JMBFS
Journal of Microbiology, Biotechnology and Food Sciences
International peer-reviewed scientific online journal
Published by Faculty of Biotechnology and Food Sciences

EVALUATION OF ANTIOXIDANT POTENTIAL OF *ASIMINA TRILOBA* (L.) DUNAL FLOWERS AND FRUITS

Olga Grygorieva[1], Olena Vergun[1], Mykhailo Zhurba[1], Antonina Ilyinska[1], Eva Ivanišová[2], Vladimíra Horčinová Sedláčková[3*], Ján Brindza[4]*

Address(es): Olga Grygorieva,
[1] M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Sadovo-Botanichna str. 1, 01014 Kyiv, Ukraine.
[2] Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Institute of Food Sciences, Tr. A. Hlinku 2, 949 76, Nitra, Slovak Republic.
[3] Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic.
[4] Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Institute of Plant and Environmental Sciences, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic.

*Corresponding author: olgrygorieva@gmail.com , vladimira.sedlackova@uniag.sk

https://doi.org/10.55251/jmbfs.11605

ARTICLE INFO

Received 28. 7. 2024
Revised 28. 4. 2025
Accepted 30. 4. 2025
Published 1. 6. 2025

Regular article

OPEN ACCESS

ABSTRACT

This study aimed to test the antioxidant parameters of the flower and fruit ethanol extracts of 15 genotypes of *Asimina triloba* (L.) Dunal. (AzTr-01 – AzTr-15) collected in the M.M. Gryshko National Botanical Garden (Kyiv, Ukraine). Antioxidant activity of the extracts of the investigated genotypes was measured with free radical scavenging activity (FRSA) by the DPPH method and molybdenum reducing power (MRP) expressed as mg TE (Trolox equivalent) per g of DW (dry weight). The total polyphenol content (TPC) was expressed as mg GAE (gallic acid equivalent) per g of DW, total flavonoid content (TFC) was expressed as mg QE (quercetin equivalent) per g of DW, and total phenolic acid content (TPAC) expressed as mg CAE (caffeic acid equivalent) per g of DW. It was determined that the flower and fruit extracts of *A. triloba* demonstrated 5.45-77 and 2.33-7.21 mg TE/g of FRSA, respectively. Depending on a genotype, MRP of the flower and fruit extracts was 85.13-114.65 and 98.19-261.33 mg TE/g, respectively. TPC of the flower extracts ranged from 40.63 to 55.47 mg GAE/g and fruit extracts from 22.59 to 38.13 mg GAE/g. The flower extracts demonstrated 22.54-36.18 mg QE/g of TFC and 9.31-16.24 mg CAE/g of TPAC. The fruit extracts exhibited 15.07-30.55 mg QE/g and 3.11-6.58 mg CAE/g. These results indicated that various plant parts of *A. triloba* genotypes are appropriate for usage in food and pharmaceutical products as a raw material with a high content of biologically active compounds.

Keywords: Pawpaw, genotypes, antioxidant activity, phenolic compounds

INTRODUCTION

Recently, numerous studies have highlighted the growing interest in the search for new plant species, especially neglected, non-traditional, and underutilized plant species that are an important source of biologically active compounds due to their beneficial role (**Klymenko *et al.*, 2019a, b; Szot *et al.*, 2020; Levon and Klymenko, 2021; Zhurba *et al.*, 2021; Mendelova *et al.*, 2022; Ňorbová *et al.*, 2023**). *Asimina triloba* (L.) Dunal (pawpaw, paw paw, paw-paw, common pawpaw) native to eastern North America and Canada belongs to the family Annonaceae Juss. (**Layne, 1996; Brannan and Coyle, 2021; Tulowiecki, 2021**). *Asimina triloba* is extensively cultivated in 26 states, in addition, this species is widely distributed in Asia, including in Korea, China, and Japan (**Brannan *et al.*, 2015; Nam *et al.*, 2017; Brannan and Coyle, 2021**).
The fruits of *Asimina triloba* are a valuable source of vitamins (particularly riboflavin and niacin) and mineral elements such as potassium, magnesium, iron, copper, and manganese (**Galli *et al.*, 2007**), as well as high polyphenolic content (**Kobayashi *et al.*, 2008; Harris and Brannan, 2009; Brindza *et al.*, 2019**), and essential amino acids, fatty acids (**Wood and Peterson, 1999**), annonacin (**Tran *et al.*, 2021**), and polysaccharides (**Arifkhodzhaev *et al.*, 1985**) are studied by many authors.
Extracts from different parts of the plant (roots, twigs, leaves, fruit, and seeds) have potent anticancer properties due to the presence of acetogenins (**Gu *et al.*, 1999; Brannan and Farag, 2009; Coothankandaswamy *et al.*, 2010; Levine *et al.*, 2015; Avula *et al.*, 2018; Nam *et al.*, 2018**). The pawpaw extracts can be natural products that may be used for the prevention and treatment of gastric and cervical cancers (**Nam *et al.*, 2021**).
Bullatacin, asimicin, and trilobacin represent the most potent and major bioactive acetogenins that are found in extract twigs from the paw paw tree (**Hui *et al.*, 1989; Zhao *et al.*, 1992**).
Fruits of *Asimina triloba* are very fragrant and may be used in cosmetics and skin products (**Layne, 1996; Brannan *et al.*, 2012**).
Biologically active compounds in *A. triloba* are presented in many plant parts, such as roots, bark, twigs, leaves, flowers, and seeds (**Hui *et al.*, 1989; Zhao *et al.*, 1992, 1994; Alali *et al.*, 1999; Goodrich *et al.*, 2006; Cuendet *et al.*, 2008; Farag, 2009; Pande and Akoh, 2010; Nam *et al.*, 2021**). Acetogenins, located in roots, twigs, flowers, and seeds of *A. triloba*, and essential oil obtained from leaves (**Alali *et al.*, 1999; Farag, 2009**), are strong inhibitors of cancer cells (**Ratnayake *et al.*, 1992; Woo *et al.*, 1995; Ko *et al.*, 2011; Sica *et al.*, 2016**). The extracts from fruit, leaf, bark, and twig are used as insecticidal against insects (**Rupprecht *et al.*, 1986; Ratnayake *et al.*, 1992; Zhao *et al.*, 1994; Gu *et al.*, 1999**).
The stem bark extracts of *Asimina triloba* (Annonaceae) have three further acetogenins: asimin, asiminacin, and asiminecin, and potent antitumor and pesticidal effects (**Zhao *et al.*, 1994**). Three new biologically active annone acetogenins were isolated from the ethanol extract of *Asimina triloba* seeds: asimilobin, cis-murisolinone, and trans-murisolinone (**Woo *et al.*, 1995**). Asimicin was the first acetogenin isolated from the seeds and stem bark of *Asimina triloba* (**Rupprecht *et al.*, 1986**).
Considering the above review, it should be noted that the investigation of different parts of plants for the presence of antioxidant agents is very important for the development of new pharmaceutical and food products. In this regard, the study of the antioxidant activity of non-traditional fruit plants is essential for searching for new plant raw materials rich in phenolics, flavonoids, or phenolic acids.
This study aimed to evaluate antioxidant parameters of *A. triloba* flowers and fruits, and to compare the less studied flowers of *A. triloba* genotypes in the context of biologically active compounds.

MATERIAL AND METHODS

Biological material

The flowers (Figure 1) and fruits (Figure 2) of 15 genotypes of *Asimina triloba* (AzTr-01 – AzTr-15) collected in the M.M. Gryshko National Botanical Garden were the objects of these investigations. Flowers were collected during the period of full flowering. The fruits were harvested at full ripeness.
The research was conducted in 2023 in the NBG, which is located on the right bank of the Dnipro River in the southeastern part of Kyiv on the low Pechersky slopes of the Kyiv Highlands (197 m above sea level) in the Zvirynets tract (50°27'N.; 30°31' E.). The climate is moderately continental, the winter is mild, the summer is warm. The average monthly temperature in January is −3.8°C, in July +21.5°C.

The average annual temperature is +7.7 °C. The average annual precipitation is about 640 mm; fall throughout the year.

Figure 1 Flowers of *Asimina triloba* (L.) Dunal.

