potravinárstvo®

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 15, 2021, p. 1104-1111
https://doi.org/10.5219/1694
Received: 8 August 2021. Accepted: 14 October 2021.
Available online: 28 October 2021 at www.potravinarstvo.com

ISSN 1337-0960 (online)

THE CONTENT OF BIOACTIVE COMPOUNDS AND ANTIOXIDANT ACTIVITY OF GARLIC (*ALLIUM SATIVUM* L.)

Natália Čeryová, Iveta Čičová, Judita Lidiková, Marek Šnirc, Jarmila Horváthová, Helena Lichtnerová, Hana Franková

ABSTRACT
Garlic (*Allium sativum* L.) is one of the most commonly grown vegetables and thanks to its sensory properties, it has an important place in numerous world cuisines. Garlic is also known for its health-promoting properties, which are attributed to its chemical composition. The health benefits of garlic depending on the content of biologically active compounds, which vary between cultivars and geographical areas. Seven cultivars of garlic, namely Sukoradsky, Zahorsky, Germidour, Mojmir, Karel IV., Arkus, Makoi, were analyzed in this study. This study aimed to determine the total polyphenol content, total flavonoid content, and antioxidant activity of garlic. Studied characteristics were analyzed by the UV-VIS spectrometry method. Total polyphenol content ranged from 430.26 to 640.04 mg GAE.kg^{-1} FW. Total flavonoid content ranged from 10.29 to 60.49 mg CE.kg^{-1} FW. Antioxidant activity measured by ABTS assay ranged from 1.098 to 1.955 mmol TE.kg^{-1} FW. Antioxidant activity measured by FRAP assay ranged from 0.63 to 1.467 mmol.kg^{-1} FW. Highest TPC, TFC, and AA were determined in the cultivar Mojmir. The lowest TPC and TFC were determined in the cultivar Zahorsky. The lowest AA was determined in the cultivar Sukoradsky. High positive correlations were determined between individual parameters.

Keywords: *Allium sativum*; garlic; polyphenols; flavonoids; antioxidants

INTRODUCTION
The genus Allium includes the most widespread and commonly grown vegetables such as onion (*Allium cepa* L.), garlic (*Allium sativum* L.), leek (*Allium porrum* L.), and many others. All these species are very important for agriculture, gastronomy, and the food industry. This genus includes plants with a very specific aroma and taste, for which sulfur-containing phytochemicals are responsible. Substances in these species have a positive effect on human health **(Poojary et al., 2017)**. Allium vegetables have maintained a leading position in cultivation throughout the centuries. All these species are characterized by a content of valuable components with significant beneficial effects on human health. In addition to their popularity in the therapeutic area, they have an important place in almost every kitchen. From a nutritional point of view, it contains important components such as chemoprotective substances, which also include natural plant antioxidants. They also contain a wide range of vitamins and trace elements that are essential for the proper functioning of the body **(Hedges and Lister, 2007; Choi et al., 2011)**. The genus *Allium* is rich in flavonoids, saponins, sapogenins, and volatile sulfur compounds. Due to the content of rare phytochemicals, Allium plants have several positive effects on human health, including antimicrobial, antidiabetic, antioxidant, antiviral, anticarcinogenic, antimutagenic, hepatoprotective, and neuroprotective. Since ancient times, these plants have been used in the treatment of cardiovascular diseases, inflammatory diseases, vascular diseases, elevated blood cholesterol levels, and various degenerative diseases **(Putnik et al., 2019)**. Plant species belonging to the genus Allium are characterized by their pungent taste and significant medicinal properties. Individual plant species differ mainly in morphological structure, taste, and color. In terms of chemical composition, plants belonging to the genus Allium are similar **(Lorigooini et al., 2014)**.

Garlic (*Allium sativum* L.) is a monocotyledonous species belonging to the *Alliaceae* family and is one of the oldest traditional crops in the world **(Khan et al., 2017)**. It is one of the most common types of vegetables and is an important part of many world cuisines. Garlic is used mainly for its sensory properties, but also for its health-promoting properties, which are attributed to its chemical composition. The health benefits of garlic depending on the content of biologically active compounds, which vary between cultivars and geographical areas **(Szychowski et al., 2018)**. The chemical composition of garlic is significantly affected by the cultivar, growing conditions, and cultivation practices. In particular, the fertilization regime and soil properties can have a significant effect on quality properties such as mineral composition, dry matter, protein content, and total soluble solids content. Garlic is considered a rich source of volatile compounds, which are responsible for the typical taste and bioactive properties of garlic. There is also a high content of non-volatile compounds with well-known medicinal and therapeutic properties, such as amides, nitrogen oxides, proteins, saponins as well as antioxidants, minerals (especially P, K, and Se), vitamins (vitamin C and B vitamins), and phenolic compounds, especially flavonoids and phenolic acids **(Petropoulos et al., 2018)**. Garlic is characterized by a high content of polyphenolic compounds that have a positive effect on the human body. Phenolic acids and flavonoids account for the largest proportion of polyphenolic compounds in garlic. The total content of polyphenols in garlic can be influenced by variety, environmental influences (sun exposure, precipitation, different types of cultivation, fruit yield), but also by the storage and technological processing of garlic **(Srivastava et al., 2013; Rasouli et al., 2017)**.

Polyphenol compounds have been identified as nutrients, plant secondary metabolites, phytonutrients, antioxidants, dietary bioactive agents, and protective factors **(Cory et al., 2018)**. Polyphenols form one of the most important groups of secondary metabolites of plants. They are widespread in the plant kingdom and can be obtained directly from plants and other foods rich in antioxidants, gaining worldwide attention as nutraceuticals in the prevention of multiple diseases. The health and antitumor effects associated with regular consumption of foods rich in polyphenols are an effective therapy for maintaining health against reactive oxygen species **(Losada-Barreiro and Bravo-Díaz, 2017)**. Polyphenol compounds are partly responsible for determining the sensory and nutritional characteristics of foods. They represent a wide variety of different pigments, are involved in attracting pollinators, performing structural functions, protecting against ultraviolet radiation, and protecting plants from microbial invasion and herbivores **(Cutrim and Cortez, 2018)**. The availability of polyphenols depends primarily on their bioavailability. The rate of absorption in the intestines depends on their chemical structure **(Abbas et al., 2017)**.

