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Quality assessment of elderberry (*Sambucus nigra* L.) jams

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Abstract: Elderberries belong to the spontaneous flora of *Sambucus nigra* L., being considered wild fruits and even improper to be consumed. Dark violet-black and slightly glossy elderberry fruits are rich in bioactive compounds such as agglutinin, total anthocyanins and polyphenols. The importance of heating is claimed by the seasonal and toxic specific elderberry fruits. Moreover, the need to transform the fruits from not suitable for consumption into functional products and to prolong the shelf life of the product should be highlighted. Based on these affirmations, the aim of the study was to preserve the elderberries as jam with or without refined sugar. Phytochemical, textural, colour and sensory analyses were used to characterize three samples of jams (one without sugar, one with refined sugar and one with stevia sugar). The samples with stevia sweetener addition showed the highest values of anthocyanins (1.43 ± 0.16 mg·g^{-1} dry matter, DM) among the processed samples; as for the raw fruits, the anthocyanin content showed a decrease. The antioxidant activity determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay revealed similar values between all the analysed elderberry jams. In accordance with the other results, the most appreciated sample by the sensory evaluation was the sample with stevia sweetener. As a conclusion, the total sugar substitution could contribute to a more valuable matrix than the original one. The novelty of the study consists in the use of such popular spontaneous flora of *Sambucus nigra* L. berries and in a change of the inedible character of the raw fruits into edible functional foods with a prolonged shelf-life.

Keywords: berries; sugar; stevia sweetener; phytochemicals; texture; colour

Elderberry (*Sambucus nigra* L.) is a plant belonging to the family *Adoxaceae*, widespread in subtropical and temperate areas, in Europe, North Africa, North America and some parts of Asia. Generally, it can be found in the spontaneous flora but there are also countries that cultivate this valuable plant (Domínguez et al. 2020; Zhou et al. 2020). Its flowers and berries have been used for centuries in traditional medicine for the prevention and treatment of common cold or upper respiratory infections, diabetes, obesity, constipation, haemorrhoids, skin rashes and many others (Sidor and Gramza-Michałowska 2015; Caruso et al. 2019; Goud and Prasad 2019; Schön et al. 2021).

Recent studies have shown that elderberry extract exhibits antiviral and immunomodulatory properties (Schön et al. 2021). The healing potential of elderberries is due to the multitude of functional compounds like the phenolic ones: anthocyanins (mainly cyanidin-3-sambubioside and cyanidin-3-glucoside), quercetins (mainly quercetin-3-O-rufinamide and isoquercitrin), phenolic acids (chlorogenic acid, sinapic acid and t-cinnamic acid), to mention just a few of them (Młynarczyk et al. 2018; Caruso et al. 2019; Natić et al. 2019; Vujanović et al. 2020; Pascariu and Israel-Roming 2022; Terzić et al. 2023). Their concentrations depend on the growing and harvesting conditions, fruit maturity, and post-harvest processing. Despite being highly

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valuable in functional compounds, elderberries are well known for their potential toxicity owned to cyanogenic glycosides such as sambunigrin and prunasin, zierin and holocain as well as lectins (Młynarczyk et al. 2018; Pascariu and Israel-Roming 2022), especially in immature, unripe fruits. These compounds are temperature sensitive and thermal processing leads to their degradation (Sidor and Gramza-Michałowska 2015; Młynarczyk et al. 2018); thus, jam manufacturing represents a proper preservation method and a solution to reduce toxicity.

Traditionally, jam manufacturing involves the use of refined sugar in high quantities to increase the total solids in the final product, to create a specific texture and to enhance the taste when the fruits are rich in organic acids. Considering the negative effect of sugar intake on human health and the World Health Organization's (WHO) recommendations to reduce sugar intake, several sweeteners are used to partially or totally replace sugar in foods. Such a sweetener is stevia which contains steviol diterpene glycosides, with sweet taste and antidiabetic, antihypertensive, antitumor, anticarcinogenic, anti-inflammatory and bactericidal effects (Peteliuk et al. 2021).

Although elderberries are mentioned as raw materials for jam manufacturing, in literature there is a lack of studies regarding elderberry jam. A few studies published in 2018 were focused on the use of elderberries in low-sugar cherry jams (Banaś and Korus 2018), sour cherry jams with various plant additives (Banaś et al. 2018a), low-sugar gooseberry jams enriched with plant ingredients (Banaś et al. 2018b) and low-sugar jams with plant raw materials (Banaś et al. 2018c). They presented the advanced phytochemical characterization of samples, antioxidant activity, as well as complex sensory and physicochemical analysis in terms of colour and texture, but in all of them the elderberries were mentioned as plant additives. The use of elderberries as the main raw material was mentioned by Negomireanu and Miscă (2018), who described the technological process, taste, physicochemical and microbiological characteristics.

