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Original Scientific Paper

NUTRITIONAL, ANTIOXIDANT AND SENSORY PROPERTIES OF CEREAL BARS FORTIFIED BY EDIBLE FLOWERS

NUTRICIONALNA, ANTIOKSIDANTNA I SENZORSKA SVOJSTVA ŽITARIČNIH BAROVA OBOGAĆENIH JESTIVIM CVEĆEM

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ABSTRACT

The aim of this study was to determine the antioxidant activity (DPPH method), total polyphenols, and phenolic acids (spectrophotometrically), as well as total dry matter, fat content, crude protein (Kjeldahl method), and ash content in cereal bars fortified with a 5 % addition of edible flowers. The prepared products were also assessed through sensory evaluation using a 9-point hedonic scale, which considered overall appearance, aroma, taste, consistency, aftertaste, and overall acceptability. The following variants of cereal bars were prepared: a control variant (without added flowers), a variant with elderberry flowers (EF), a variant with lavender flowers (LF), a variant with calendula flowers (CF), and a variant with damascene rose flowers (RD). Antioxidant activity ranged from 3.15 mg TEAC/g (RD) to 0.83 mg TEAC/g (ML; TEAC - Trolox equivalent antioxidant capacity). The total polyphenol content ranged from 3.39 mg GAE/g (RD) to 0.91 mg GAE/g (LF; GAE - Gallic acid equivalent). The content of total phenolic acids was highest in the variant with elderberry flowers (11.80 mg CAE/g) and calendula (9.80 mg CAE/g; CAE - Caffeic acid equivalent). The values for total dry matter, fat, and crude protein did not change significantly, remaining at levels of 79 % (dry matter), 15 % (fat), and 12 % (crude protein) in the analyzed samples. The ash content increased with the addition of edible flowers, reaching its highest level in the variant with calendula flowers (2.02 %). The sensory evaluation of the prepared cereal bars indicated that the aroma and taste were characteristic of the flowers, and the consistency was deemed satisfactory. The variant with damascene rose flowers was evaluated as the best among the additions.

Keywords*: alternative sources; antioxidants; flavonoids; polyphenols; fortification*

REZIME

Cilj ovog istraživanja bio je određivanje antioksidativne aktivnosti (DPPH metoda), ukupnih polifenola i fenolnih kiselina (spektrofotometrijski), kao i ukupne suve materije, sadržaja masti, sirovih proteina (Kjeldahlova metoda) i sadržaja pepela u žitaričnim barovima obogaćenim dodatkom 5 % jestivog cveća. Pripremljeni proizvodi ocenjivani su i senzornom ocenom pomoću hedonističke skale od 9 tačaka, koja je uzela u obzir celokupni izgled, aromu, okus, konzistenciju, retroukus i ukupnu prihvatljivost. Pripremljene su sledeće varijante žitaričnih barova: kontrolna varijanta (bez dodatog cveća), varijanta cveta bazge (EF), varijanta cveta lavande (LF), varijanta cveta nevena (CF) i varijanta ruže damasta (RD). Antioksidativna aktivnost se kretala od 3,15 mg TEAC/g (RD) do 0,83 mg TEAC/g (ML; TEAC - Trolox ekvivalentan antioksidativni kapacitet). Ukupni sadržaj polifenola kretao se od 3,39 mg GAE/g (RD) do 0,91 mg GAE/g (LF; GAE - ekvivalent galne kiseline). Sadržaj ukupnih fenolnih kiselina bio je najveći u varijanti sa cvetovima bazge (11,80 mg CAE/g) i nevena (9,80 mg CAE/g; CAE - ekvivalent kafeinske kiseline). Vrednosti ukupne suve materije, masti i sirovih proteina nisu se značajno menjale, ostajući na nivoima od 79% (suva materija), 15% (mast) i 12% (sirov protein) u analiziranim uzorcima. Sadržaj pepela je povećan dodatkom jestivog cveća, dostigavši najviši nivo u varijanti sa cvetovima nevena (2,02%). Senzorno ocenjivanje pripremljenih žitnih barova pokazalo je da su aroma i okus karakteristični za cveće, a konzistencija je ocenjena kao zadovoljavajuća. Varijanta sa cvjetovima damascenske ruže ocenjena je kao najbolja među dodacima.