Polyphenol compounds are potent antioxidants. Unlike several sulfur compounds in garlic, polyphenols are more stable and can be extracted from fresh, frozen, or dried plant samples. The content of biologically active compounds in garlic varies between cultivars grown in different geographical areas **(Szychowski et al., 2018)**. Given the unique combination of bioactive compounds, representatives of the genus *Allium* should be a regular part of our diet. Garlic has a wide range of applications as an antioxidant, antifungal, antithrombotic and hypoglycemic agent. It reduces glucose metabolism in diabetics, slows the development of arteriosclerosis, and reduces the risk of the development of various types of cancer. In addition, it reduces the possibility of myocardial infarct in patients and could also improve the function of the immune system **(Suleria et al., 2015)**.

Scientific hypothesis

Garlic is a natural source of polyphenols and antioxidants. The concentration of polyphenols in garlic is cultivar dependant.

MATERIAL AND METHODOLOGY

Samples

Seven cultivars of garlic, namely Sukoradsky, Zahorsky, Germidour, Mojmir, Karel IV., Arkus, and Makoi, were conventionally cultivated and harvested in full ripeness.

Chemicals

Folin-Ciocalteau reagent (Merck, Germany), anhydrous natrium carbonate p.a. (Sigma-Aldrich, USA), monohydrate of gallic acid p.a., (Sigma-Aldrich, USA), aluminium chloride p.a., (Sigma-Aldrich, USA), sodium nitrite p.a., (Sigma-Aldrich, USA), sodium hydroxide p.a., (Sigma-Aldrich, USA), catechin hydrate 98%, (Sigma-Aldrich, USA), methanol p.a., 80% (Sigma-Aldrich, USA), Trolox (2,5,7,8-tetramethylchroman-2-carboxylic acid, Sigma-Aldrich, USA), ABTS (2,2′-azino-bis (3-ethylbenzthiazoline-6-sulfonic) acid, Sigma-Aldrich, USA), potassium persulfate p.a. (Sigma Aldrich, USA), acetic acid p.a. (CH3COOH, Sigma Aldrich, USA), sodium acetate p.a. (COONa, Sigma Aldrich, USA) , TPTZ (2,4,6-tri (2-pyridyl) -s-triazine, Sigma-Aldrich, USA), hydrochloric acid (HCl, Sigma Aldrich, USA) , ferric chloride p.a. ($FeCl_3$), distilled water

Biological material

Garlic (*Allium sativum* L.)

Instruments

Unimax 2010 Horizontal Shaker (Heidolph Instrument, GmbH, Germany).

Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer (Shimadzu, Japan).

Laboratory Methods

Folin – Ciocalteau method was modified by **Lachman et al. (2003)**.

Aluminium chloride method was modified by **Chang et al. (2002)**.

ABTS radical scavenging assay **(Re et al., 1999)**.

FRAP assay by **(Pedersen et al., 2000)**.

Description of the Experiment

Sample preparation: To prepare extracts, 25 g of homogenized peeled garlic bulbs were shaken in 50 mL of 80% methanol for 16 hours on the Unimax 2010 horizontal shaker (Heidolph Instrument, GmbH, Germany), and filtered through Munktell No. 390 filtrating paper (Munktell and Filtrac, Germany).

Number of samples analyzed: 7

Number of repeated analyses: 4

Number of experiment replication: 1

Total polyphenol content

Total polyphenol content was determined by the method of **Lachman et al**. **(2003)**, using Folin – Ciocalteau phenol reagent, 20% Na_2CO_3, and distilled water. 0.1 mL of extract was pipetted into a 50 mL volumetric flask and diluted with distilled water. Then, 0.85 mL of Folin – Ciocalteau reagent was added, and after 3 minutes, 5 mL of 20% Na_2CO_3 was added. Volume was made up to 50 mL with distilled water. and left at laboratory temperature for 2 hours. Absorbance was measured against blank solution at 765 nm, using Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer, Shimadzu, Japan.

Total polyphenol content was expressed as mg of gallic acid equivalent in 1 kg of fresh garlic, based on the calibration curve ($R^2 = 0.9948$).

Total flavonoid content

Total flavonoid content was determined by the aluminium chloride method **(Chang et al., 2002)**, using 5% $NaNO_2$, 10% $AlCl_3$, 1M NaOH, and distilled water. 1 mL of extract was pipetted into a 10 mL volumetric flask and diluted with 5 mL of distilled water. Then, 0.3 mL of 5% $NaNO_2$ was added. After 6 minutes, 0.6 mL of 10% $AlCl_3$ was added. After 5 minutes, 2 mL of 1M NaOH was added. After mixing on vortex, volume was made up to 10 mL with distilled water and left at laboratory temperature for 15 minutes. Absorbance was measured against blank solution at 510 nm, using Shimadzu UV-1800 UV/ Visible Scanning Spectrophotometer, Shimadzu, Japan.

Total flavonoid content was expressed as mg of catechin equivalent in 1 kg of fresh garlic, based on the calibration curve ($R^2 = 0.9981$).

Antioxidant activity using ABTS assay

Antioxidant activity was determined by the ABTS assay **(Re et al., 1999)**, using $ABTS^{\bullet+}$ radical cation - (2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid), potassium persulfate ($K_2S_2O_8$), and acetate buffer (pH = 4.3) Working ABTS solution was produced by the reaction of $ABTS^{\bullet+}$ solution, $K_2S_2O_8$ solution, and acetate buffer. 0.05 mL of extract was pipetted into 3 mL of working ABTS solution, stirred, and left at laboratory temperature for 20 minutes. Absorbance was measured against blank solution at 734 nm, using Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer, Shimadzu, Japan.