Figure 2 Fruits of *Asimina triloba* (L.) Dunal.

Chemicals

All the chemicals used were of analytical grade and were purchased from Sigma-Aldrich (St. Louis, MO, USA) and CentralChem (Slovakia).

Preparation of the sample extracts

Each 0.25 g sample was extracted with 20 mL of 80% ethanol for 2 hours using a GFL 3005 laboratory shaker (GFL, Burgwedel, Germany). Following extraction, the samples were centrifuged at 4605 RCF for 10 minutes (Rotofix 32 A, Hettich, Germany). The resulting supernatant was subsequently utilized to assess FRSA (free radical scavenging activity) via the DPPH assay, MRP (antioxidant capacity) using the phosphomolybdenum method, as well as to determine other antioxidant parameters, including total polyphenol, flavonoid, and phenolic acid contents.

Free radical scavenging activity – DPPH method

The antiradical activity, or free radical scavenging activity (FRSA), of the samples was determined according to the method of **Sánchéz-Moreno *et al*. (1998)** using 2,2-diphenyl-1-picrylhydrazyl (DPPH). For the assay, 0.4 mL of each sample was mixed with 3.6 mL of a DPPH solution (prepared by dissolving 0.025 g DPPH in 100 mL ethanol). After incubation, the absorbance was measured at 515 nm using a Jenway 6405 UV/Vis spectrophotometer (England). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) was used as the calibration standard within a concentration range of 10–100 mg/L (R^2 = 0.989). Antioxidant activity was expressed in terms of Trolox equivalents per gram of dry matter (mg/g DM).

Molybdenum reducing power

The molybdenum reducing power (MRP) of the samples was assessed using the method described by **Prieto *et al.* (1999)**, with minor modifications. A mixture containing 1 mL of the sample, 2.8 mL of 0.1 M monopotassium phosphate, 6 mL of 1 M sulfuric acid, 0.4 mL of 0.1 M ammonium heptamolybdate, and 0.8 mL of distilled water was incubated at 90 °C for 120 minutes, followed by cooling to room temperature. Absorbance at 700 nm was measured using a Jenway 6405 UV/Vis spectrophotometer (England). Trolox (concentrations ranging from 10–1000 mg/L; R^2 = 0.998) was used as the reference standard, and the results were expressed as Trolox equivalents (mg/g DM).

Total polyphenol content

The total polyphenol content (TPC) was measured by the method of **Singleton and Rossi (1965)** using the Folin-Ciocalteu reagent. A quantity of 0.1 mL of each sample was mixed with 0.1 mL of the Folin-Ciocalteu reagent, 1 mL of 20% (w/v) sodium carbonate, and 8.8 mL of distilled water. After 30 min in darkness, the absorbance at 700 nm was measured with the spectrophotometer Jenway (6405 UV/Vis, England). Gallic acid (25–300 mg/L; R^2 = 0.998) was used as the standard. The results were expressed in mg/g DW gallic acid equivalent.

Total flavonoid content

The total flavonoid content (TFC) was measured using a modified procedure based on the method of **Shafii *et al.* (2017)**. A 0.5 mL sample was combined with 0.1 mL of a 10% (w/v) ethanolic aluminum chloride solution, 0.1 mL of 1 M potassium acetate, and 4.3 mL of distilled water. The mixture was allowed to stand in the dark for 30 minutes, after which the absorbance was recorded at 415 nm with a Jenway 6405 UV/Vis spectrophotometer (England). Quercetin, with concentrations ranging from 1–400 mg/L (R^2 = 0.9977), was used as the standard. Results were expressed as quercetin equivalents (mg/g DW).

Total phenolic acid content

The total phenolic acid content (TPAC) was quantified using the method described by **Árvay *et al.* (2017)**. A 0.5 mL aliquot of the sample was combined with 0.5 mL of 0.5 M hydrochloric acid, 0.5 mL of Arnov's reagent, 0.5 mL of 1 M sodium hydroxide, and 0.5 mL of water. After mixing, the absorbance was measured at 490 nm using a Jenway 6405 UV/Vis spectrophotometer (England). Caffeic acid, with a concentration range of 1–200 mg/L (R^2 = 0.999), was used as the standard. The results were expressed as caffeic acid equivalents (mg/g DW).

Statistical analysis

The results are presented as the mean values of three replicates ± standard deviation (SD). The data were analyzed using the ANOVA test, and mean differences were assessed using the Tukey-Kramer test ($p < 0.05$).

RESULTS AND DISCUSSION

As far as we are aware, this is the first report that investigates the antioxidant potential of Asimina triloba flowers and contrasts it with the activity observed in its fruits.

Many authors studied flowers of various plant species as a part of the human diet for their beneficial health effects (**Takahashi *et al.*, 2020; Janarny *et al.*, 2021**). More than 180 species of flowers have been used worldwide as dietary supplements in the form of tea, wine, food ingredients for cakes, smoothies, or even vegetables (**Lu *et al.*, 2016**).

The flowers are good sources of phenolic acids, flavanols, flavones, flavanones, and anthocyanins (**Zheng *et al.*, 2019**) as well as carotenoids, alkaloids, and lignans (**Lu *et al.*, 2016**). Research has indicated that the antioxidant activity of certain edible flowers is either comparable to or exceeds that of some vegetables and fruits, based on experimental findings (**Cavaiuolo *et al.*, 2013**). Flower extracts of some plant species have high antioxidant activity (**Pires *et al.*, 2018**), anti-inflammatory properties (**Lee *et al.*, 2018**), anticancer properties (**Solomon *et al.*, 2016**), anti-diabetic properties (**Nambirajan *et al.*, 2018**), anti-Alzheimer's effect (**Bekir *et al.*, 2016**), hepatoprotective effects (**Singhal and Gupta, 2012**), cardioprotective (**Ittagi *et al.*, 2014**), gastroprotective (**Guedes *et al.*, 2002**), antimicrobial activity (**Najda *et al.*, 2021**).

DPPH is a fast, straightforward, and cost-effective technique for assessing the antioxidant capacity of foods. It utilizes the free radical 2,2-Diphenyl-1-picrylhydrazyl, commonly employed to evaluate the potential of compounds to function as free radical scavengers or hydrogen donors, and to measure their antioxidant activity (**Shekhar and Anju, 2014**).

TEAC (Trolox equivalent antioxidant capacity) by DPPH and phosphomolybdenum method was used in this study to evaluate the antioxidant potential of the investigated plant extracts.

We determined that the mean antioxidant activity of the ethanol extracts of the flower and fruits of *Asimina triloba* measured in the DPPH method was 6.59 and 4.96 mg TE/g DW (Figure 3). This parameter for flowers and fruits varieties was from 5.45 (AzTr-11) to 7.77 (AzTr-09) mg TE/g DW and from 2.33 (AzTr-07) to 7.21 (AzTr-06) mg TE/g DW, respectively.

The ethanol extracts of *Asimina triloba* flowers exhibited molybdenum reducing power of extracts from 85.13 (AzTr-04) to 114.65 (AzTr-09) mg TE/g DW, fruits from 98.19 (AzTr-04) to 261.33 (AzTr-06) mg TE/g DW (Figure 4).

Comparison of the antioxidant activity values of fruits *A. triloba* with other species by the DPPH method showed some similarities or differences.

Horčinová Sedláčková *et al.* (2022) demonstrated in the berries of *M. aquifolium* the antioxidant activity determined by the Trolox method in the methanolic extracts (76.2 mg $TE.g^{-1}$ DW), in the ethanolic extracts (54.3 mg $TE.g^{-1}$ DW), in acetone extracts (63.4 mg $TE.g^{-1}$ DW) and aqueous extracts (35.5 mg $TE.g^{-1}$ DW). The results for antioxidant activity (μMol Trolox/g) of *Cornus mas* berries determined by the DPPH method varied from 5.94 to 16.56, ABTS method varied from 13.560 to 33.96, FRAP method varied from 8.45 to 22.49 (**Klymenko *et al.*, 2019b**).