The objective of the present study is to obtain and characterize a low-sugar elderberry jam. To achieve this purpose stevia was used as a replacer of sugar. The obtained samples were subjected to the phytochemical characterization related to antioxidant activity, instrumental colour and textural and sensory analysis. The original contribution is related to the revaluation of a local spontaneous and cheap, but rich in bioactive compounds raw material, as well as the complex characterization of the final products.

MATERIAL AND METHODS

Material

The experimental material included elderberries from the spontaneous flora of *Sambucus nigra* L. from Galati city, Romania, cane sugar (Sanovita, Vâlcea România) and stevia sweetener (Nutrivita, Ilfov România).

Elderberry processing

Almost 2.5 kg of elderberry infructescences was collected from a wild tree of *Sambucus nigra* L. at an optimal state of ripeness in August 2021. The maturity stage was determined according to the external fruit colour and the high percentage (more than 75%) of fully coloured berries in the infructescence.

The elderberries were separated into berries and clusters in order to facilitate the jam manufacturing process, then they were washed with water and after that they were frozen at –18 °C.

Jam making (preparation of samples without and with cane sugar or stevia sweetener)

The elderberries were processed in order to be more suitable for consumption and to avoid any possible gastrointestinal disorders generated by the cyanogenic glycosides, which are denatured during the thermal processing (Senica et al. 2016). The applied heat treatments will assure a decrease of these harmful compounds to an acceptable level (0.04–1.2 $mg \cdot g^{-1}$) (Bolarinwa et al. 2014).

The elderberries were processed without any addition, which was considered the control sample; with cane sugar at a ratio of 2:1 m/m or with stevia sweetener with a sweetening power of 1:8 m/m, used as a sugar replacer in equivalence with the sugar ratio. The heat treatment (96 °C per 10' for the control sample, 100 °C per 20' for the samples with sugar and 96 °C per 11' for the samples with stevia sweetener) of the elderberry jams was performed using a MultiCooker pot Phillips HD 3037/70, 980W, 5L (Phillips, The Netherlands). All the samples were obtained in triplicate.

The heat treatment parameters are influenced by different types of sugar addition, osmotic processes and evaporation of the water content, which leads to the jam structure formation. We also take into consideration the dry matter of the jams to sufficiently satisfy the general jam condition – 'sheet' test. Moreover, when neither pectin nor other gelling agents were added, only the classical evaporation will contribute to the jam making process, so the parameter differences are expectable.

Figure 1 presents a detailed scheme for the conceptualization of the elderberry jam making and characterization.

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The sample designation is as follows: FS – raw elderberries, DM – elderberry jam without any addition, DZ – elderberry jam with sugar addition, DS – elderberry jam with stevia sweetener addition.

Chemicals and reagents

2,2-diphenyl-1-picrylhydrazyl (DPPH), potassium persulfate, Folin-Ciocalteu reagent, gallic acid 99.5% purity, sodium carbonate 20%, quercetin 98% purity, sodium nitrite 5%, aluminium chloride 10%, sodium hydroxide 1M, and (-)-catechin 98% purity were all purchased from Sigma-Aldrich (Germany). All the chemicals and reagents were of analytical purity.

Determination of elderberry jam physicochemical composition

The moisture, fat and carbohydrate contents were determined by using the standard official methods of the Association of Official Analytical Chemists (AOAC), whereas the Kjeldahl method was used to determine the protein content.

The moisture content was determined by measuring the loss in the weight of the sample on heating using an MRS 120-3 Moisture Analyzer (Kern, Balingen, Germany), until the samples reached the constant mass.

The total dry matter used as a basis for reporting the phytochemical analysis was determined by calculation pointing out the difference after subtracting the moisture content from the material.

Preparation of extracts from elderberry fruits and jams

The sample preparation for the phytochemical analysis consisted of 1 g of jam samples and 7 mL of 70% ethanol$^{(aq)}$ and HCl 1 N (ratio 9:1, *v/v*) mixed at 30 °C for 1 h in an ultrasound water bath (MRC Scientific Instruments, UK). The extracts were centrifuged at 7 000 × *g* for 10 min at 4 °C.

The main compounds with bioactive potential (total phenols, total flavonoids and anthocyanins) were extracted from the samples using the method described by Nistor et al. (2020). All the assays were performed in triplicate.

All the samples were dried using a moisture analyser (Kern MRS 120-3, Kern & Sohn GmbH, Germany) in order to use the values of dry mass in the calculation formula.