Antioxidant activity was expressed as mmol of Trolox equivalent in 1 kg of fresh garlic, based on the calibration curve ($R^2 = 0.9931$).

Antioxidant activity using FRAP assay

Antioxidant activity was determined by the FRAP assay **(Pedersen et al., 2000)**, using TPTZ - (2,4,6-tris(2-pyridyl)-S-triazine), ferric chloride ($FeCl_3$), and acetate buffer (pH = 3.5) Working FRAP solution was produced by the reaction of TPTZ solution, $FeCl_3$ solution, and acetate buffer. 0.05 mL of extract was pipetted into 3 mL of working FRAP solution, stirred, and left at laboratory temperature for 20 minutes. Absorbance was measured against blank solution at 593 nm, using Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer, Shimadzu, Japan.

Antioxidant activity was expressed as mmol of Trolox equivalent in 1 kg of fresh garlic, based on the calibration curve ($R^2 = 0.9956$).

Statistical Analysis

The **RStudio (2020)** software package was used to perform statistical analysis. A nonparametric Kruskal-Wallis test was performed to obtain statistically significant information about the differences among the tested samples (p <0.05). Each variety was compared with the median value using the Wilcoxon test. To determine the relationship between individual parameters, linear regression and Spearman’s correlation test ($\alpha = 0.05$) were performed.

RESULTS AND DISCUSSION

Total polyphenol content, total flavonoid content, and antioxidant activity of garlic cultivars are given in Table 1 and Table 2.

Total polyphenol content

The total polyphenol content in studied garlic cultivars ranged from 430.26 to 640.04 mg GAE.kg^{-1} FW (966.01 to 1365.56 mg GAE.kg^{-1} DM), with a mean value of 505.32 mg GAE.kg^{-1} FW (1099.83 mg GAE.kg^{-1} DM). Highest TPC was determined in the cultivar Mojmir, while the lowest TPC was determined in the cultivar Zahorsky.

Based on their TPC, an order for garlic cultivars could be as following: Zahorsky< Sukoradsky< Germidour< Arkus< Karel IV.< Makoi< Mojmir.

Similar values were determined by other authors. **Lenková et al**. **(2016)** reported TPC in garlic cultivar Mojmir 1051 mg GAE.kg^{-1} FW. **Lenková et al**. **(2017)** reported TPC in garlic cultivars in the range from 621.13 to 763.28 mg GAE.kg^{-1} FW. (In Zahorsky – 621.13, in Makoi – 678.18, in Mojmir – 698.82 mg GAE.kg^{-1} FW). **Lenková et al**. **(2018)** reported TPC in garlic cultivars in the range from 566.01 to 612.23 mg GAE.kg^{-1} FW. (In Mojmir – 612.23, in Makoi – 612.21, in Zahorsky – 577.68, in Lukan – 566.01 mg GAE.kg^{-1} FW). **Kavalcová et al**. **(2014)** reported TPC in garlic cultivars in the range from 260.62 to 279.74 mg GAE.kg^{-1} FW. (In Mojmir – 260.62 mg GAE.kg^{-1} FW). **Kovarovič et al**. **(2017)** determined TPC in garlic cultivar Dukat 600.30 mg GAE.kg^{-1} FW. **Micová et al**. **(2019)** reported TPC in garlic cultivars in the range from 635.1 to 742.0 mg GAE.kg^{-1} FW. (In Zahorsky – 665.2, in Makoi – 635.1, in Mojmir – 742.0 mg GAE.kg^{-1} FW). **Bystrická et al**. **(2018)** determined TPC in garlic cultivars in the range from 401.25 to 595.00 mg GAE.kg^{-1} FW. **Najman et al**. **(2020)** reported TPC in garlic in the range from 562 to 728 mg GAE.kg^{-1} DM. **Khalid et al**. **(2014)** reported 390 mg GAE.kg^{-1} FW. **Khan et al**. **(2016)** reported 408 mg GAE.kg^{-1} FW.

Higher TPC was determined by **Beato et al**. **(2011)** – 6500 mg GAE.kg^{-1} DM, and **Zhou et al**. **(2017) –** 2719.3 mg GAE.kg^{-1} FW. **Škrovánková et al**. **(2018)** determined TPC in garlic cultivars in the range from 922 to 1196 mg GAE.kg^{-1} FW. **Kim et al**. **(2013)** determined lower TPC in garlic – 105.73 mg GAE.kg^{-1} DM.

Total flavonoid content

The total flavonoid content in studied garlic cultivars ranged from 10.3 to 60.49 mg CE.kg^{-1} FW (23.12 to 129.05 mg CE.kg^{-1} DW), with a mean value of 24.75 mg CE.kg^{-1} FW (53.65 mg CE.kg^{-1} DW).

Highest TFC was determined in the cultivar Mojmir, while the lowest TFC was determined in the cultivar Zahorsky. Based on their TFC, an order for garlic cultivars could be as following: Zahorsky< Germidour< Sukoradsky< Arkus< Karel IV.< Makoi< Mojmir.

Similar values were determined by other authors. **Chun et al**. **(2005)** reported 54.3 mg CE.kg^{-1} FW in garlic. **Priecina and Karlina (2013)** determined 89 mg CE.kg^{-1} DM in garlic. **Bhandari et al**. **(2014)** determined TFC in garlic in the range from 100 to 219 mg CE.kg^{-1} DM, with a mean value of 161 mg CE.kg^{-1} DM.

Table 1 Total polyphenol content, total flavonoid content, and antioxidant activity of garlic (in fresh weight).