Polyphenols, as key phytochemicals found in different plant parts, are extensively studied for their use in both traditional and modern medicine. They play a significant role in the development of new medicinal products and are recognized for their wide range of health benefits (**Yang *et al.*, 2000; Bose *et al.*, 2008; Visioli *et al.*, 2011; Khurana *et al.*, 2013; Mrduljaš *et al.*, 2017; García-Conesa and Larossa, 2020**). Moreover, these compounds exhibit low toxicity to the human body and are essential for maintaining the oxidative stability of foods. Their inclusion in food and pharmaceutical products has significantly enhanced their quality (**Rasouli *et al.*, 2017**).

The total content of polyphenol compounds in our study was for *Asimina triloba* flowers of 40.63 (AzTr-04) to 55.47 (AzTr-06) mg GAE/g DW, for fruits from 22.59 (AzTr-04) to 38.13 (AzTr-06) mg GAE /g DW (Figure 5).

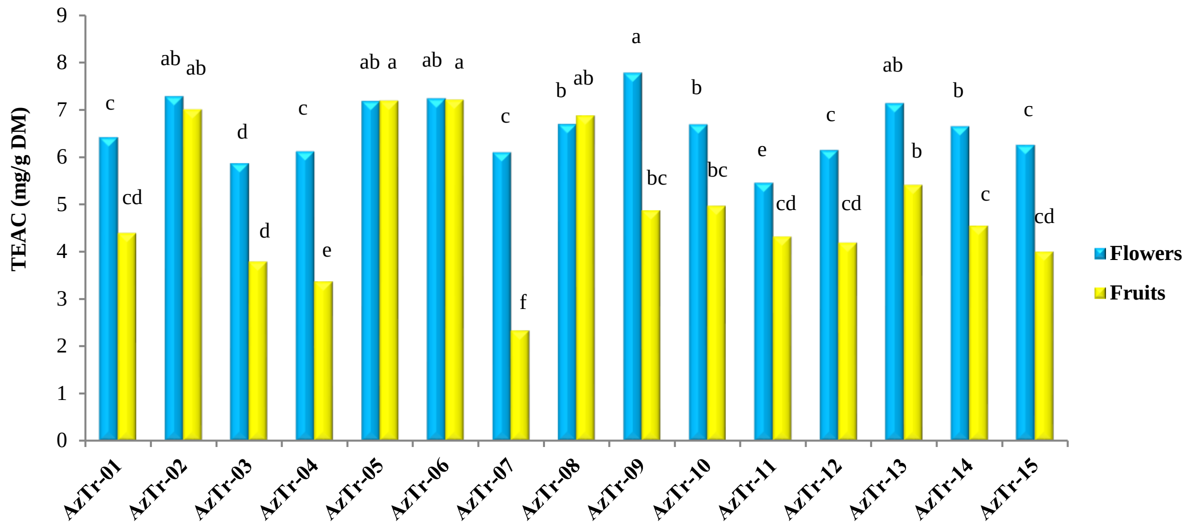

Figure 3 Free radical scavenging activity of *Asimina triloba* (L.) Dunal. flowers and fruits evaluated by the DPPH method (different superscripts in each column indicate the significant differences in the mean at $p < 0.05$); TEAC – Trolox equivalent antioxidant capacity

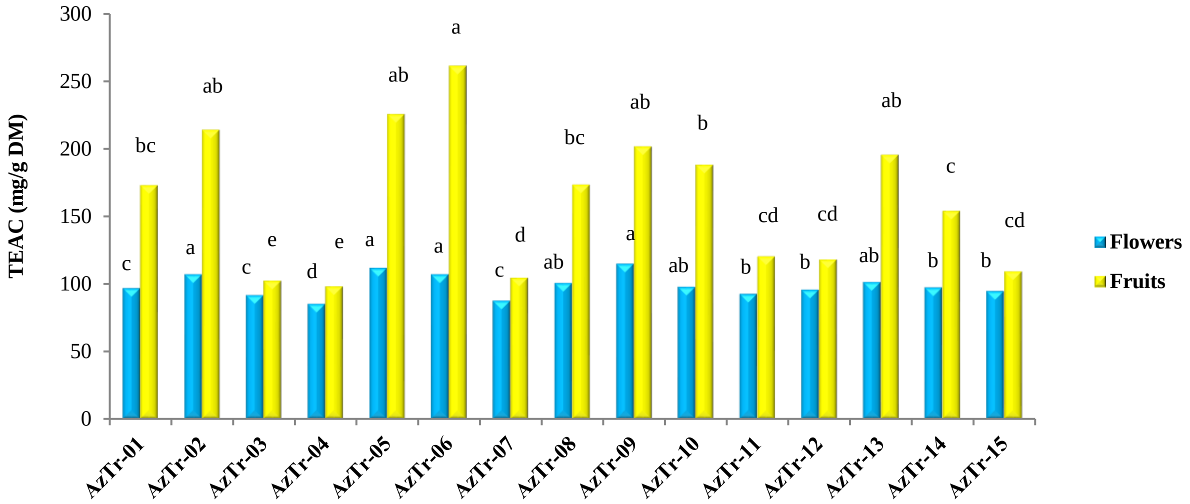

Figure 4 Molybdenum reducing power of *Asimina triloba* (L.) Dunal. flowers and fruit extracts (different superscripts in each column indicate the significant differences in the mean at $p < 0.05$); TEAC – Trolox equivalent antioxidant capacity

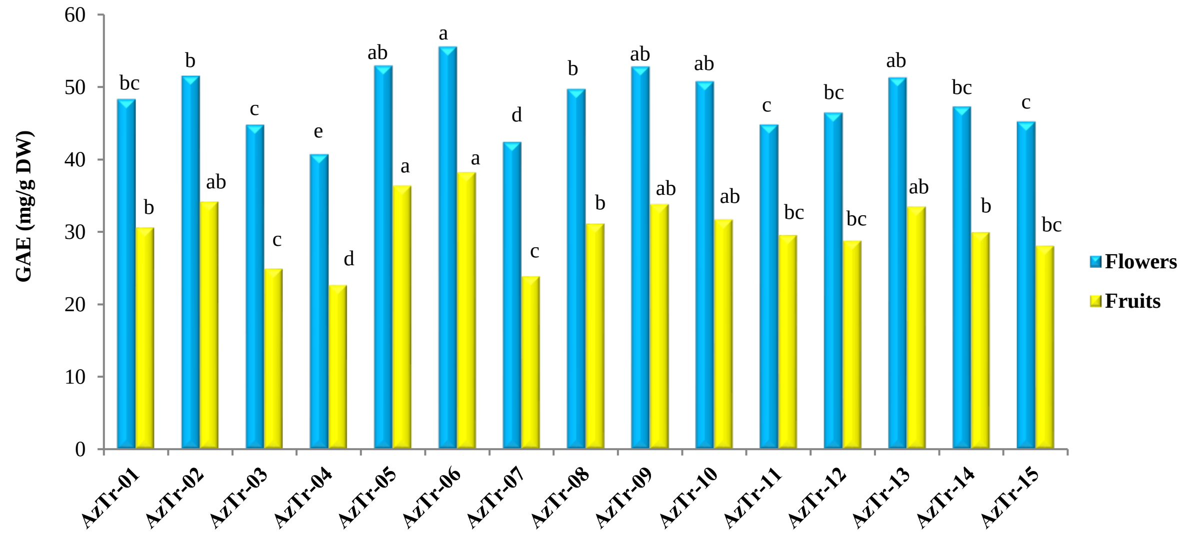

Figure 5 Total polyphenol content in *Asimina triloba* (L.) Dunal. flowers and fruits (different superscripts in each column indicate the significant differences in the mean at $p < 0.05$); GAE – gallic acid equivalent

Regarding the total phenolic content in *Crataegus oxyacantha*, the values for flowers varied between 2364.1 and 3179.6 mg GAE/100 g DW, while for fruits, they ranged from 1912.1 to 4339.0 mg GAE/100 g DW (**Issaadi *et al.*, 2020**). **Edwards *et al.* (2012)** reported the total phenols quantified in the flowers of different *Crataegus species*: in *C. azarolus* values ranged from 46 to 1014 mg/100 g DW. As regards TFC, the average content in flowers was almost two-fold higher than in fruits (660.7 and 367.1 mg QE/100 g DW, respectively) (**Issaadi *et al.*, 2020**).

