18
Average length of the period without frosts	187 days
Highest multi-year average precipitation	July, 90 mm
Lowest multi-year average precipitation	February, 24 mm
Multi-year average sum of precipitation	592 mm
SAT	2774

2.2. Dry Matter, Total Soluble Solids, pH, Titratable Acidity, and Pectin

The dry matter content was determined using a moisture analyzer (MB 25, Ohaus, Newark, NJ, USA). Approximately 1.5 g of whole grape was dried at 105 °C (dryer Binder

ED CL 400, Tuttlingen, Germany) [12]. Measurements were carried out in triplicate and are expressed as a percentage.

The total soluble solids were determined refractometrically using an electronic Pocket Refractometer PAL-1 (Atago, USA). The measurements were taken in triplicate and expressed in °Brix. The pH of the samples was determined using a pH meter (IQ's Scientific Instruments).

Titrateable acidity (TA) was determined according to titration aliquots using a titrator (Orion Star T910, Thermo Fisher Scientific, Beijing, China) and following the Polish standard [13]. NaOH (0.1 N) was added slowly to the whole fresh grape homogenate until the endpoint was reached (pH 8.1), and this process was controlled via an automatic pH titration system, with the result expressed as grams of tartaric acid per 100 g. The measurements were carried out in triplicate and expressed as $\text{g } 100 \text{ g}^{-1}$ of tartaric acid.

The determination methods were as follows: vitamin C as L-ascorbic acid content was determined according to the Polish standard [14], after removing anthocyanins on Sep-Pak C18 mini columns. The method involves oxidation of l-ascorbic acid to dehydroascorbic acid in an acid medium containing the blue dye 2,6-dichloroindophenol, followed by dye reduction to the leuco (colorless) form, which takes on a red color at a pH of 4.2.

2.3. Preparation of Grape Extract

Samples for the analysis of total polyphenol, radical scavenging activity (DPPH), antioxidant activity (ABTS), and ferric-reducing ability (FRAP) were prepared as follows. Grape (5 g) was weighed into a test tube. A total of 20 mL of 80% of aqueous methanol with 1% of HCl was added and then blended using a hand-blender. Samples were sonicated for 15 min twice and left for 24 h at 4 °C in darkness. The extract was centrifuged for 10 min ($20,878 \times g$), and supernatants were collected at 4 °C to be used within 24 h.

2.4. Total Phenolic Content (TPC)

Total polyphenol content was determined according to the Folin–Ciocalteu method [15], using gallic acid (GA) as a standard for the calibration curve. After an hour, the results were read at 765 nm in a spectrophotometer (Shimadzu UV-2401 PC, Kyoto, Japan). All determinations were performed in triplicate. The results of the assay were calculated and expressed as milligrams of GA equivalent (GAE) per 100 g of fresh mass.

2.5. Antioxidant Activity Determination

2.5.1. DPPH Radical Scavenging Spectrophotometric Assay

The DPPH radical scavenging activity of the grapes was determined according to the method of Yen and Chen [16]. DPPH (0.5 mL) and ethyl alcohol (1.5 mL) were both added to an aliquot of supernatant (0.5 mL) from each sample. The mixture was shaken and left at room temperature for 10 min. The antioxidant capacity for each sample (3 replications) was measured separately by recording the absorbance at 517 nm in a spectrophotometer (Shimadzu UV-2401 PC; Kyoto, Japan). Ethanol was used as a blank. All determinations were performed in triplicate. The results were expressed as $\mu\text{mol Trolox per } 100 \text{ g f.m.}$

2.5.2. ABTS⁺ Radical Scavenging Spectrophotometric Assay

The ABTS⁺ radical scavenging activity of the sample was measured according to the method developed by Re et al. [17], using a Shimadzu UV-2401 PC spectrophotometer (Kyoto, Japan). The results were expressed as $\mu\text{mol Trolox per } 100 \text{ g f.m.}$