2,2-diphenyl-1-picrylhydrazyl scavenging activity

The antioxidant activity of the samples was determined using the DPPH assay as it was detailed by Nistor et al. (2020). Therefore, 100 µL of elderberry jam extract was mixed in triplicate with 3.0 mL of a DPPH work solution in absolute methanol. The mixture was incubated for 120 minutes in the dark at room temperature, then the absorbance was measured at 515 nm against absolute methanol. For the control sample, 100 µL of elderberry jam extract was replaced with 100 µL of absolute methanol. The experiments were performed in triplicate.

$$\text{DPPH inhibition (\%)} = \frac{A_0 - A_1}{A_0 \times 100} \qquad (1)$$

where: DPPH – 2,2-diphenyl-1-picrylhydrazyl; A_0 – the absorbance of the control; A_1 – the absorbance of the standard.

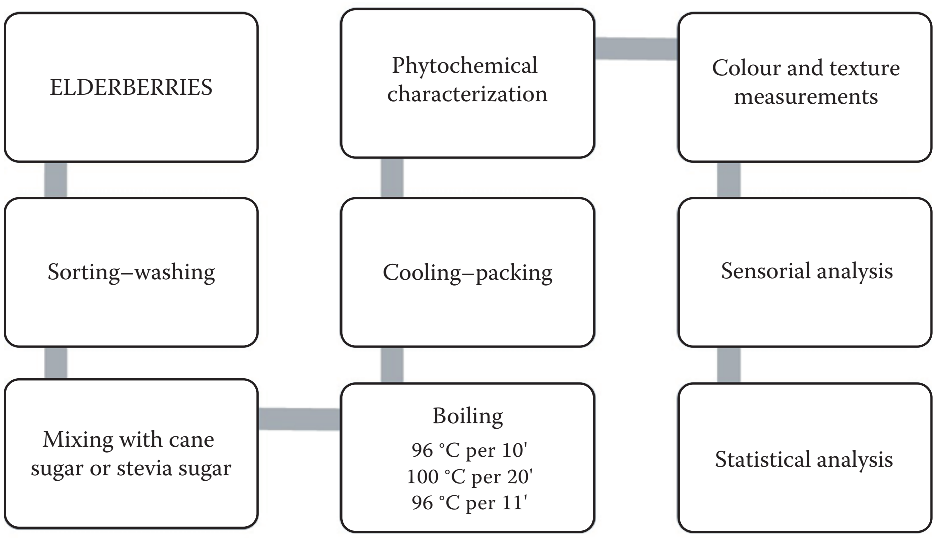

Figure 1. Scheme of elderberry jam making and characterization

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Determination of the total phenolic content of elderberries and elderberry jams

The total phenolic content (TPC) of elderberries and jams was determined using the Folin-Ciocalteu method according to Singleton et al. (Singleton et al. 1999) with some modifications. Thereby, 500 µL of the extract from each sample was introduced into test tubes and mixed with 2.5 mL of tenfold diluted Folin-Ciocalteu reagent and 2 mL of 7.5% sodium carbonate. To ensure the darkness, the tubes were covered with aluminium foil and kept for 30 min at room temperature before the absorbance was measured at 765 nm using a UV-Vis spectrophotometer (Biochrom Libra S22 UV/Vis, UK). Each assay was performed in triplicate. The results were expressed as milligrams of gallic acid equivalent per gram of dry mass (mg GAE·g^{-1} DM, GAE – gallic acid equivalents, DM – dry matter).

Determination of the total flavonoid content of elderberries and elderberry jams

Total flavonoid content (TFC) was determined according to the method presented by Butnariu et al. (2022). An amount of 0.250 mL of ethanolic extract solution was mixed with 0.075 mL of sodium nitrite solution (5% $NaNO_2$ in distilled water). Then, the samples were left for 5 min at room temperature, followed by the addition of 150 µL of 10% $AlCl_3$. The test tubes were vortexed and incubated for 6 min at room temperature. Afterwards, 0.5 mL of sodium hydroxide (1 N NaOH) was added. The volume of the mixture was diluted with 0.775 mL of distilled water. The tubes were mixed and then incubated for 15 min. After incubation, the absorbance was measured by a spectrophotometer at 510 nm. Catechin was used for the preparation of the standard curve. Flavonoid content was expressed as catechin equivalents (mg CE·g^{-1} DM, CE – catechin equivalents).

Total monomeric anthocyanin content

Total monomeric anthocyanin content (TAC) was determined using the pH differential method, as explained by Giusti and Worsltad (2001). An aliquot of 0.2 mL of the supernatant was added to 0.8 mL of buffers with pH 1.0 and 4.5, respectively, followed by absorbance measuring (Biochrom Libra S22 UV/Vis, Biochrom Ltd.) at 520 and 700 nm, respectively. TAC content was calculated using Equation 1 and expressed as milligrams of cyanidin-3-O-glucoside equivalents per g of dry mass (mg C_3G·g^{-1} DM) (Equtation 2).

$$\text{TAC} = \frac{[(A_{500\,pH_1}) - (A_{500\,pH_{4.5}} - A_{700\,pH_{4.5}})]}{\varepsilon \times L} \times M_m \times \frac{m}{V} \times D \quad (2)$$

where: TAC – total monomeric anthocyanin content (mg C3G·g^{-1} DM); ε –the molar extinction coefficient for C_3G of 26 900 L·mol^{-1}·cm^{-1}; L – cell path length (1 cm); M_m – molecular mass of C_3G (449.2 Da), D – dilution factor; V – final volume (mL); m – sample mass in dry mass (g).