Flavonoids are a group of bioactive compounds that are extensively found in foodstuffs of plant origin (**Prasad *et al.*, 2009**). Flavonoids are classified into subgroups based on their chemical structure: flavanones, flavones, flavonols, flavan-3-ols, anthocyanins, and isoflavones. The growing body of scientific evidence indicates that flavonoids play a beneficial role in the prevention of many diseases, thus a diet rich in flavonoids has beneficial effects on human health (**Majewska and Czeczot, 2009; Shabrova *et al.*, 2011; Hui *et al.*, 2013; Kozłowska and Szostak-Węgierek, 2014; Ballard and Maróstica Junior, 2019; Mondal and Rahaman, 2020**).

The total content of flavonoids in the investigated ethanolic flower extracts of *Asimina triloba* was from 22.54 (AzTr-07) to 36.18 (AzTr-06) mg QE/g DW, for fruits from 15.07 (AzTr-04) to 30.55 (AzTr-06) mg QE/g DW (Figure 6).

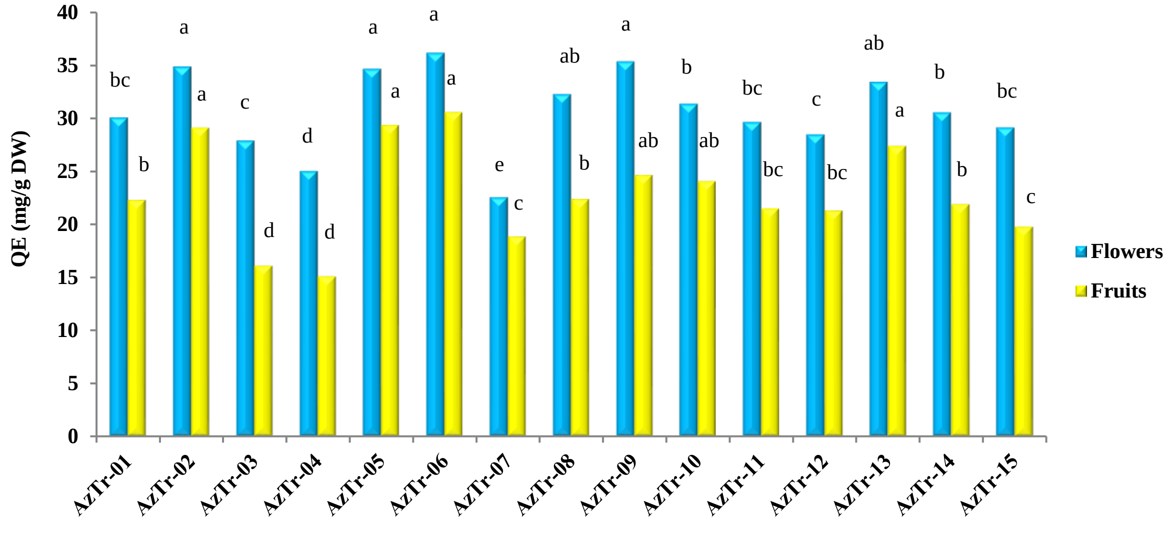

Figure 6 Total flavonoid content in *Asimina triloba* (L.) Dunal. flowers and fruit (different superscripts in each column indicate the significant differences in the mean at p <0.05); QE – quercetin equivalent

The mean concentrations of flavonoids and phenolics in these five cultivars were 1.59 and 7.86 mg/g DW, respectively (**Zhou *et al.*, 2011**).

The average daily intake of flavonoids for Greek and Spanish participants is 93 mg and 126.1 mg per person, respectively (**Dilis and Trichopoulou, 2010; Zamora-Ros *et al.*, 2010**). In Western Europe, the daily flavonoid intake per person generally falls within the range of 100 to 1000 mg (**Majewska and Czeczot, 2009; Wilczyńska and Retel, 2011**). In Far Eastern countries like Japan, individuals may consume as much as 2 g of flavonoids daily due to a high intake of legumes, soy, and tea (**Wang *et al.*, 2009**).

Phenolic acids, as secondary metabolites, are widely distributed across the plant kingdom. These compounds contribute to the distinct taste, flavor, and health benefits of fruits and vegetables (**Tomas-Barberan and Espin, 2001**), enhancing their overall quality for consumers. In recent years, there has been growing recognition of the antioxidant properties of phenolic compounds and their potential application as natural antioxidants in processed foods. Numerous studies in agriculture, biology, chemistry, and medicine have demonstrated the roles and effects of phenolic acids on human health (**Cotelle, 2001; Hwang *et al.*, 2006; Madlener *et al.*, 2007; Ghasemzadeh and Ghasemzadeh, 2011; Godos *et al.*, 2021**).

The determination of the total phenolic acid content showed that in fruit extracts of *Asimina triloba* genotypes, they accumulated from 9.31 (AzTr-07) to 16.24 (AzTr-06) mg CAE/g DW, in flowers from 3.11 (AzTr-03) to 6.58 (AzTr-06) mg CAE/g DW (Figure 7).

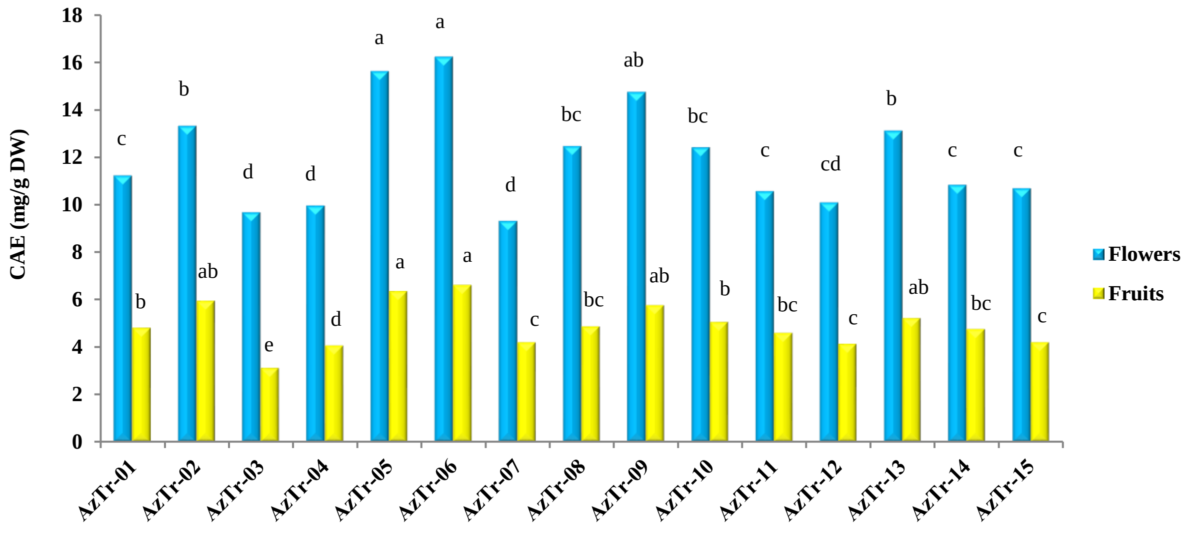

Figure 7 The total phenolic acid content in *Asimina triloba* (L.) Dunal. flowers and fruits (different superscripts in each column indicate the significant differences in the mean at p < 0.05); CAE – caffeic acid equivalent

We can compare our results with previous studies of *A. triloba* fruits. The TPC ranged from 22.13 to 37.36 mg GAE/g, TFC ranged from 15.10 to 32.03 mg QE/g, and phenolic acids content ranged from 0.23 to 0.76 mg CAE/g. All the tested samples exhibited DPPH radical scavenging activities with values from 2.84 to 7.04 mg TE/g. Antioxidant activity by the molybdenum-reducing antioxidant power method ranged from 97.25 to 275.41 mg TE/g of DW (**Brindza *et al.*, 2019**).

In their study, **Kobayashi *et al.* (2008)** measured the phenolic compound levels in *A. triloba* fruits at different ripening stages. The highest concentration was found in the puree of unripe fruits (123.06 mg GAE/100g FW), and the lowest in the puree of ripe fruits (98.42 mg GAE/100g FW).