Cultivar	TPC (mg GAE.kg^{-1} ±SD)	TFC (mg CE.kg^{-1} ±SD)	AA ABTS (mmol TE.kg^{-1} ±SD)	AA FRAP (mmol TE.kg^{-1} ±SD)
Sukoradsky	456.15 ±5.93	12.73 ±0.61	1.098 ±0.021	0.63 ±0.017
Zahorsky	430.26 ±3.65	10.29 ±0.37	1.23 ±0.037	0.737 ±0.018
Germidour	461.22 ±5.91	10.86 ±0.43	1.148 ±0.011	0.72±0.025
Mojmir	640.04 ±5.75	60.49 ±0.72	1.955 ±0.015	1.467 ±0.018
Karel IV.	506.40 ±4.90	26.78 ±0.72	1.36 ±0.013	0.888 ±0.21
Arkus	503.76 ±4.32	20.60 ±0.43	1.203 ±0.018	0.791 ±0.016
Makoi	539.41 ±5.36	31.46 ±0.61	1.463 ±0.022	1.001 ±0.025
Mean	505.32 ±66.06	24.75 ±16.74	1.351 ±0.278	0.891 ±0.266

Note: TPC – total polyphenol content, TFC – total flavonoid content, AA ABTS – antioxidant activity measured by ABTS assay, AA FRAP – antioxidant activity measured by FRAP assay.

Table 2 Total polyphenol content, total flavonoid content, and antioxidant activity of garlic (in dry matter).

Cultivar	TPC (mg GAE.kg^{-1} ±SD)	TFC (mg KE.kg^{-1} ±SD)	AA ABTS (mmol TE.kg^{-1} ±SD)	AA FRAP (mmol TE.kg^{-1}± SD)
Sukoradsky	1002.08 ±13.03	27.97 ±1.34	2.412 ±0.046	1.383 ±0.039
Zahorsky	966.01 ±8.20	23.12 ±0.84	2.762 ±0.083	1.655 ±0.040
Germidour	1010.55 ±12.96	23.80 ±0.95	2.516 ±0.024	1.578 ±0.055
Mojmir	1365.56 ±12.26	129.05 ±1.53	4.17 ±0.031	3.13 ±0.039
Karel IV.	1132.63 ±10.96	59.89 ±1.6	3.043 ±0.028	1.986 ±0.047
Arkus	1026.20 ±8.80	41.96 ±0.88	2.45 ±0.037	1.611 ±0.034
Makoi	1195.77 ±11.87	69.74 ±1.36	3.244 ±0.048	2.219 ±0.054
Mean	1099.83 ±134.67	53.65 ±35.72	2.942 ±0.591	1.937 ±0.563

Note: TPC – total polyphenol content, TFC – total flavonoid content, AA ABTS – antioxidant activity measured by ABTS assay, AA FRAP – antioxidant activity measured by FRAP assay.

Soto et al. **(2015)** determined TFC in garlic cultivars in the range from 70 to 110 mg CE.kg^{-1} DM. **Park and Kim (2015)** determined higher TFC in garlic – 334.27 mg CE.kg^{-1} DM.

Antioxidant activity using ABTS assay

Antioxidant activity in analyzed garlic cultivars measured by ABTS assay ranged from 1.098 to 1.955 mmol TE.kg^{-1} FW (2.41 to 4.17 mmol TE.kg^{-1} DM), with a mean value of 1.35 mmol TE.kg^{-1} FW, (2.94 mmol TE.kg^{-1} DM). The highest AA was determined in the cultivar Mojmir, while the lowest AA was determined in the cultivar Sukoradsky. Based on their TPC, an order for garlic cultivars could be as following: Sukoradsky< Germidour< Zahorsky< Arkus< Karel IV. < Makoi< Mojmir.

Azzini et al. (2014) reported AA of garlic in the range from 4.42 to 6.27 mmol TE.kg^{-1} DM. **Boonpeng et al. (2014)** determined 7.62 mmol TE.kg^{-1} FW. Other authors reported higher AA in garlic. **Lu et al**. **(2011)** reported 57.86 to 65.22 mmol TE.kg^{-1} FW. **Gorinstein et al. (2006)** determined 21.4 mmol TE.kg^{-1} FW. **Gorinstein et al. (2009)** 23.71 to 37.02 mmol TE.kg^{-1} DM. **Zhou et al. (2017)** determined lower antioxidant activity in garlic – 0.49 mmol TE.kg^{-1} DM.

Antioxidant activity using FRAP assay

Antioxidant activity in studied garlic cultivars measured by FRAP assay ranged from 0.63 mmol TE.kg^{-1} FW to 1.467 mmol TE.kg^{-1} FW (1.383 to 3.13 mmol TE.kg^{-1} DM), with a mean value of 0.89 mmol TE.kg^{-1} FW (1.94 mmol TE.kg^{-1} DM). The highest AA was determined in the cultivar Mojmir, while the lowest AA was determined in the cultivar Sukoradsky. Based on their AA, an order for garlic cultivars could be as following: Sukoradsky < Germidour< Zahorsky<Arkus< Karel IV. < Makoi< Mojmir.

Nencini et al. (2011) determined 0.38 mmol TE.kg^{-1} in aged garlic extracts. **Bhatt and Patel (2013)** determined 2.3 mmol TE.kg^{-1} FW. **Lu et al. (2011)** reported 7.62 to 11.45 mmol TE.kg^{-1} FW in garlic. **Gorinstein et al. (2009)** reported 6.9 to 10.8 mmol TE.kg^{-1} DM in garlic. **Boonpeng et al. (2014)** reported lower AA of garlic – 0.01 mmol TE.kg^{-1} FW.

As shown in Figure 1., a significantly higher content of total polyphenols and total flavonoids was observed in the cultivar Mojmir. In this cultivar, significantly higher antioxidant activity was also observed. Significantly lower total polyphenol content was observed in cultivar Zahorsky. Significantly lower total flavonoid content was also observed in cultivar Zahorsky, and cultivar Germidour. Significantly lower antioxidant activity was observed in cultivar Sukoradsky.