Colour evaluation of elderberry jams

The colour parameters of the jams were determined using a colorimeter (NR110 3nh, Shenzhen 3nh Technology, China). L^* (lightness/darkness), a^* (red/green) and b^* (yellow/blue) parameters were measured. Three replicates were carried out for each sample.

The total colour difference (ΔE) between samples was calculated according to the equation:

$$\Delta E = \sqrt{(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2} \quad (3)$$

where: ΔE – total colour difference; L_0^* – lightness/darkness parameters of blank sample (fresh elderberries); a_0^* – red/green parameters of blank sample (fresh elderberries); b_0^* – yellow/blue parameters of blank sample (fresh elderberries); L^* – lightness/darkness parameters of analysed samples; a^* – red/green parameters of analysed samples; b^* – yellow/blue parameters of analysed samples.

Textural analysis of elderberry jams

The texture of elderberry jams was analysed with a Brookfield CT3 Texture Analyzer (AMETEK Brookfield, U.K.), using the Texture Profile Analysis (TPA) method. This implied a double penetration of the samples, packed into cylindrical containers (43 mm diameter, 30 mm height), with a 12.7 mm diameter acrylic probe. The test speed was set at 1 mm/s, the trigger load was 0.067 N, the penetration depth of the probe was 10 mm and the load cell was 1 000 g. The texture parameters (firmness, adhesiveness, cohesiveness, springiness and gumminess) were determined from the force-deformation curve using the TexturePro CT V1.5 software. Five tests were applied for each sample and the results are presented as their mean.

Sensory analysis of elderberry jams

The sensory analysis was carried out according to the method of Kavaya et al. (2019) with some adaptation. Twenty panellists were used for the study. A 9-point hedonic scale (where 9-like extremely,

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while 1-dislike extremely) was used to assess different attributes (smooth aspect, specific taste, specific colour, consistency, adhesiveness, flavour, texture, aroma, spreadability and acceptability) of elderberry fruit jams.

Statistical analysis

Three samples per treatment were analysed and data are reported as the mean and standard deviation (SD). To determine the effect of processing or of the type of sugar addition on the studied samples, a one-way analysis of variance (ANOVA) was performed.

The statistical analysis was carried out using the Minitab 19 statistical software (free trial).

The experimental design and statistical analysis were performed using CurveExpert Professional 2.7.3 (Daniel G. Hyams) for curve fitting and data analysis (Grández-Yoplac et al. 2021; Rojas-Ocampo et al. 2021). CurveExpert Professional is a cross-platform solution for curve fitting and data analysis. Data can be modelled using a toolbox of linear regression models, nonlinear regression models, smoothing methods, or various kinds of splines. Data were modelled using a toolbox of linear regression models and nonlinear regression models. The software has generated 30 models. The best model was chosen according to correlation coefficient (R), standard error, coefficient of determination (R^2), sum of squares, F-tests, Akaike Information Criterion Test (AICC) and residual plots.

CurveExpert Professional 2.7.3 software was used to analyse the correlation between dry matter content, total phenolic content, total flavonoid content, total anthocyanins and DPPH inhibition values.

RESULTS AND DISCUSSION

The composition of elderberry jams

The jams were characterized by the physicochemical composition as it follows: fat, carbohydrate, protein and dry matter content.

Antioxidant activity and bioactive compounds

The inhibition of 2,2-diphenyl-1-picrylhydrazyl radical. The DPPH scavenging activity illustrated in Figure 2 was measured for the raw sample representing the elderberries and for the jam samples after a day from the initial processing. The values of the DPPH inhibition do not differ significantly between the analysed elderberry jams, ranging from 80.96 ÷ 82.61%. This could be related to the fact that the thermal treatment does not affect the native bioactive compounds of elderberries. Moreover, the samples with the highest inhibition percentage correspond to those that contain the highest levels of phytochemicals, especially total anthocyanins (Pliszka et al. 2005). The sample with stevia sweetener addition showed the highest value (82.61%) of the DPPH inhibition in accordance with Seo et al. (2016).

Berry jams with low-sugar content were found to be effective antioxidants in the radical-scavenging assays comparable with the results reported by Rababah et al. (2011) for several other types of berry jams.

In Table 2 are presented the results of the phytochemical analysis for the raw elderberries (FS) and the processed samples (DM, DZ and DS). As expected, the raw fruits showed the highest values for the analysed phytochemicals. The TPC results for the raw material are comparable with those reported by Gomez Mattson et al. (2021).