Research on the phenolic profile is also valuable in lesser-known and underutilized species, which are significant for their potential in preventing various diseases. **Klymenko *et al.* (2019b)** determined antioxidant activity in *Chaenomeles japonica* fruits by using DPPH method in the interval 10.08 to 21.42 µMol Trolox/g , those obtained by ABTS method varied from 31.13 to 70.87 µMol Trolox/g, and those obtained by the FRAP method varied from 14.97 to 42.51 µMol Trolox/g. The results for total phenolic content varied from 162.46 to 408.09 mg GAE/100 g. The results for the total phenolic content of *Cornus mas* fruits by the same method varied from 91.34 to 289.79 mg GAE/100g (**Klymenko *et al.*, 2019a**). **Horčinová Sedláčková *et al.* (2021)** demonstrated in the fruits of *Chaenomeles speciosa* various contents of total polyphenols profile in methanolic extract (13 214.2 mg GAE/100g DW), ethanolic extract (782.8 mg/100g DW), acetone extract (685.8 mg GAE/100g DW), and in aqueous extract (591.6 mg GAE/100g DW). Fruits contained a high amount of flavonoids 480–11 680 mg GAE/100g DW, in aqueous and methanolic extracts, respectively.

There can be considerable variation in bioactive constituents and antioxidant activities among species, varieties, cultivars, and depending on the agro-ecological conditions in which they are grown (**Zhou *et al.*, 2011; Młynarczyk, 2020; Issaadi *et al.*, 2020**).

The results of bivariate correlation analysis for Pearson correlation coefficients are presented in Table 1.

Table 1 Results of bivariate correlation analysis for Pearson correlation coefficients

Content	Polyphenols	Phenolic acids	Flavonoids	DPPH	MRP
	Flowers				
Polyphenols	1				
Phenolic acids	0.646*	1			
Flavonoids	0.516*	0.756*	1		
DPPH	0.933**	0.804**	0.803**	1	
MRP	0.847**	0.910**	0.922**	0.888**	1
	Fruits				
Polyphenols	1				
Phenolic acids	0.662*	1			
Flavonoids	0.571*	0.733*	1		
DPPH	0.918**	0.810**	0.842**	1	
MRP	0.950**	0.942**	0.837**	0.861**	1

Legend: *Correlation significance at 0.05 level. **Correlation significance at 0.001 level.

The lowest correlation values between polyphenols and flavonoids were found in flowers and fruits (r = 0.516, r = 0.571, respectively) as well as between polyphenols and phenolic acids (r = 0.646, r = 0.662, respectively), but still, it can be considered moderate.

The highest value was obtained for the correlation between polyphenols and DPPH AOA (r = 0.966 in flowers) as well as between polyphenols and MRP AOA (r = 0.950 in fruits).

A strong correlation was observed between the DPPH and MRP antioxidant activities (r = 0.888 and r = 0.861, respectively, with significance at the 1% level), which is expected as both methods assess the same property, albeit using different approaches.

Furthermore, significant correlations were found between phenolic acids, flavonoids, and both AOA measurements, clearly indicating that phenolic compounds play a major role in the antioxidant activity of the analyzed flowers.

These findings indicate that the phenolic compounds in pawpaw flowers and fruits significantly influence their antioxidant capacity, as has been observed in other fruit and vegetable species (**Kobayashi *et al.*, 2008; Klymenko *et al.*, 2019b; Brindza *et al.*, 2019**).

CONCLUSION

This study demonstrated the high antioxidant potential of raw plant material, namely flowers and fruits, of fifteen *A. triloba* genotypes. The values of antioxidant activity depended on the investigated plant extracts and genotypes of *A. triloba*. The highest values of total polyphenol, flavonoid, and phenolic acid content, and antioxidant activities were determined in all the flower ethanolic extracts, except the flower extract AzTr-08 which demonstrated a slightly lower average value of FRSA compared with fruit extract. Our results suggest that strong antioxidant activity was correlated with total polyphenol, phenolic acid, and flavonoid content by both the DPPH method (r = 0.803–0.933) and molybdenum-reducing power of extracts (r = 0.837–0.950). A strong correlation was found also between FRSA and MRP of flower and fruit extracts (r = 0.888 and r= 0.861). Therefore, *A. triloba* genotypes can be regarded to be valuable sources of the plant raw material with a high content of antioxidants of a polyphenol nature. The data obtained can be useful for further investigations and the development of new functional food products.

Acknowledgments: This work was supported by the Bilateral Scholarship of the Ministry of Education, Science, Research and Sport (Slovak Republic), Visegrad Fund, and SAIA. Experimental activities were realized in the laboratories of the Centre of excellence for the conservation and use of agrobiodiversity at the Faculty of Agrobiology and Food Resources, Slovak Agricultural University in Nitra.

Conflicts of Interest: The authors declare no conflict of interest

REFERENCES

Alali, F. Q., Liu, X. X., & McLaughlin, J. L. (1999). Annonaceous acetogenins: recent progress. *Journal of Natural Products*, *62*(3), 504-540. https://doi.org/10.1021/np980406d

Arifkhodzhaev, H. A., Khamodkhodzhaev, S. A. & Shtonda, N. I. (1985). Polysaccharides of *Asimina triloba*. *Chemistry of Natural* Compounds, *21*, 661-662. https://doi.org/10.1007/BF00579075

Avula, B., Bae, J-Y., Majrashi, T., Wu, T-Y., Wang, Y-H., Wang, M., Ali, Z., Wu, Y-C., & Khan, I. A. (2018). Targeted and non-targeted analysis of annonaceous alkaloids and acetogenins from *Asimina* and *Annona* species using UHPLC-QToF-MS. *Journal of Pharmaceutical and Biomedical Analysis*, *159*, 548–566. https://doi.org/10.1016/j.jpba.2018.07.030

Ballard, C. R., & Maróstica Junior, M. R. (2019). Health benefits of flavonoids. 185-201. *Bioactive Compounds*, Elsevier Inc., https://doi.org/10.1016/B978-0-12-814774-0.00010-4

Bekir, J., Cazaux, S., Mars, M., & Bouajila, J. (2016). In vitro anti-cholinesterase and anti-hyperglycemic activities of flowers extracts from seven pomegranate varieties. *Industrial Crops and Products*, *81*, 176-179. https://doi.org/10.1016/j.indcrop.2015.11.066

Bose, M., Lambert, J. D., Ju, J., Reuhl, K. R., Shapses, S. A., & Yang, C. S. (2008). The major green tea polyphenol, (-)-epigallocatechin-3-gallate, inhibits obesity, metabolic syndrome, and fatty liver disease in high-fat–fed mice. *The Journal of Nutrition*, *138*(9), 1677-1683. https://doi.org/10.1093/jn/138.9.1677

Brannan, R. G., & Coyle, M. N. (2021). Worldwide introduction of North american pawpaw (*Asimina triloba*): Evidence based on scientific reports. *Sustainable Agriculture Research*, 10(3), 19-24. https://doi.org/10.5539/sar.v10n3p19

Brannan, R. G., Peters, T., Talcott, S.T. (2015). Phytochemical analysis of ten varieties of pawpaw (*Asimina triloba* [L.] Dunal) fruit pulp. *Food Chemistry*, *168*, 656-661. https://doi.org/10.1016/j.foodchem.2014.07.018

Brannan, R. G., Salabak, D. E., & Holben, D. H. (2012). Sensory analysis of pawpaw (*Asimina triloba*) pulp puree: Consumer appraisal and descriptive lexicon. *Journal of Food Research*, *1*(1), 179-192. https://doi.org/10.5539/jfr.v1n1p179

Brannan1, R. G., & Coyle, M. N. (2021). Worldwide introduction of north american pawpaw (*Asimina triloba*): Evidence based on scientific reports. *Sustainable Agriculture Research*, *10*(3), 19-24. https://doi.org/10.5539/sar.v10n3p19

Brindza, J., Grygorieva, O., Klymenko, S., Vergun, O., Mareček, J., & Ivanišová, E. (2019). Variation of fruits morphometric parameters and bioactive compounds of *Asimina triloba* (L.) Dunal germplasm collection. *Potravinarstvo Slovak Journal of Food Sciences*, *13*(1), 1-7. https://doi.org/10.5219/1019