Ključne reči*: alternativni izvori; antioksidansi; flavonoidi; polifenoli; utvrđenje.*

INTRODUCTION

Edible flowers are emerging as a captivating trend in modern cuisine, meeting consumer demands for novel, visually appealing, and healthy products (*Wilczyńska et al., 2021*). Edible flowers can be categorized into four main types: vegetable, fruit, herb, and aromatic flowers (*Chen et al., 2020*). Edible flowers provide health benefits due to their antioxidant content, aligning with the current focus on functional foods (*Guiné et al., 2017*). Biologically active compounds, including flavonoids, coumarins, and terpenoids, are primarily responsible for the pharmacological effects of lavender (*Prusinowska and Śmigielski, 2014; Zhou et al., 2017*). Although there are other phenolic acids (gallic, syringic, ferulic, caffeic, and chlorogenic), ferulic acid is the one found in high concentrations in lavender. Other phenolic chemicals, including rutin (*Alasalvar and Yildirim, 2021*), apigenin, luteolin, catechin, quercetin, and kaempferol, were also discovered to be present (*Lim, 2014a*). Calendula is well-known for its antibacterial, antifungal, anti-inflammatory, and antioxidant qualities (*Escher et al., 2019; Kozlowska et al., 2019*). Calendula contains a variety of phenolic acids, including ferulic, ellagic, salicylic, gentisic, caffeic, syringic acid (*Lim, 2014b*), *p*-coumaric, chlorogenic, protocatechuic, and vanillic (*Escher et al., 2019*). Carotenoids, which give calendula its yellow and orange petals, are abundant in the plant (*Sausserde, 2014).* The anthocyanin content ranged from 390 to 970 mg/100 g of fresh weight, according to a study that examined 13 distinct elderberry cultivars (*Młynarczyk et al., 2020)*. Elderberry fruits are abundant in phenolic acids (chlorogenic acid) (*Ağalar, 2019*), flavonols (quercetin, rutin, isorhamnetin), proanthocyanidins

(*Cais-Sokolińska and Walkowiak-Tomczak, 2021*), and anthocyanins (cyanidin-3-glucoside and cyanidin-3-sambubioside), which give the berries their color (*Senica et al., 2016).* Damascena rose contains organic acids (citric, malic), pectin, tannins, carotenoids, and vitamins C, A, B_1, B_2, B_3, and K (*Nayebi et al., 2017*). Flavonoids, glycosides, terpenes, and anthocyanins are among the several phytochemicals that have been extracted from roses (*Nayebi et al., 2017*). Important constituents are quercetin and kaempferol, which are responsible for pharmacological effects (*Boskabady et al., 2011*). Gallic, protocatechuic, pyrogallic, and *p*-hydroxybenzoic acids are examples of phenolic acids present (*Liu et al., 2020*). Numerous studies have recently explored the incorporation of various plants into a range of food products, such as yogurt (*Pires et al., 2018; Qiu et al., 2021*), bread (*Podgórska-Kryszczuk & Pankiewicz, 2023*), cookies (*Hnin et al., 2020*), and chicken meat nuggets (*Madane et al., 2019*). These investigations indicate that the culinary role of flowers should extend beyond their traditional use as mere decorative elements. The safety concerns surrounding certain artificial food additives have sparked discussions about their health risks. In contrast, natural colorants are considered safer, as they do not pose the same health risks as their artificial counterparts. Research on the color properties of yogurt enhanced with various flowers revealed that rose extract serves as an excellent natural substitute for E163 (anthocyanin extract) in yogurt coloring (*Pires et al., 2018*). Although many flowers may not be suitable for coloring due to their pigmentation, they still possess significant potential. For example, *Madane et al. (2019)* demonstrated that incorporating Moringa flowers (which are white) into chicken meat nuggets can enhance their quality and minimize lipid peroxidation during cooking. Additionally, *Loizzo et al. (2015)* examined the antioxidant and hypoglycemic properties of various edible flowers, finding that *Sambucus nigra* flower extract shows strong antioxidant activity, while *Malus sylvestris* exhibits promising hypoglycemic effects compared to the commercial medication acarbose.