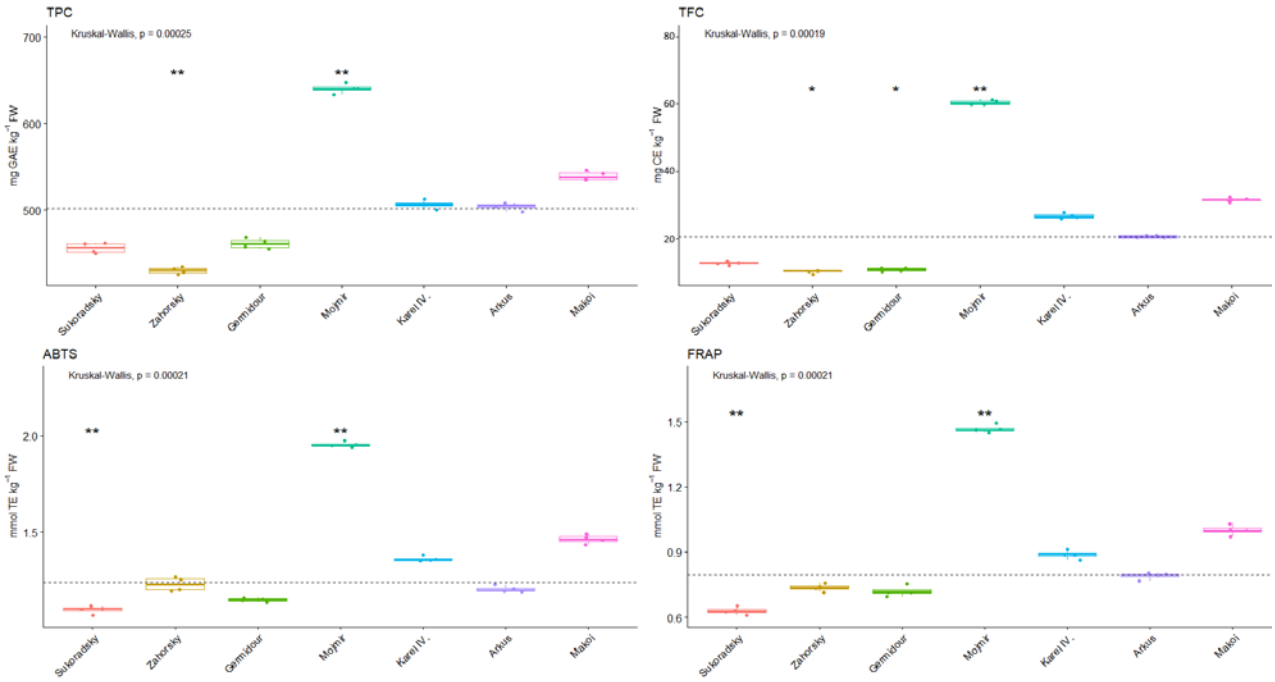

Figure 1 Differences in the content of bioactive compounds in selected garlic cultivars.

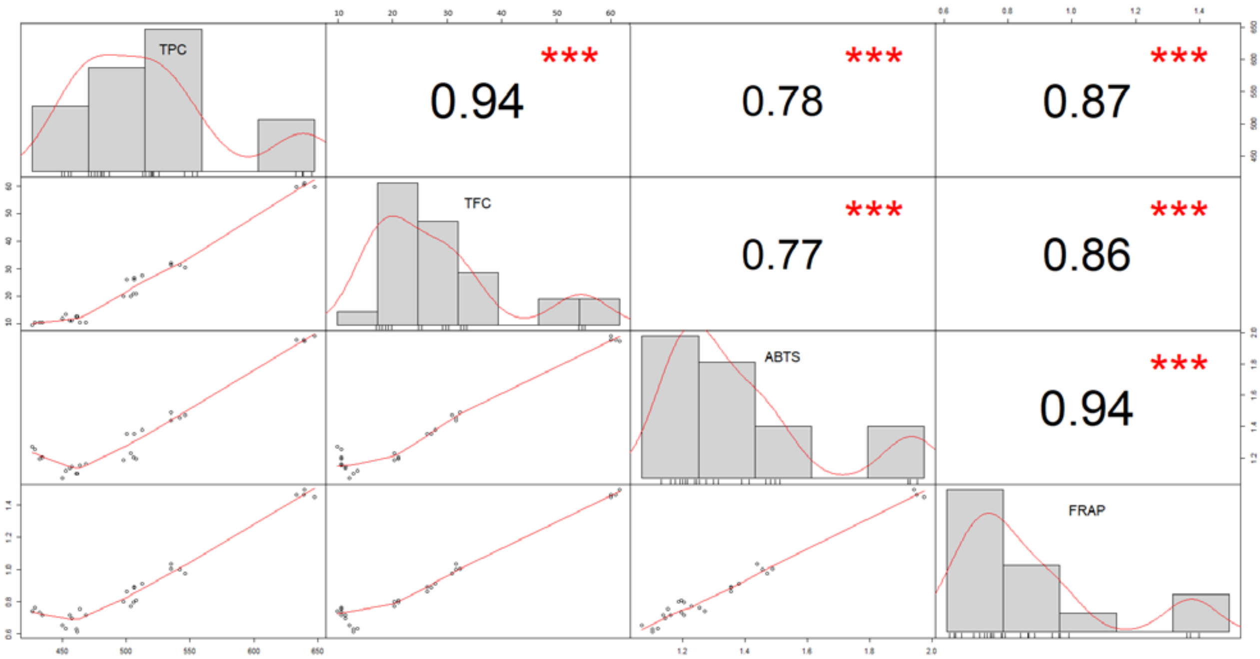

Figure 2 The relationships between the analysed parameters.

The relationships between the parameters are shown as the Spearman correlation matrix. Statistical evaluation of results confirmed strong positive linear correlation between TPC and TFC (r= 0.94), TPC and ABTS (r= 0.78), TPC and FRAP (r= 0.87), TFC and ABTS (r= 0.77), TFC and FRAP (r= 0.86), and ABTS and FRAP (r= 0.94). **Bhandari et al. (2014)** also determined a positive correlation between TPC and TFC of garlic. **Škrovánková et al. (2018)**, and **Locatelli et al. (2017)** also determined **a** positive correlation between TPC and ABTS of garlic. **Locatelli et al. (2017)** and **Chen et al. (2013)** also determined a positive correlation between TPC and FRAP of garlic. **Soto et al. (2015)** also determined a positive correlation between ABTS and FRAP of garlic.