2.5.3. FRAP Procedure (Ferric-Reducing Antioxidant Power)

The reducing potential of the samples was determined using the FRAP assay proposed by Benzie and Strain [18] as a measure of antioxidant power. This assay is based on the reduction of the ferric ion (Fe^{3+}) to the ferrous ion (Fe^{2+}). An antioxidant reduces the ferric ion (Fe^{3+}) to the ferrous form (Fe^{2+}), leading to formation of a blue complex ($\text{Fe}^{2+}/\text{TPTZ}$) that can be measured as an increase in absorbance at 593 nm. A standard curve was prepared using different concentrations of Trolox. The results were corrected for dilution

and expressed as μmol Trolox per 100 g f.m. The determination of all characteristics was carried out in triplicate using a Shimadzu UV-2401 PC spectrophotometer (Kyoto, Japan).

2.6. Macronutrients

The macronutrient content of the grapes was determined via instrumental analysis using the Nowosielski method [19]. Colorimetric measurements were made using a Perkin Elmer Model Lambda 1A spectrophotometer (Perkin Elmer, Waltham, MA, USA) and flame emission spectroscopy (Sherwood, Model 410, Cambridge, UK).

2.7. Statistical Analysis

The results are given as the means of three independent determinations $\pm$ standard deviation. All statistical analyses were performed with Statistica version 10.0 (StatSoft, Tulsa, OK, USA). Principal component analysis (PCA) was carried out using the Statistica version 12.5 software (StatSoft, Krakow, Poland).

3. Results and Discussion

All grapes were harvested at the agrotechnical date at which the wine was planned to be produced. All grape cultivars were characterized by a high dry matter content, resulting in notable quantities of waste in the winemaking process (Table 2). This may also indicate that the grapes were harvested too early. The grapes of Bacchus and Chardonnay were characterized by a lower dry matter content due to their soft and thinner skins. This was previously confirmed by Porro et al. [4], showing that the skins of hybrid cultivar grapes are thicker than *V. vinifera* skins, which contributes to their increased resistance to disease. The content of the total soluble solids for each individual trial was sufficient for allocating these grapes for wine making, except for ‘Bacchus’ and ‘Chardonnay’, both of which would require chaptalization (Table 2). The highest level of total soluble solids was found in the ‘Solaris’ grape variety, which is characterized by its adaptation to the cool climate and early harvesting date. ‘Muscaris’ grapes accumulated slightly lower sugars, labeled as total soluble solids, whereas ‘Johanniter’ and ‘SOUVIGNIER gris’ had similar sugar contents. Similarly, in the research of Porro et al. [4], ‘Solaris’ and ‘Muscaris’ grapes tended to accumulate more sugar than the ‘Johanniter’ and ‘SOUVIGNIER gris’ grapes. The values obtained by Pedo et al. [20] support this investigation but have not been statistically confirmed.

Table 2. Dry matter content, total soluble solids, pH, acidity, and vitamin C of grape samples.

Cultivar	Dry Matter%	Total Soluble Solids °Brix	pH	Total Acidity $\text{g}\cdot 100\text{ g}^{-1}$ *	Vitamin C $\text{mg}\cdot 100\text{ g}^{-1}$ f.m.
‘Chardonnay’	33.35 ± 1.76 c	17.6 ± 1.26 d	2.71 ± 0.08 b	0.72 ± 0.08 c	1.36 ± 0.10 a
‘Bacchus’	32.99 ± 1.95 d	15.7 ± 0.99 e	2.64 ± 0.06 a	0.56 ± 0.09 d	1.10 ± 0.09 b
‘Johanniter’	36.06 ± 2.98 a	20.3 ± 1.72 c	2.93 ± 0.06 c	0.93 ± 0.10 a	0.86 ± 0.09 d
‘Muscaris’	33.23 ± 4.25 c	22.0 ± 2.16 b	2.92 ± 0.04 c	0.94 ± 0.09 a	1.18 ± 0.09 b
‘Solaris’	34.11 ± 2.58 b	23.0 ± 2.31 a	2.96 ± 0.05 d	0.83 ± 0.09 b	0.96 ± 0.08 c
‘SOUVIGNIER gris’	35.56 ± 2.58 a	20.8 ± 1.04 c	2.93 ± 0.04 c	0.85 ± 0.09 b	0.93 ± 0.09 c

* Expressed as malic acid; mean values with different letters (a–e) within the same column are statistically different ($p = 0.05$). Values expressed as mean $\pm$ standard deviation.