Cereal bars align with current trends and are crafted from a blend of grains that offer a sweet and enjoyable flavor. They provide essential vitamins, minerals, fiber, protein, and complex carbohydrates. These products incorporate diverse ingredients and target different consumer groups interested in maintaining a healthy lifestyle (*Palazzolo,2003).* Their appealing sensory qualities, combined with their growing interest in health benefits, have facilitated the creation of cereal bars that include innovative food components, which are both nutritious and functional (*Ak et al., 2020*).

The main aim of this study was to evaluate the nutritional, antioxidant, and sensory characteristics of cereal bars enriched with edible flowers: lavender (*Lavandula angustifolia* L.), calendula (*Calendula officinalis* L.), elderberry (*Sambuscus nigra* L.) and damascene rose (*Rosa damascena* L.).

MATERIAL AND METHOD

The raw materials used to produce cereal bars (oatmeal, hemp seeds, dried raisins, butter, and honey) were purchased from a local market in Slovakia. Samples of edible flowers used in the production of the cereal bars were collected during their flowering period from the locality of locality Michalovce, Slovakia at an altitude of 114 meters above sea level. The drying process of the flowers took place at room temperature without direct sunlight. In the period between drying and the analyses carried out the samples were stored in paper and cloth bags, which were kept free from access to sunlight. Before the application to biscuits the medicinal herbs were milled into powder (Sencor Scg 1050wh, Japan). All used chemicals were analytical grade and purchased from CentralChem (Bratislava, Slovakia).

Preparation of cereal bars

To prepare the cereal bars, fine oatmeal, dried raisins, hemp seeds, honey, butter, water, and edible flowers were mixed and homogenized. Each variant of cereal bar was prepared separatory (control, sample with elderberry, sample with lavender, sample with rose, and sample with marigold) The mixture was placed over a wax paper, manually pressed, and wrapped in foil. Thereafter, the mixture was cooled for 15 min to acquire a firm consistency, characteristic of cereal bars, being cut with a thickness of approximately 2.0 cm and length of 10 cm. The cereal bars were wrapped in aluminum foil, placed in a plastic container, and stored at room temperature (18 °C) until analyses were carried out.

Preparation of extracts for the determination of antioxidant characteristics

On a shaker (GFL 3005, Germany), 0.25 g of the homogenized material was extracted in 20 ml of 80 % ethanol for two hours at room temperature. The extract was then filtered (Whatman n.1) and utilized to test the phenolic acids, total polyphenols, and DPPH.

Determination of antioxidant activity by the DPPH method

The amount of DPPH radical scavenged was determined according to the method described by (*SánchezMoreno et al., 1998).* For the determination, 2 ml of DPPH- radical (Sigma Aldrich, GE; 0.025 g was dissolved in 100 ml of ethanol and subsequently diluted as needed) and 0.5 ml of sample were pipetted into a cuvette. The mixture was stirred and placed in the dark for 10 min, after which the decrease in absorbance was monitored on a spectrophotometer (Jenway 6405 UV/Vis, UK) at 515 nm. The analyses were carried out in triplicate. The antioxidant activity was expressed based on the Trolox equivalent antioxidant capacity (TEAC) calibration curve in mg/g sample (R^2=0.9829).