CONCLUSION

Total polyphenol content, total flavonoid content, and antioxidant activity of 7 garlic cultivars were determined in this study. Based on the results of the study, we can state that garlic is a natural source of polyphenols and antioxidants. Significantly higher TPC, TFC, and AA were determined in cultivar Mojmir. Significantly lower TPC and TFC were determined in cultivar Zahorsky. Significantly lower AA was determined in cultivar Sukoradsky.
Based on statistical evaluation strong positive correlations were determined between individual studied parameters.

REFERENCES

Abbas, M., Saeed, F., Anjum, F. M., Afzaal, M., Tufail, T., Bashir, M. S., Suleria, H. A. R. 2017. Natural polyphenols: An overview. *International Journal of Food Properties*, vol. 20, no. 8, p. 1689-1699. https://doi.org/10.1080/10942912.2016.1220393

Azzini, E., Durazzo, A., Foddai, M. S., Temperini, O., Venneria, E., Valentini, S., Maiani, G. 2014. Phytochemicals content in Italian garlic bulb (*Allium sativum* L.) cultivars. *Journal of Food Research*, vol. 3, no. 4, p. 26. https://doi.org/10.5539/jfr.v3n4p26

Beato, V. M., Orgaz, F., Mansilla, F., Montaño, A. 2011. Changes in phenolic compounds in garlic (*Allium sativum* L.) owing to the cultivar and location of growth. *Plant foods for human nutrition*, vol. 66, no. 3, p. 218-223. https://doi.org/10.1007/s11130-011-0236-2

Bhandari, S. R., Yoon, M. K., Kwak, J. H. 2014. Contents of phytochemical constituents and antioxidant activity of 19 garlic (*Allium sativum* L.) parental lines and cultivars. *Horticulture, Environment and Biotechnology*, vol. 55, p. 138-147. https://doi.org/10.1007/s13580-014-0155-x

Bhatt, A., Patel, V. 2013. Antioxidant activity of garlic using conventional extraction and in vitro gastrointestinal digestion. *Free Radicals and Antioxidants*, vol. 3, no. 1, p. 30-34. https://doi.org/10.1016/j.fra.2013.03.003

Boonpeng, S., Siripongvutikorn, S., Sae-wong, C., Sutthirak, P. 2014. The antioxidant and anti-cadmium toxicity properties of garlic extracts. *Food Science & Nutrition*, vol. 2, no. 6, p. 792-801. https://doi.org/10.1002/fsn3.164

Bystrická, J., Kovarovič, J., Lenková, M., Horváthová, J., Končeková, L., Halmová, D., Lidiková, A. 2018. The content of polyphenols, antioxidant activity and macroelements in selected garlic varieties. *Journal of Microbiology, Biotechnology and Food Sciences*, vol. 8, no. 1, p. 738-740. https://doi.org/10.15414/jmbfs.2018.8.1.738-740

Chang, C. C., Yang, M. H., Wen, H. M., Chern, J. C. 2002. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. *Journal of Food and Drug Analysis*, vol. 10, no. 3, p. 178-182. https://doi.org/10.38212/2224-6614.2748

Chen, S., Shen, X., Cheng, S., Li, P., Du, J., Chang, Y., Meng, H. 2013. Evaluation of garlic cultivars for polyphenolic content and antioxidant properties. *PloS one*, vol. 8, no. 11, p. e79730. https://doi.org/10.1371/journal.pone.0079730

Chun, O. K., Kim, D. O., Smith, N., Schroeder, D., Han, J. T., Lee, C. Y. 2005. Daily consumption of phenolics and total antioxidant capacity from fruit and vegetables in the American diet. *Journal of the Science of Food and Agriculture*, vol. 85, no.10, p. 1715-1724. https://doi.org/10.1002/jsfa.2176

Cory, H., Passarelli, S., Szeto, J., Tamez, M., Mattei, J. 2018. The role of polyphenols in human health and food systems: A mini-review. *Frontiers in Nutrition*, vol. 5, p. 87. https://doi.org/10.3389/fnut.2018.00087

Cutrim, C. S., Cortez, M. A. S. 2018. A review on polyphenols: Classification, beneficial effects and their application in dairy products. *International Journal of Dairy Technology*, vol. 71, no. 3, p. 564-578. https://doi.org/10.1111/1471-0307.12515

Gorinstein, S., Leontowicz, H., Leontowicz, M., Drzewiecki, J., Najman, K., Katrich, E., Trakhtenberg, S. 2006. Raw and boiled garlic enhances plasma antioxidant activity and improves plasma lipid metabolism in cholesterol-fed rats. *Life Sciences*, vol. 78, no. 6, p. 655-663. https://doi.org/10.1016/j.lfs.2005.05.069

Gorinstein, S., Park, Y. S., Heo, B. G., Namiesnik, J., Leontowicz, H., Leontowicz, M., Kang, S. G. 2009. A comparative study of phenolic compounds and antioxidant and antiproliferative activities in frequently consumed raw vegetables. *European Food Research and Technology*, vol. 228, no. 6, p. 903-911. https://doi.org/10.1007/s00217-008-1003-y

Hedges, L. J., Lister, C. E. 2007. The nutritional attributes of Allium species. *Crop and food research confidential report*, report no. 1814. http://doi.org/10.13140/2.1.4265.4402

Choi, J. H., Davis, A. R., Hugo Cota-Sánchez, J. 2011. Comparative floral structure of four new world Allium (*Amaryllidaceae*) species. *Systematic Botany*, vol. 36, no. 4, p. 870-882. https://doi.org/10.1600/036364411x604895

Kavalcová, P., Bystrická, J., Tomáš, J., Karovičová, J., Kuchtová, V. 2014. Evaluation and comparison of the content of total polyphenols and antioxidant activity in onion, garlic and leek. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 8, no. 1, p. 272-276. https://doi.org/10.5219/394