No correlation was found between the quantity of total soluble solids and vitamin C and acidity in the test trials, indicating the different nature of the selected cultivars. However, the acidity of the hybrid cultivars was higher than in Porro et al. [4] and the three-year averages in Pedo et al. [20], while the reaction pH was lower.

The vitamin C content, determined as the ascorbic acid content in the grape cultivars tested, was low. This ingredient is an important antioxidant, and its content is important both in the raw materials and the products. The highest concentration of ascorbic acid was found in ‘Chardonnay’ ($1.36\text{ mg}\cdot 100\text{ g}^{-1}$ f.m.), and the lowest was found in ‘Johanniter’ ($0.86\text{ mg}\cdot 100\text{ g}^{-1}$ f. m.), as shown in Table 2. In a studies by Isci et al. [21], the vitamin

C content was 10 times higher (13.67 to 15.55 mg 100 g⁻¹ f.m.) in grapes cvs. ‘Aplhonse Lavalley’, ‘Red Globe’, ‘Trakya Ilkeren’, and ‘Buca Razaikis’. Such a difference may result from the differences in cultivars and harvest date as well as the methods used to determine vitamin C. In a study conducted by Çağlarirmak [22], the vitamin C content in grapes grown in Turkey was slightly higher than the vitamin C levels reported in this study (1.54–5.77 mg·100 g⁻¹ f.m.) depending on the grape cultivar. Vitamin C is the vitamin most sensitive to physical and chemical factors such as heat, exposure to oxygen, and the Maillard reaction. There was no correlation between the contents of total soluble solids and vitamin C in the tested grapes.

The polyphenol content in plant raw materials is very important for nutritional reasons. The greater the share of polyphenols in the raw material, the greater the potential of the finished product. Therefore, this ingredient should be tested in all raw materials that are intended for processing. The total polyphenol content of the tested grape cultivars ranged from 661.1 to 2041.1 µM GEA·100 g⁻¹ f.m. (Table 3). The highest content was found in ‘Chardonnay’ grapes, while the lowest was found in grapes of the ‘Bacchus’ cultivar. A study by Isci et al. [21] reported a similar total polyphenol content (780–2050 µM GEA·100 g⁻¹ f.m.) in four grape cultivars grown in Turkey. Most of the results reported in the literature concern the analysis of grape skins. Grape skins have a higher polyphenol content and antioxidant activity than grape pulp [23,24].

Table 3. Total polyphenol content and antioxidant activity of six cultivars of white whole grape berries.

Cultivar	Polyphenols [µM GAE·100 g ⁻¹ f.m.]	DPPH *	ABTS * [µMTrolox·100 g ⁻¹ f.m.]	FRAP *
‘Chardonnay’	2041.4 ± 119.79 a	547.9 ± 52.37 a	3143.7 ± 171.40 b	398.6 ± 31.95 d
‘Bacchus’	661.1 ± 48.09 e	435.2 ± 41.72 c	2637.2 ± 99.50 d	207.7 ± 12.58 e
‘Johanniter’	1777.5 ± 108.2 b	535.5 ± 32.84 a	4578.9 ± 201.90 a	622.9 ± 62.98 a
‘Muscaris’	908.4 ± 96.21 d	513.2 ± 52.16 b	2800.7 ± 176.10 c	512.6 ± 51.76 c
‘Solaris’	920.7 ± 89.67 d	380.6 ± 21.26 d	2555.8 ± 101.70 d	548.3 ± 52.58 b
‘Souvignier gris’	1484.9 ± 100.00 c	537.8 ± 44.76 a	4491.6 ± 121.20 a	562.3 ± 54.25 b

* ABTS. 2,2'-azino-bis-3-ethylbenzothiazoline-6-sulphonic acid; FRAP. ferric reducing antioxidant potential; DPPH. radical scavenging activity; Mean values with different letters (a–e) within the same column are statistically different ($p = 0.05$). Values expressed as mean ± standard deviation.