Cavaiuolo, M., Cocetta, G., & Ferrante, A. (2013). The Antioxidants Changes in Ornamental Flowers during Development and Senescence. *Antioxidants (Basel, Switzerland)*, *2*(3), 132-155. https://doi.org/10.3390/antiox2030132

Coothankandaswamy, V., Liu, Y., Mao, S. C., Morgan, J. B., Mahdi, F., Jekabsons, M. B., Nagle, D. G., & Zhou, Y. D. (2010). The alternative medicine pawpaw and its acetogenin constituents suppress tumor angiogenesis via the HIF-1/VEGF pathway. *Journal of Natural Products*, *73*(5), 956-961. https://doi.org/10.1021/np100228d

Cotelle, N. 2001. Role of flavonoids in oxidative stress. *Current Topics in Medicinal Chemistry*, *1*(6), 569-590. https://doi.org/10.2174/1568026013394750

Cuendet, M., Oteham, C. P., Moon, R. C., Keller, W. J., Peaden, P. A., & Pezzuto, J. M. (2008). Dietary administration of *Asimina triloba* (Paw Paw) extract

increases tumorlatency in n.-methyl-n.-nitrosourea–treated rats. *Pharmaceutical Biology*, 46(1-2), 3-7. https://doi.org/10.1080/13880200701729497
Dilis, V., & Trichopoulou, A. (2010). Antioxidant intakes and food sources in Greek Aduls. *The Journal of Nutrition*, *140*(7), 1274-1279. https://doi.org/10.3945/jn.110.121848
Edwards, J. E., Brown, P. N., Talent, N., Dickinson, T. A., & Shipley, P. R. (2012). A review of the chemistry of the genus *Crataegus*. *Phytochemistry*, *79*, 5-26. https://doi.org/10.1016/j.phytochem.2012.04.006
Farag, M. A. (2009). Chemical composition and biological activities of *Asimina triloba* leaf essential oil. *Pharmaceutical Biology*, *47*(10), 982-986. https://doi.org/10.1080/13880200902967995
Farmakopea Polska. (1999). The Polish Farmaceutical Society. Available at: http://www.ptfarm.pl/?pid=1&language=en
Galli, F., Archbold, D. D., & Pomper, K. W. (2007). Pawpaw: An old fruit for new needs. *Acta Horticulturae, 744*, 461-466. https://doi.org/10.17660/ActaHortic.2007.744.56
García-Conesa, M.-T., & Larossa, M. (2020). Polyphenol-rich foods for human health and disease. *Nutrients*, *12*(400), 1-5. http://dx.doi.org/10.3390/nu12020400
Ghasemzadeh, A., & Ghasemzadeh, N. 2011. Flavonoids and phenolic acids: Role and biochemical activity in plants and human. *Journal of Medicinal Plants Research*, *5*(31), 6697-6703. https://doi.org/10.5897/JMPR11.1404
Godos, J., Caraci, F., Micek, A., Castellano, S., D'Amico, E., Paladino, N., … & Grosso, G. (2021). Dietary phenolic acids and their major food sources are associated with cognitive status in older Italian Adults. *Antioxidants*, 10(5), Special Issue *Dietary Antioxidants and Brain Health: Focus on Cognitive and Affective Disorders*, 700. https://doi.org/10.3390/antiox10050700
Goodrich, K. R., Zjhra, M. L., Ley, C. A., & Raguso, R. A. (2006). When flowers smell fermented: the chemistry and ontogenyof yeasty floral scent in pawpaw (*Asimina triloba*: Annonaceae). *International Journal of Plant Sciences*, *167*(1), 33-46. https://doi.org/10.1086/498351
Gu, Z-M., Zhou, D., Lewis, N. J., Wu, J., Johnson, H. A., McLaughlin, J. L., & Gordon, G. (1999). Quantitative evaluation of Annonaceous acetogenins in monthly samples of paw paw (*Asimina triloba*) twigs by liquid chromatography/electrospray ionization/tandem mass spectrometry. *Phytochemical analysis*, *10*, 32-38.
Guedes, M. M., Cunha, A. N., & Rao, V. S. (2002). Antinociceptive and gastroprotective effects of diterpenes from the flower buds of *Egletes viscosa*. *Planta Medica*, *68*(11), 1044-1046. https://doi.org/10.1055/s-2002-3566
Harris, G. G., & Brannan, R. G. (2009). A preliminary evaluation of antioxidant compounds, reducing potential, and radical scavenging of pawpaw (*Asimina tribloba*) fruit pulp from different stages of ripeness. *LWT-Food Science Technology*, *42*(1), 275-279. https://doi.org/10.1016/j.lwt.2008.05.006
Horčinová Sedláčková, V., Brindza, J., Maliniaková, P., Pancurák, F., & Grygorieva, O. (2022). Morphological and biochemical characteristics of plant parts *Mahonia aquifolium* (Pursh) Nutt. and some physical indicators of its extracts in activated water. *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *6*(1), 103-116. https://doi.org/10.15414/ainhlq.2022.0012
Horčinová Sedláčková, V., Mňahončáková, E., Klymenko, S. V., Brindza, J. 2021. Study of fruits polyphenols profile of Chaenomeles speciosa (sweet) Nakai. Globaľni naslidky introdukcij roslinv umavach klimatyčnych zmin: Kyiv, Vydavnyctvo Lira -K. 234 p. p. 182-183. ISBN 978-617-520-173-2.
Hui, C., Qi, X., Qianyong, Z., Xiaoli, P., Jundong, Z., & Mantian, M. (2013). Flavonoids, flavonoid subclasses and brest cancer risk: a meta-analysis of epidemiologic studies. *Plos One*, 8(1), e54318. https://doi.org/10.1371/journal.pone.0054318
Hui, Y. H., Rupprecht, J. K., Liu, Y. M., Anderson, J. E., Smith, D. L., Chang, C. J., & McLaughlin, J. L. (1989). Bullatacin and bullatacinone: Two highly potent bioactive acetogenins from *Annona bullata*. *Journal of Natural Products*, *52*, 463-477. https://doi.org/10.1021/np50063a002
Hwang, H. J., Park, H. J., Chung, H. J., Min, H. Y., Park, E. J., Hong, J. Y., & Lee, S. K. (2006). Inhibitory effects of caffeic acid phenethyl ester on cancer cell metastasis mediated by the down-regulation of matrix metalloproteinase expression in human HT1080 fibrosarcoma cells. *The Journal of Nutritional Biochemistry*, *17*(5), 356-362. https://doi.org/10.1016/j.jnutbio.2005.08.009
Issaadi, O., Fibiani, M., Picchi, V., Scalzo, R. L., & Madani, K. (2020). Phenolic composition and antioxidant capacity of hawthorn (*Crataegus oxyacantha* L.) flowers and fruits grown in Algeria. *Journal of Complementary and Integrative Medicine*, *17*(4). https://doi.org/10.1515/jcim-2018-0125
Ittagi, S., Merugumolu, V. K., & Siddamsetty, R. S. (2014). Cardioprotective effect of the hydroalcoholic extract of *Tecoma stans* flowers against isoproterenol-induced myocardial infarction in rats. *Asian Pacific Journal of Tropical Disease*, *4*(1), S378-S384. https://doi.org/10.1016/S2222-1808(14)60474-6