Khalid, N., Ahmed, I., Latif, M. S. Z., Rafique, T., Fawad, S. A. 2014. Comparison of antimicrobial activity, phytochemical profile and minerals composition of garlic *Allium sativum* and Allium tuberosum. *Journal of the Korean Society for Applied Biological Chemistry*, vol. 57, no.3, p. 311-317. https://doi.org/10.1007/s13765-014-4021-4

Khan, M. S., Quershi, N. A., Jabeen, F., Asghar, M. S., Shakeel, M. 2016. Analysis of minerals profile, phenolic compounds and potential of Garlic (*Allium sativum*) as antioxidant scavenging the free radicals. *International Journal of Biosciences*, vol. 8, no. 4, p. 72-82. https://doi.org/10.12692/ijb/8.4.72-82

Khan, N., Fayyaz, M., Abbasi, A. M., Khan, S. A., Nazir, A. 2017. Development of an efficient callus derived regeneration system for garlic (*Allium sativum* L.) from root explant. *Journal of Plant Breeding and Agriculture*, vol. 1, no. 1, p. 3. http://doi.org/10.1079/IVP2002378

Kim, J. S., Kang, O. J., Gweon, O. C. 2013. Comparison of phenolic acids and flavonoids in black garlic at different thermal processing steps. *Journal of Functional Foods*, vol. 5, no. 1, p. 80-86. https://doi.org/10.1016/j.jff.2012.08.006

Kovarovič, J., Bystrická, J., Fehér, A., Lenková, M. 2017. Evaluation and comparison of bioactive substances in selected species of the genus Allium. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 11, no. 1, p. 702-708. https://doi.org/10.5219/833

Lachman, J., Proněk, D., Hejtmanková, A., Dudjak, J., Pivec, V., Faitová, K. 2003. Total polyphenol and main flavonoid antioxidant in different onion (*Allium cepa* L.) varieties. *Horticultural Science*, vol. 30, no. 4, p. 142-147. https://doi.org/10.17221/3876-hortsci

Lenková, M., Bystrická, J., Chlebo, P., Kovarovič, J. 2018. Garlic (*Allium sativum* L.)–the content of bioactive compounds. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 12, no. 1, p. 405-412. https://doi.org/10.5219/830

Lenková, M., Bystrická, J., Hrstková, M. 2016. Evaluation and comparison of the content of total polyphenols and antioxidant activity of selected species of the genus Allium. *Journal of Central European Agriculture*, vol. 17, no. 4, p. 1199-1133. http://doi.org/10.5513/JCEA01/17.4.1820

Lenková, M., Bystrická, J., Vollmannová, A., Tóth, T., Kovarovič, J. 2017. Evaluation and comparison of the content of total polyphenols and antioxidant activity in garlic (*Allium sativum* L.). *Potravinarstvo Slovak Journal of Food Sciences*, vol. 11, no. 1, p. 65-70. https://doi.org/10.5219/830

Locatelli, D. A., Nazareno, M. A., Fusari, C. M., Camargo, A. B. 2017. Cooked garlic and antioxidant activity: Correlation with organosulfur compound composition. *Food chemistry*, vol. 220, p. 219-224. https://doi.org/10.1016/j.foodchem.2016.10.001

Lorigooini, Z., Kobarfard, F., Ayatollahi, S. A. 2014. Anti-platelet aggregation assay and chemical composition of essential oil from *Allium atroviolaceum Boiss* growing in Iran. *International Journal of Biosciences* (IJB), vol. 5, no. 2, p. 151-156. https://doi.org/10.12692/ijb/5.2.151-156

Losada-Barreiro, S., Bravo-Díaz, C. 2017. Free radicals and polyphenols: The redox chemistry of neurodegenerative diseases. *European Journal of Medicinal Chemistry*, vol. 133, p. 379-402. https://doi.org/10.1016/j.ejmech.2017.03.061

Lu, X., Ross, C. F., Powers, J. R., Aston, D. E., Rasco, B. A. 2011. Determination of total phenolic content and antioxidant activity of garlic (*Allium sativum*) and elephant garlic (*Allium ampeloprasum*) by attenuated total reflectance–Fourier transformed infrared spectroscopy. *Journal of agricultural and food chemistry*, vol. 59, no. 10, p. 5215-5221. https://doi.org/10.1021/jf201254f

Micová, M., Urminská, D., Bystrická, J., Kovarovič, J., Harangozo, Ľ. 2019. The influence of variety on the content of bioactive compounds in garlic (*Allium sativum* L.). *Journal of Microbiology, Biotechnology and Food Sciences*,vol. 8, no. 4, p. 1076-1079. https://doi.org/10.15414/jmbfs.2019.8.4.1076-1079

Najman, K., Sadowska, A., Hallmann, E. 2020 Influence of Thermal Processing on the Bioactive, Antioxidant, and Physicochemical Properties of Conventional and Organic Agriculture Black Garlic (*Allium sativum* L.). *Applied Science*, vol. 10, no. 23, p. 8638. https://doi.org/10.3390/app10238638

Nencini, C., Menchiari, A., Franchi, G. G. 2011. In vitro Antioxidant Activity of Aged Extracts of some Italian Allium Species. *Plant Foods for Human Nutrition*, vol. 66, p. 11-16. https://doi.org/10.1007/s11130-010-0204-2

Park, M. H., Kim, J. G. 2015. Low-dose UV-C irradiation reduces the microbial population and preserves antioxidant levels in peeled garlic (*Allium sativum* L.) during storage. *Postharvest Biology and Technology*, vol. 100, p. 109-112. https://doi.org/10.1016/j.postharvbio.2014.09.013

Pedersen, C. B., Kyle, J., Jenkinson, A., Gardner, P. T., McPhail, D. B., Duthie, G. G. 2000. Effects of blueberry and cranberry juice consumption on the plasma antioxidant capacity of healthy female volunteers. *European Journal of Clinical Nutrition*, vol. 54, no. 5, p. 405-408. https://doi.org/10.1038/sj.ejcn.1600972