As could be seen, the thermal treatment decreased TPC, TFC and total anthocyanins for all the samples. Congruent findings were reported by Levaj et al. (2012) for strawberry jam and by Banaś et al. (2018c) for gooseberry jam. All the results are correlated among themselves.

Processing of elderberry fruits induces changes in the composition of polyphenols, similarly like blanching generally reduces the polyphenol content according to Sidor and Gramza-Michałowska (2015).

Even like this, the DM and the DS sample had the highest total anthocyanin content (1.40 ± 0.08 mg·g^{-1}

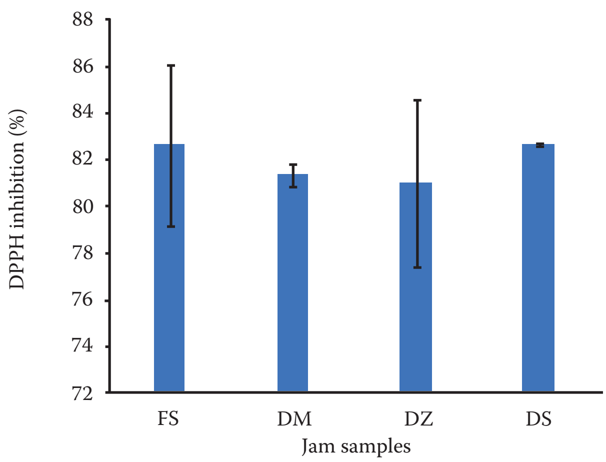

Figure 2. The inhibition of DPPH radical

The values for the antioxidant activity are the average of 3 consecutive determinations; DPPH – 2,2-diphenyl-1-picrylhydrazyl; FS – raw elderberries; DM – the sample of jam without any addition; DZ – elderberry jam with sugar addition; DS – elderberry jam with stevia sweetener addition

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Table 2. Total phenolic, total flavonoid and total anthocyanin contents in raw elderberries and elderberry jams

Samples	Total phenolic content (mg GAE·g^{-1} DM)	Total flavonoids content (mg QE·g^{-1} DM)	Total anthocyanins (mg·g^{-1} DM)
FS	32.78 ± 0.33^{a}	24.00 ± 0.28^{a}	2.55 ± 0.20^{a}
DM	14.88 ± 0.71^{b}	7.92 ± 0.20^{c}	1.40 ± 0.08^{b}
DZ	9.70 ± 0.33^{c}	7.11 ± 0.11^{c}	0.97 ± 0.13^{c}
DS	15.97 ± 0.90^{b}	10.28 ± 0.28^{b}	1.43 ± 0.16^{b}

The averages of three determinations for each phytochemical content with different superscripts (a–c) indicates that the values are statistically significantly different ($P > 0.05$); FS – raw elderberries; DM – the sample of jam without any addition; DZ – elderberry jam with sugar addition; DS – elderberry jam with stevia sweetener addition; GAE – gallic acid equivalents; DM – dry matter; QE – quercetin equivalents

DM and 1.43 ± 0.16 mg·g^{-1} DM). The total anthocyanin level was decreased by the thermal treatment, and it was also influenced by the sugar addition type. This statement is correlated with the conclusion of another study of Cejpek et al. (2009) on elderberry spread, where the chlorogenic acid group was diminished by almost 40%.

The highest values of TFC (10.28 ± 0.28 mg QE·g^{-1} DM, QE – quercetin equivalents) and TPC (15.97 ± 0.9 mg GAE·g^{-1} DM) shown by the DS sample could be attributed to the beneficial properties of steviol glycoside and its capacity to maintain the other native properties of the elderberries. The results are in accordance with the findings of Bender et al. (2015), who highlighted the antioxidant activity of *Stevia rebaudiana* using cellular approaches.

Figure 3 represents the main colour parameters of the analysed samples to explain the possible changes induced by the type of sugar addition or by the thermal processing.

The *L** parameter fluctuated between 11.89 and 14.46, which indicates the lightness of the samples. No significant differences in lightness were obtained between the samples with sugar and stevia addition.

The evaluation of the *b** parameter shows values within the range of yellow coloration (12.64–21.87) similar to Banaś et al. (2018b). The less yellow colour was found in jams with sugar or stevia sweetener addition (a decrease in *b** parameter values) when compared to the control sample, which is expected due to the primary colour of red-blue substances.

A slightly increase in redness compared to DM was determined for the DZ and DS samples. The DS sample showed the highest value (8.70) for *a** parameter due to the protective effect of steviol glycosides on total anthocyanins.

In summary, the colour of elderberry jams varied depending on the sugar or stevia sweetener content and the thermal treatment. On the other hand, the preservation method does not significantly ($P = 0.999$) influence the brightness of the samples.