Janarny, G., Gunathilake, K. D. P. P., & Ranaweera, K. K. D. S. (2021). Nutraceutical potential of dietary phytochemicals in edible flowers – A review. Journal *of Food Biochemistry*, *45*(4). https://doi.org/10.1111/jfbc.13642
Khurana, S., Venkataraman, K., Hollingsworth, A., Piche, M., & Tai, T. (2013). Polyphenols: Benefits to the cardiovascular system in health and in aging. *Nutrients*, *5*(10), 3779-3827. https://doi.org/10.3390/nu5103779
Klymenko, S., Kucharska, A. Z., Sokół-Łętowska, A., & Piórecki, N. (2019a). Antioxidant activities and phenolic compounds in fruits of cultivars of cornelian cherry (*Cornus mas* L.). *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *3*(2019), 484-499. https://doi.org/10.15414/agrobiodiversity.2019.2585-8246.484-499
Klymenko, S., Kucharska, A. Z., Sokół-Łętowska, A., & Piórecki, N. (2019b). Determination of antioxidant capacity and polyphenols contents in fruits of genotypes of *Chaenomeles japonica* (Thunb.) Lindl. *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *3*(2019), 473-783. https://doi.org/10.15414/agrobiodiversity.2019.2585-8246.473-48
Ko, Y., Wu, T., Wu, Y., Chang, F., Guh, J., & Chuang, L. (2011). Annonacin induces cell cycle-dependent growth arrest and apoptosis in estrogen receptor-α-related pathways in MCF-7 cells. *Journal of Ethnopharmacology*, *137*(3), 1283-1290. https://doi.org/10.1016/j.jep.2011.07.056
Kobayashi, H., Wang, C., & Pomper, K. W. (2008). Phenolic content and antioxidant capacity of pawpaw fruit (*Asimina triloba* L.) at different ripening stages. *HortScience*, *43*(1), 268-270. https://doi.org/10.21273/HORTSCI.43.1.268
Kozłowska, A., & Szostak-Węgierek, D. (2014). Flavonoids – Food sources and health benefits. *Roczniki Państwowego Zakładu Higieny*, *65*(2), 79-85.
Layne, D. R. (1996). The pawpaw (*Asimina triloba* (L.) Dunal): A new fruit crop for Kentucky and the United States. *Horticultural Science*, *31*(5), 777-784. https://doi.org/10.21273/HORTSCI.31.5.777
Lee, M. H., Nam, T. G., Lee, I., Shin, E. J., Han, A. R., Lee, P., Lee, S. Y., & Lim, T. G. (2018). Skin anti-inflammatory activity of rose petal extract (Rosa gallica) through reduction of MAPK signaling pathway. *Food Science and Nutrition*, *6*, 2560-2567. https://doi.org/10.1002/fsn3.870
Levine, R. A., Richards, K. M., Tran, K., Luo, R., Thomas, A., & Smith, R. E. (2015). Determination of neurotoxic acetogenins in pawpaw (*Asimina triloba*) fruit by LC-HRMS. *Journal of Agricultural and Food Chemistry*, *63*, 1053-1056. https://doi.org/10.1021/jf504500g
Levon, V., & Klymenko, S. (2021). Content of anthocyanins and flavonols in the fruits of *Cornus* spp. *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *5*(1), 9-17. https://doi.org/10.15414/ainhlq.2021.0002
Lu, B., Li, M., Yin, R. (2016).. Phytochemical content, health benefits, and toxicology of common edible flowers: a review (2000-2015). *Critical Reviews in Food Science and Nutrition*, *56*(1), S130-S148. https://doi.org/10.1080/10408398.2015.1078276
Madlener, S., Illmer, C., Horvath, Z., Saiko, P., Losert, A., Herbacek, I., … & Bernhaus, A. (2007). Gallic acid inhibits ribonucleotide reductase and cyclooxygenases in human HL-60 promyelocytic leukemia cells. *Cancer Letters*, *245*(1-2), 156-162. https://doi.org/10.1016/j.canlet.2006.01.001
Majewska-Wierzbicka, M., & Czeczot, H. (2012). Flavonoids in the prevention and treatment of cardiovascular diseases. *Polski Merkuriusz Lekarski*, *32*(187), 50-54.
Mendelova, A., Mendel, Ľ., Solgajová, M., Kolesárová, A., Mareček, J., & Zeleňáková, L. (2022). Comparison of the influence of different fruit drying methods on the content of selected bioactive substances. *Journal of Microbiology, Biotechnology and Food Sciences*, *12*(Special issue), e9223. https://doi.org/10.55251/jmbfs.9223
Młynarczyk, K., Walkowiak-Tomczak, D., Staniek, H., Kidoń, M., & Łysiak, G. P. (2020). The content of selected minerals, bioactive compounds, and the antioxidant properties of the flowers and fruit of selected cultivars and wildly growing plants of *Sambucus nigra* L. *Molecules*, *25*(4), 876. https://doi.org/10.3390/molecules25040876
Mondal, S., & Rahaman, S. T. (2020). Flavonoids: A vital resource in healthcare and medicine. *Pharmacy & Pharmacology International Journal*, *8*(2), 91-104. https://doi.org/10.15406/ppij.2020.08.00285
Mrduljaš, N., Krešić, G., & Bilušić, T. (2017). *Polyphenols: Food Sources and Health Benefits*. In Hueda, M.C., (Ed.). (2017). Functional Food - Improve Health through Adequate Food. IntechOpen. https://doi.org/10.5772/66263
Nam, J. S., Jang, H. L., & Rhee, Y.H. (2017). Antioxidant activities and phenolic compounds of several tissues of pawpaw (*Asimina triloba* [L.] Dunal) grown in Korea. *Journal of Food Science*, *82*(8), 1827-1833. https://doi.org/10.1111/1750-3841.13806
Nam, J.-S., Park, S.-Y., Lee, S.-O., Lee, H.-J., Jang, H.-L., & Rhee, Y. H. (2021). The growth-inhibitory effects of pawpaw (*Asimina triloba* [L.] Dunal) roots, twigs, leaves, and fruit against human gastric (AGS) and cervical (HeLa) cancer cells and their anti-inflammatory activities. *Molecular Biology Reports*, *48*, 2173-2181. https://doi.org/10.1007/s11033-021-06226-y
Nam, J.-S., Park, S.-Y., Oh, H.-J., Jang, H.-L., & Rhee, Y. H. (2018). Phenolic profiles, antioxidant and antimicrobial activities of pawpaw pulp (*Asimina triloba*[L.] Dunal) at different ripening stages. *Journal of Food Science*, *84*(1), 174-182. https://doi.org/10.1111/1750-3841.14414
Nambirajan, G., Karunanidhi, K., Ganesan, A., Rajendran, R., Kandasamy, R., Elangovan, A., & Thilagar, S. (2018). Evaluation of antidiabetic activity of bud and flower of Avaram Senna (*Cassia auriculata* L.) in high-fat diet and streptozotocin-induced diabetic rats. *Biomedicine and Pharmacotherapy*, *108*, 1495-1506. https://doi.org/10.1016/j.biopha.2018.10.007
Ňorbová, M., Vollmannová, A., Pintér, E., Šnirc, M., Franková, H., Fedorková, S., & Čeryová, N. (2023). The content of vitamin c and antioxidant activity in less-