The antioxidant activity varied among the different grape cultivars (Table 3), which is due to the different compositions of specific cultivars, which lead to different responses for antioxidant activity. The fruits of the ‘Bacchus’ cultivar statistically had the lowest total polyphenol content and the lowest FRAP (Table 3). The highest DPPH activity was recorded in ‘Chardonnay’ grapes, and the highest ABTS and FRAP activities were found in ‘Johanniter’ grapes. The literature data [25,26] indicate that polyphenols play an important role in antioxidant activity and, in particular, in scavenging DPPH.

The grape cultivars included in this study contained a varied concentration of macronutrients, even though they were grown on the same soil. The grapes of ‘Souvignier gris’—pink berries—accumulated the most magnesium and calcium, while phosphorus and potassium were highest in ‘Bacchus’ grapes (Table 4). The grapes of ‘Souvignier gris’ also contained significant amounts of potassium but had the least amount of phosphorus.

Table 4. Macronutrient content of six cultivars of white grapes.

Cultivar	Ca	Mg	P	K
[mg·100 g ⁻¹ d.m.]				
‘Chardonnay’	1.06 ± 0.10 d *	0.008 ± 0.00 d	0.375 ± 0.08 c	5.08 ± 0.46 c
‘Bacchus’	1.00 ± 0.09 d	0.007 ± 0.00 d	0.435 ± 0.10 d	5.54 ± 0.45 a
‘Johanniter’	1.65 ± 0.14 b	0.011 ± 0.00 b,c	0.308 ± 0.09 a	4.63 ± 0.41 e
‘Muscaris’	1.09 ± 0.10 d	0.010 ± 0.00 c	0.105 ± 0.09 a	4.89 ± 0.39 d
‘Solaris’	1.28 ± 0.11 c	0.012 ± 0.00 b	0.080 ± 0.03 b	4.57 ± 0.42 d
‘Souvignier gris’	2.13 ± 0.18 a	0.015 ± 0.00 a	0.082 ± 0.04 b	5.24 ± 0.49 b

* Mean values with different letters (a–e) within the same column are statistically different ($p = 0.05$). Values expressed as mean ± standard deviation.

4. Conclusions

The six varieties of white grapes studied differed from each other in their contents of the elements and compounds that were assessed. These variations, along with the high sugar content and low vitamin C and macronutrient contents found, are supported by findings from other studies. The studied fruits were characterized by a fairly high level of antioxidant activity and a medium total polyphenol content. Grapes of the ‘Bacchus’ and ‘Johanniter’ varieties had a significantly higher total polyphenol content and a higher antioxidant activity. Although the fruits of the ‘Johanniter’ variety contained slightly fewer polyphenols and less vitamin C, the antioxidant activity was the highest among the studied varieties. It follows that factors other than polyphenols or vitamin C content affected the antioxidant activity. The fruits of the ‘Bacchus’ variety contained the lowest amount of sugars and had a low level of acidity for a fairly high vitamin C content.

Of the tested varieties, none could be clearly selected as the best or worst in terms of their parameters; rather, each of the varieties was unique. Therefore, depending on the preferred characteristics, suitable varieties should be selected for preparation according to the intended final product.

Author Contributions: Conceptualization, A.N.-O. and M.C.; methodology, A.N.-O. and E.G.; software, A.S. and E.G.; validation, A.N.-O., A.S. and M.C.; formal analysis, A.N.-O., E.G. and A.S.; investigation, M.A.Z., K.P. and M.R.; resources, K.P. and M.R.; data curation, A.N.-O., M.C. and A.S.; writing—original draft preparation, A.N.-O., M.C. and E.G.; writing—review and editing, A.S.; visualization, K.P., M.R. and M.A.Z.; supervision, A.N.-O. and A.S.; funding acquisition, M.C., A.S. and E.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This publication was the result of the activity of the Plants4food research group.

Conflicts of Interest: The authors declare no conflict of interest.

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