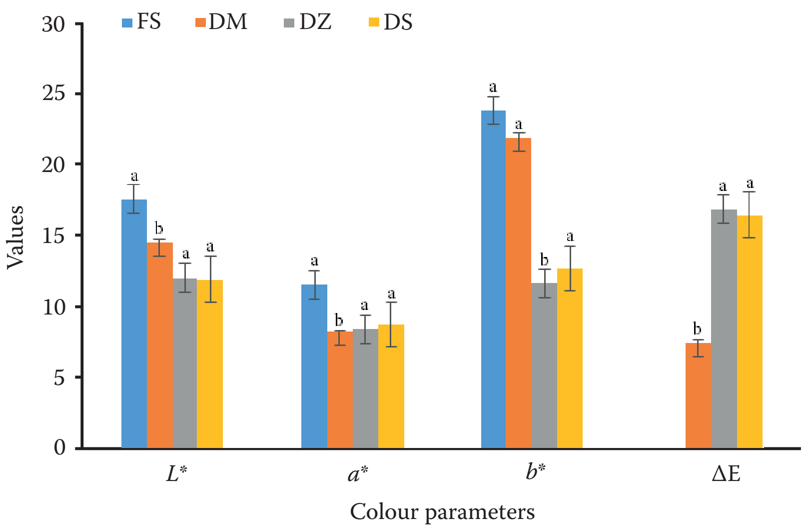

Figure 3. Colour parameters of elderberry jams

The values for the colour parameters are the average of 3 determinations; the presence of a and b means significant statistical differences between the tested samples in the colour parameters; *L** – lightness/darkness; *a** – red/green; *b** – yellow/blue; ΔE – total colour difference; FS – raw elderberries; DM – the sample of jam without any addition; DZ – elderberry jam with sugar addition; DS – elderberry jam with stevia sweetener addition.

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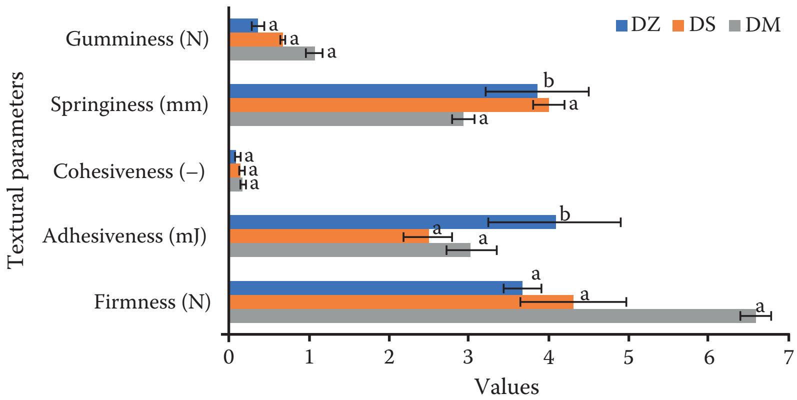

Figure 4. Textural profile analysis of elderberry jams

DZ – elderberry jam with sugar addition; DS – elderberry jam with stevia sweetener addition; DM – the sample of jam without any addition

Textural profile analysis of elderberry jams

The textural analysis represents an important part of consumer acceptance. Thus, the complete evaluation of textural parameters was extremely necessary.

As could be observed from Figure 4, the sugar and stevia sweetener additions influenced the textural parameters of the samples. Firmness ranged between 3.66 and 6.59 N, the highest values being registered for the control sample. This result could be explained by the absence of sugar which inhibited the water expulsion from the fruits during the thermal treatment. Thus, the fruits remained unbroken, and the force required to penetrate the sample during testing was higher for the DM sample compared to the others. Contrarily, sugar contributed to the fruit tissue disruption proportionally to the added amount, so the lowest firmness was found for the DZ sample. The firmness values for jam samples are comparable with those presented in the literature (Banaś et al. 2018a, b). The same tendency could be observed for gumminess and cohesiveness. The sugar addition resulted in an increase in the energy required for the probe retraction from the sample during the textural test. This behaviour explains the highest adhesiveness value of the DZ sample (4.08 mJ). The most elastic structure was achieved by the sample in which a part of sugar was replaced with stevia (4 mm springiness).

Sensory analysis of elderberry jams

These attributes were determined based on the opinion of 20 panellists. The most appreciated sample was the DS sample, but the other ones were not less appreciated.

The low-sugar jams with steviol glycosides were rated higher by the panellists who limit or do not limit sugar consumption (Figure 5).