known types of fruit. *Journal of Microbiology, Biotechnology and Food Sciences*, *13*(1), e9937. https://doi.org/10.55251/jmbfs.9937
Pande, G., & Akoh, C. C. (2010). Organic acids, antioxidant capacity, phenolic content and lipid characterisation of Georgia-grown underutilized fruit crops. *Food Chemistry*, *120*(2), 1067-1075. https://doi.org/10.1016/j.foodchem.2009.11.054
Pires, T. C., Dias, M. I., Barros, L., Calhelha, R. C., Alves, M. J., Oliveira, M. B. P., Santos-Buelga, C., & Ferreira, I. C. (2018). Edible flowers as sources of phenolic compounds with bioactive potential. *Food Research International*, *105*, 580-588. https://doi.org/10.1016/j.foodres.2017.11.014
Prasad, K. N., Yang, B., Dong, X., Jiang, G., Zhang, H., Xie, H., & Jiang, Y. (2009). Flavonoid contents and antioxidant activities from *Cinnamomum* species. Innovative *Food* Science and Emerging Technologies, *10*(4), 627-32. https://doi.org/10.1016/j.ifset.2009.05.009
Prieto, P., Pinera, M., & Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of aphosphomolybdenumcomplex: Specific application to the determination of vitamin E. *Analytical Biochemistry*, 269(2), 334-337. https://doi.org/10.1006/abio.1999.4019
Rasouli, H., Farzaei, M. H., & Khodarahmi, R. (2017). Polyphenols and their benefits: A review. *International Journal of Food Properties*, *20*(2), S1700-S1741. https://doi.org/10.1080/10942912.2017.1354017
Ratnayake, S., Rupprecht, J. K., Potter, W. M., & McLaughlin, J. L. (1992). Evaluation of various parts of the paw paw tree, Asimina triloba(Annonaceae), as commercial sources of the pesticidal annonaceous acetogenins. *Journal of Economic Entomology*, *85*(6), 2353-2356. https://doi.org/10.1093/jee/85.6.2353
Rupprecht, J. K., Chang, C.-J., Caeeady, J. M., McLaughlin, J. L., Mikolajaak, J. L., & Weieleder, D. (1986). Asimicin, a new cytotoxicand pesticidical acetogenin from the pawpaw, *Asimina triloba* (Annonaceae). *Heterocycles*, *24*, 1197-1201. https://doi.org/10.3987/R-1986-05-1197
Sanches-Moreno, C., Larrauri, A., & Saura-Calixto, F. (1998). A procedure to measure the antioxidant efficiency of polyphenols. *Journal of Sciences and Food Agricultural*, *76*(2), 270-276. https://doi.org/10.1002/(SICI)1097-0010(199802)76:2<270::AID-JSFA945>3.0.CO;2-9
Shabrova, E. V., Tarnopolsky, O., Singh, A. P., Singh, A. P., Plutzky, J., Vorsa, N., & Quadro, L. (2011). Insights into the molecular mechanism of the anti-atherogenic actions of flavonoids in normal and obese mice. *Plos One*, *6*(10), e24634. https://doi.org/10.1371/journal.pone.0024634
Shafii, Z. A., Basri, M., Malek, E. A., & Ismail, M. (2017). Phytochemical and antioxidant properties of Manilkara zapota(L.) P roenfruit extracts and its formulations for cosmceueticalapplication. *Asian Journal of Plant Science and Research*, *7*(3), 29-41.
Shekhar, T. C., & Anju, G. (2014). Antioxidant activity by DPPH radical scavenging method of *Ageratum conyzoides* Linn. leaves. *American Journal of Ethnomedicine*, *1*(4), 244-249.
Sica, V. P., El-Elimata, T., & Oberlies, N. H. (2016). In situ analysis of Asimina triloba(paw paw) plant tissues for acetogenins via the droplet-liquid microjunction-surface sampling probe coupled to UHPLC-PDA-HRMS/MS. *Analytical Methods :Advancing Methods and Applications*, *8*(32), 6143-6149. https://doi.org/10.1039/C6AY01583B
Singhal, K. G., & Gupta, G. D. (2012). Hepatoprotective and antioxidant activity of methanolic extract of flowers of *Nerium oleander* against CCl 4-induced liver injury in rats. *Asian Pacific Journal of Tropical Medicine*, *5*, 677-685. https://doi.org/10.1016/S1995-7645(12)60106-0
Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Agricultural*, *6*, 144-158.
Solomon, S., Muruganantham, N., & Senthamilselvi, M. M. (2016). Anticancer activity of Abelmschus esculentus (flowers) against human liver cancer. *International Journal of Pharmacy and Biological Sciences*, *6*, 154–157. https://doi.org/10.21276/ijpbs.2016.6.3.18
Szot, I., Zhurba, M., & Klymenko, S. (2020). Pro-health and functional properties of Goji Berry (*Lycium* spp.). *Agrobiodiversity for Improving Nutrition, Health and Life Quality*, *4*, 134-145. https://doi.org/10.15414/agrobiodiversity.2020.2585-8246.134-145
Takahashi, J. A., Rezende, F. A. G. G., Moura, M. A. F., Dominguete, L. C. B., Sande, D. (2020). Edible flowers: Bioactive profile and its potential to be used in food development. *Food Research International*, *129*, 108868. https://doi.org/10.1016/j.foodres.2019.108868
Tomás-Barberán, F. A., & Espín, J. C. (2001). Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. *Journal of the Science of Food and Agriculture*, *81*(9), 853-876. https://doi.org/10.1002/jsfa.885
Tran, K., Ryan, S., McDonald, M., Thomas, A. L., Maia, J. G. S., & Smith, R. E. (2020). Annonacin and squamocin contents of pawpaw (*Asimina triloba*) and marolo (*Annona crassiflora*) fruits and atemoya (*A. squamosa* × *A. cherimola*) Seeds. *Biological Trace Element Research*, *199*, 2320-2329. https://doi.org/10.1007/s12011-020-02320-7
Tulowiecki, S. J. (2021). Modeling the geographic distribution of pawpaw (*Asimina triloba* [L.] Dunal) in a portion of its northern range limits, western New York State, USA. *Plant Ecology*, *222*, 193-208. https://doi.org/10.1007/s11258-020-01098-x
Visioli, F., Lastra, C. A. D. L., Andres-Lacueva, C., Aviram, M., Calhau, C., Cassano, A., D'Archivio, M., Faria, A., Favé, G., & Fogliano, V. (2011). Polyphenols and human health: A prospectus. *Critical Reviews in Food Science and Nutrition*, *51*(6), 524-546. https://doi.org/10.1080/10408391003698677
Wang, L., Lee, I., Zhang, S. M., Blumberg, J. B., Buring, J. E., & Sesso, H. D. (2009). Dietary intake of selected flavonols, flavones, and flavonoid-rich foods and risk of cancer in middle-aged and older women. *The American Journal of Clinical Nutrition*, *89*(3), 905-912. https://doi.org/10.3945/ajcn.2008.26913
Wilczyńska, A., & Retel, M. (2011). Evaluation of polyphenol dietary intake considering participation of honey. *Problemy Higieny i Epidemiologii*, *92*(4), 709-712.
Woo, M. H., Cho, K. Y., Zhang, Y., Zeng, L., Gu, Z.-M., & McLaughlin, J. L. (1995). Asimilobin and cis- and trans-murisolinones, novel bioactive annonaceous acetogenins from the seeds of *Asimina triloba*. *Journal of Natural Products*, *58*(10), 1533-1542. https://doi.org/10.1021/np50124a009
Wood, R., & Peterson, S. (1999). Lipids of the pawpaw fruit: *Asimina triloba* . *Lipids*, (34), 1099-1106. https://doi.org/10.1007/s11745-999-0461-x
Yang, C. S., Chung, J. Y., Yang, G.-Y., Chhabra, S. K., & Lee, M.-J. (2000). Tea and tea polyphenols in cancer prevention. *The Journal of Nutrition*, *130*(2), 472S-478S. https://doi.org/10.1093/jn/130.2.472S
Zamora-Ros, R., Andres-Lacueva, C., Lamuela-Raventos, R., Berenguer, T., Jakszyn, P., Barricarte, A., ... & Gonzalez, C.A. (2010). Estimation of dietetary sources and flavonoid intake in Spanish adult population (EPIC-Spain). *Journal of the American Dietetic Association*, *110*(3), 390-398. https://doi.org/10.1016/j.jada.2009.11.024
Zhao, G. X., Miesbauer, L. R., Smith, D. L., & McLaughlin, J. L. (1994). Asimin, asiminacin, and asiminecin: Novel highly cytotoxic asimicin isomers from *Asimina triloba*. *Journal of Medicinal Chemistry*, *37*(13), 1971-1976. https://doi.org/10.1021/jm00039a009
Zhao, G., Hui, Y., Rupprecht, J. K., McLaughlin, J. L., & Wood, K. V. (1992). Additional bioactive compounds and trilobacin, a novel highly cytotoxic acetogenin, from the bark of *Asimina triloba*. *Journal of Natural Products*, *55*, 347-356. https://doi.org/10.1021/np50081a011
Zheng, J., Meenu, M., & Xu, B. (2019). A systematic investigation on free phenolic acids and flavonoids profiles of commonly consumed edible flowers in China. *Journal of Pharmaceutil and Biomedical Analysis*, 172, 268-277. https://doi.org/10.1016/j.jpba.2019.05.007
Zhou, C., Sun, C., Chen, K., & Li, X. (2011). Flavonoids, phenolics, and antioxidant capacity in the flower of *Eriobotrya japonica* Lindl. *International journal of molecular sciences*, *12*(5), 2935-2945. https://doi.org/10.3390/ijms12052935
Zhurba, M., Vergun, O., Klymenko, S., & Szot, I. (2021). Biochemical characterization of fruits of *Lycium* spp. in Ukraine. *Regulatory Mechanisms in Biosystems*, *12*(1), 71-77. https://doi.org/10.15421/022111