Petropoulos, S. A., Fernandes, Â., Ntatsi, G., Petrotos, K., Barros, L., Ferreira, I. C. 2018. Nutritional value, chemical characterization and bulb morphology of Greek garlic landraces. *Molecules*, vol. 23, no. 2, p. 319. https://doi.org/10.3390/molecules23020319

Poojary, M. M., Putnik, P., Kovačević, D. B., Barba, F. J., Lorenzo, J. M., Dias, D. A., Shpigelman, A. 2017. Stability and extraction of bioactive sulfur compounds from Allium genus processed by traditional and innovative technologies. *Journal of Food Composition and Analysis*, vol. 61, p. 28-39. https://doi.org/10.1016/j.jfca.2017.04.007

Priecina, L., Karlina, D. 2013. Total Polyphenol, Flavonoid Content And Antiradical Activity Of Celery, Dill, Parsley, Onion And Garlic Dried Conventive And Microwave-Vacuum Dryers. *International Conference on Nutrition and Food Sciences*, vol. 5, p. 107-112. Available at: http://www.ipcbee.com/vol53/021-ICNFS2013-F2008.pdf.

Putnik, P., Gabrić, D., Roohinejad, S., Barba, F. J., Granato, D., Mallikarjunan, K., Kovačević, D. B. 2019. An overview of organosulfur compounds from *Allium* spp.: From processing and preservation to evaluation of their bioavailability, antimicrobial, and anti-inflammatory properties. *Food Chemistry*, vol. 276, p. 680-691. https://doi.org/10.1016/j.foodchem.2018.10.068

Rasouli, H., Farzaei, M. H., Khodarahmi, R. 2017. Polyphenols and their benefits: A review. *International Journal of Food Properties*, vol. 20, no. 2, p. 1700-1741. https://doi.org/10.1080/10942912.2017.1354017

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., Rice-Evans, C. 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, vol. 26, no. 9-10, p. 1231-1237. https://doi.org/10.1016/s0891-5849(98)00315-3

RStudio. 2020. RStudio: Integrated Development for R. Boston, MA, USA : RStudio, Inc.

Škrovánková, S., Mlček, J., Snopek, L., Planetová, T. 2018. Polyphenols and antioxidant capacity in different types of garlic. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 12, no.1, p. 267-272. https://doi.org/10.5219/895

Soto, V. C., González, R. E., Sance, M. M., Galmarini, C. R. 2015. Organosulfur and phenolic content of garlic (*Allium sativum* L.) and onion (*Allium cepa* L.) and its relationship with antioxidant activity. *VII International Symposium on Edible Alliaceae*, vol. 1143, p. 277-290. https://doi.org/10.17660/actahortic.2016.1143.39

Srivastava, M. P., Tiwari, R., Sharma, N. 2013. Assessment of phenol and flavonoid content in the plant materials. *Journal on New Biological Reports*, vol. 2, no. 2, p. 163-166. https://doi.org/10.1155/2014/253875

Suleria, H. A. R., Butt, M. S., Khalid, N., Sultan, S., Raza, A., Aleem, M., Abbas, M. 2015. Garlic (*Allium sativum*): diet based therapy of 21st century–a review. *Asian Pacific Journal of Tropical Disease*, vol. 5, no. 4, p. 271-278. https://doi.org/10.1016/s2222-1808(14)60782-9

Szychowski, K. A., Rybczynska-Tkaczyk, K., Gawel-Beben, K., Swieca, M., Karas, M., Jakuczyk, A., Gminski, J. 2018. Characterization of active compounds of different garlic (*Allium sativum* L.) cultivars. *Polish Journal of Food and Nutrition Sciences*, vol. 68, no. 1, p. 73-81. https://doi.org/10.1515/pjfns-2017-0005

Zhou, L., Guo, X., Bi, J., Yi, J., Chen, Q., Wu, X., Zhou, M. 2017. Drying of garlic slices (*Allium sativum* L.) and its effect on thiosulfinates, total phenolic compounds and antioxidant activity during infrared drying. *Journal of Food Processing and Preservation*, vol. 41, no. 1, p. e12734. https://doi.org/10.1111/jfpp.12734

Funds:

This work was supported by grant VEGA No. 1/0114/18.

Conflict of Interest:

The authors declare no conflict of interest.

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

Contact Address:

*Natália Čeryová, Slovak University of Agriculture, Institute of Food Science, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia, Tel.: +421376414378,
E-mail: xceryova@uniag.sk
ORCID: https://orcid.org/0000-0002-1865-5131

Iveta Čičová, The Research Institute of Plant Production, Gene Bank of the Slovak Republic, Bratislavská cesta 122, 921 68, Piešťany, Tel.: +421337947345,
E-mail: iveta.cicova@nppc.sk
ORCID: https://orcid.org/0000-0002-4167-3733

Judita Lidiková, Slovak University of Agriculture, Institute of Food Science, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia, Tel.: +421376414353,
E-mail: judita.lidikova@uniag.sk
ORCID: https://orcid.org/0000-0001-9922-4300

Marek Šnirc, Slovak University of Agriculture, Institute of Food Science, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia, Tel.: +421376414345,
E-mail: marek.snirc@uniag.sk
ORCID: https://orcid.org/0000-0003-1732-0417

Jarmila Horváthová, Slovak University of Agriculture, Centre of Languages, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia, Tel.: +421376414353,
E-mail: jarmila.horvathova@uniag.sk

Helena Lichtnerová, Slovak University of Agriculture, Institute of Landscape Architecture, Tulipánová 7, 949 76 Nitra, Slovakia, Tel.: +421376415443,
E-mail: Helena.lichtnerova@uniag.sk

Hana Franková, Slovak University of Agriculture, Institute of Food Science, Trieda A. Hlinku 2, 949 76 Nitra, Slovakia, Tel.: +421376414375,
E-mail: xchrkavah@uniag.sk
ORCID: https://orcid.org/0000-0003-1833-1732

Corresponding author: *