The panellists identified the samples without any sugar addition (DM) maybe due to the more astrin-

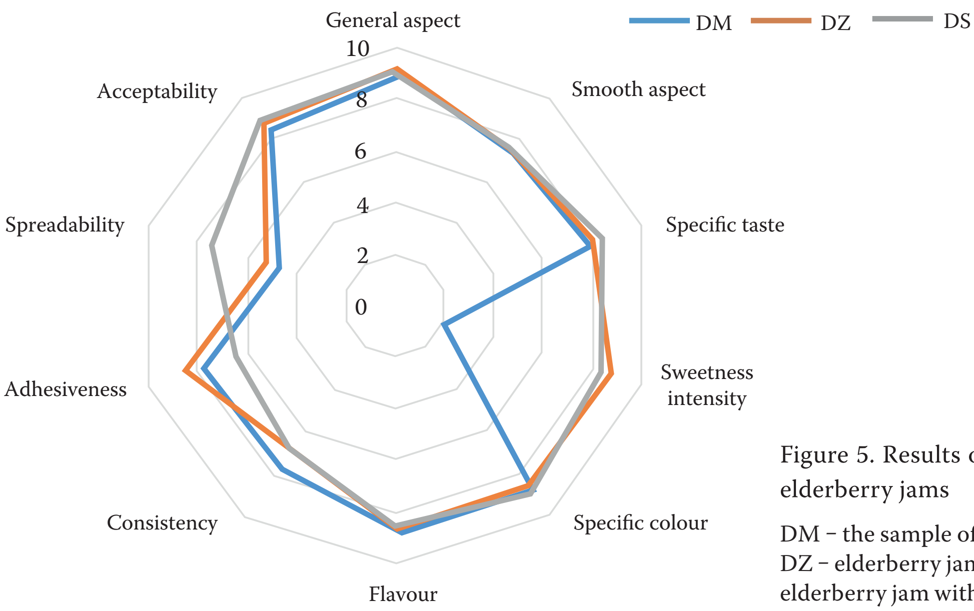

Figure 5. Results of the sensory analysis of elderberry jams

DM – the sample of jam without any addition; DZ – elderberry jam with sugar addition; DS – elderberry jam with stevia sweetener addition

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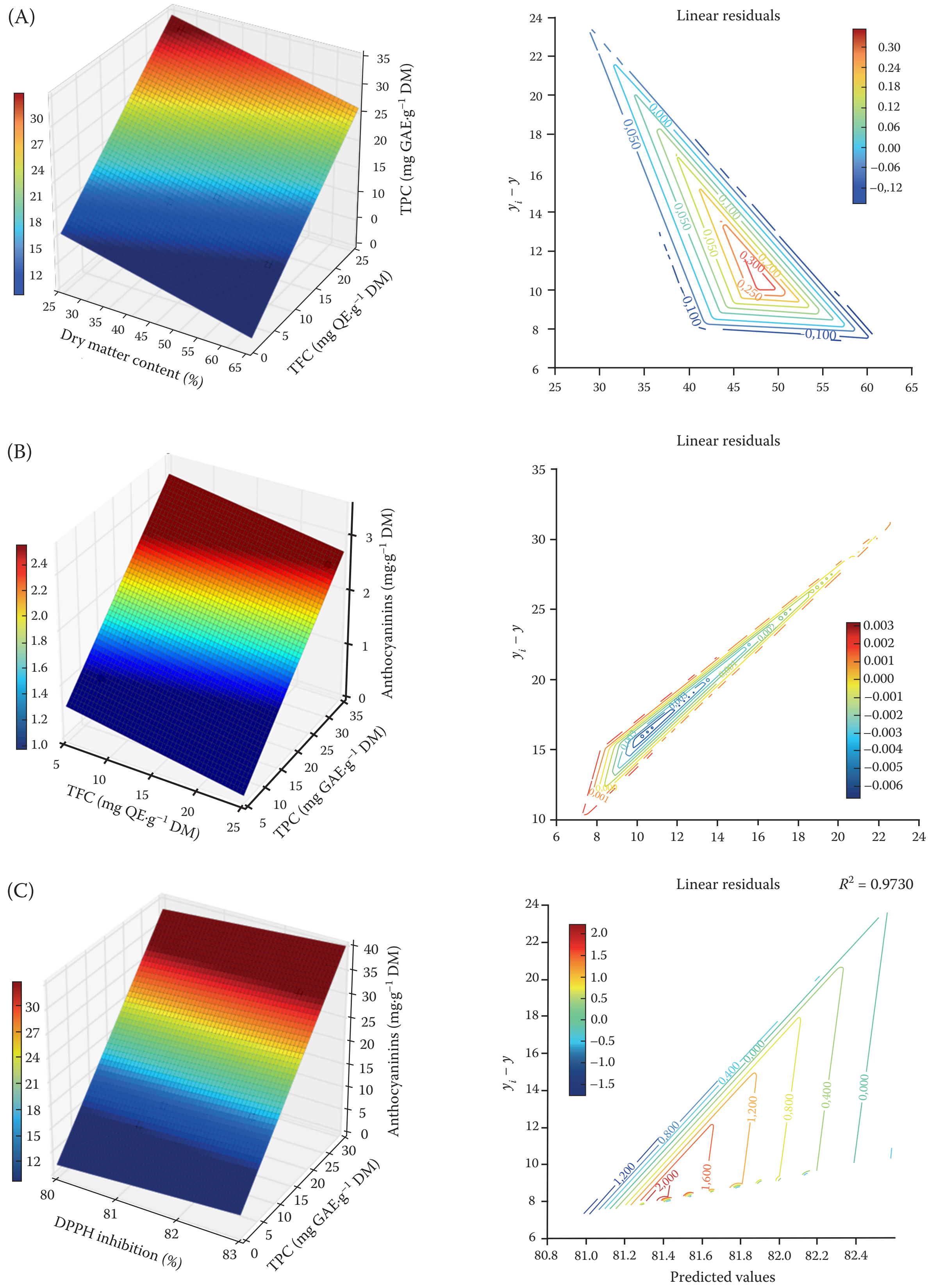

Figure 6. Data analysis of interdependence of TPC, TFC, and DPPH values

TPC – total phenolic content; DPPH – 2,2-diphenyl-1-picrylhydrazyl; TFC – total flavonoid content

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gent taste of the sample. When talking about the textural parameters evaluated by the panellists, the lowest values of consistency (6.88 ± 0.32) and adhesiveness (6.33 ± 0.25) were attributed to the DS sample, which was expected because the sweeteners could successfully replace sugar but not compete with the gelling properties. These findings are in accordance with those published by Pielak et al. (2020), who considered that these aspects were not at an acceptable level regarding the consumer's opinion, which may be due to the apple matrix which does not have the same properties as the elderberries. Therefore, the approach could be a special idea to design a new product.

Statistical analysis of data

In Figure 6, the empirical results of TPC, DPPH, TFC, total anthocyanin content and dry matter are graphically represented, namely the correlations between them. The purpose of this modelling is to demonstrate the interdependence between data.

A linear regression ($y = a + bX1 + cX2$) design was selected to evaluate the correlation between five independent variables (combined in 3 sets of dependent and independent variables): dry matter content, total phenolic content, total flavonoid content [dataset (a)], total anthocyanin content, total phenolic content, total flavonoid content [dataset (b)], and antioxidant activity, total phenolic content, total flavonoid content [dataset (c)].

It can be seen from Figure 6 that all the analyzed data sets show linearity in the selected parameters. Some sets show a positive correlation between the data (Figure 6B, C), and another dataset shows a negative correlation (Figure 6A).

The variation of the values attributed to dry matter induces an inverse proportionality dependence of the values of the bioactive compounds. The negative correlation of the dataset from Figure 6A is explained by the fact that dependent variables (total phenolic and total flavonoid contents) and an independent variable (dry matter content) move in different directions regarding the value. This can be explained by the fact that the concentration of TPC and TFC is higher in the raw material compared to the treated samples with added stevia or sugar. During heat treatment, the addition of stevia or sugar increases the dry matter concentration, but it does not increase the TPC and TFC content. This accounts for the observed linearity (R^2 = 0.9994) and the negative correlation between dry matter and TPC and TFC in the analysed samples.

A strong and positive correlation could be observed between TPC and TFC and the total anthocyanin content (Figure 6B), and between the antioxidant activity and TPC and TFC (Figure 6C).

As expected, our findings prove that, along with the increase in the content of bioactive compounds, the antioxidant capacity of the product also increases. Thus, the sample with stevia sweetener (DS) shows the best results. By adding the stevia sweetener, the content of polyphenols, flavonoids and total anthocyanins increased and enhanced the antioxidant capacity of the product. Also, the addition of stevia sweetener favours the formation of the specific jam structure.

The results demonstrated that the total anthocyanin value was strongly correlated with total phenolic content and total flavonoid content [dataset (b): R^2 =0.9999]. The low sum of squares [dataset (b): SS = 0.000006] indicates a linear relationship between datasets, which means a low variation of variables, and total anthocyanin content was strongly associated with total phenolic and total flavonoid contents. Similar results were reported by Rojas-Ocampo et al. (2021) and Grández-Yoplac et al. (2021).

A strong interdependence between DPPH inhibition, TFC and anthocyanins was determined for dataset (c): R^2 = 0.9730.

CONCLUSION

The novelty of the present study consists in using wild elderberry fruits as a free available and cheap raw material with special health benefits. The use of a raw material without financial value is essential to manufacture jellified products such as jams. In this work, the phytochemical properties, antioxidant activity, colour, textural and sensory properties of elderberry jams were determined.

Steviol glycosides, which are a potential natural sweetener, could be generally used in fruit or food processing for special nutritional uses, especially for diabetics.

Preservation by gelling using low sugar addition or sugar alternatives keeps the high nutritional value of elderberry fruits. Sensory acceptance leads to the initial purpose of the study being associated with phytochemical, textural and colour changes.

Further studies should be carried out to investigate the storage dependence of the main characteristics of jams.

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