Determination of total polyphenols

The method with the Folin-Ciocalteu reagent (*Singleton and Rossi, 1965*) was used for the determination of total polyphenols. For one determination, 0.2 ml of sample, 0.2 ml of the Folin-Ciocalteu reagent and 2 ml of 20 % Na_2CO_3 were pipetted into a tube, the mixture was then placed in a centrifuge (Neofuge VS - 100 BN, USA, 10 000 g, 10 minutes). In this prepared mixture, the absorbance was determined at 700 nm (Jenway, 6405 UV/Vis, UK). The analyses were repeated three times. The total polyphenol content was expressed as gallic acid equivalent (GAE) (R^2 = 0.9989) in mg/g of the sample.

Determination of total phenolic acids

The spectrophotometric method according to Pharmacopeia Polska, (1999) is used for the determination of phenolic acid content. For the analysis of phenolic acids, 0.5 ml of extract, 0.5 ml of 0.5 M HCl, 0.5 ml of Arn's reagent (10 % $NaNO_2$ + 10 % Na_2MoO_4), 0.5 ml of 1 M NaOH and 0.5 ml of distilled H_2O were pipetted into the tube. The absorbance of the reaction mixture was measured at 490 nm. The phenolic acid content was expressed as caffeic acid equivalent (CAE) in mg/g (R^2=0.9996).

Determination of dry matter content

For the determination, 5 g of the sample was weighed on an analytical laboratory balance into aluminum trays, so-called desiccators with lids (the weight of the empty desiccator was noted before the measurement). The samples were dried in a drying oven at 130 ± 2˚C for 60 minutes (WTB, Binder, Germany). After drying, they were allowed to cool in the desiccator and then their weight was determined *(Muchová and Frančáková, 1992).*

The dry weight was expressed according to the following formula:

$$DM\ [\%] = \frac{\text{weight of sample after drying} - \text{weight of empty dish x 100}}{\text{weight (sample weight)}}$$

Determination of total fat

The fat content of each sample was determined using a Fat Extractor - AncomXT15 (ANKOM Technology, New York, USA), using the methodology given by the manufacturer. Petroleum ether was used as the extraction reagent. From each sample, 1 g was weighed into special bags (filter bag XT4) and then sealed using a melter. The sample bags were dried in a drying oven (WTB, Binder, Germany) at 105 °C for 3 h, after which time they were placed in a desiccator to cool, and their weight was determined. They were then placed in the apparatus where the extraction was carried out with petroleum ether at 90°C for 45 min. After extraction, the bags were again dried in a drying oven (WTB, Binder, Germany) at 105 °C for 30 minutes, then placed in the desiccator and weighed. The % fat content was determined according to the following formula:

$$T\ [\%] = \frac{100 \text{ x } (W2 - W3)}{W1}$$

W1 - weight of the sample
W2 - weight of the sample bag after drying
W3 - weight of the sample bag after extraction and drying

Determination of total crude protein (CP) by Kjeldahl method

The nitrogen content of the sample was mineralized in concentrated sulphury acid in the presence of a catalyst (potassium sulphate: copper sulphate, 10:1) in a Turbotherm apparatus (Gerhardt, Germany). In this way, the organically fixed nitrogen is converted to ammonium sulfate during combustion. Mineralize 1 g of the sample with 20 ml of concentrated sulfuric acid for about 1 hour at 400 ˚ C until the contents are clear. After the sample has cooled, the mineralization tubes are transferred to a Vapodest distillation apparatus where the acid solution is diluted with water before being alkalinized by the addition of 33 % sodium hydroxide. The addition of concentrated hydroxide in excess releases the ammonia by steam distillation and traps it in a 2% boric acid solution to form ammonium borate. On completion of distillation, Tashir indicator is added and titrated with 0,1 N (0.05 M) sulphuric acid to a color change from green to violet. Consumption is fed into the formula for calculating % nitrogen. When a blank analysis (mineralization and distillation) is determined, the chemicals just used are analyzed. The consumption of these chemicals is considered in the calculation of the nitrogen content *(Muchová and Frančáková, 1992).*

The calculation of % nitrogen content is determined according to the formula:

$$\%\ N = \frac{1{,}4007 \text{ x c x } (s - b) \text{ x } 2}{w}$$

c - concentration of sulphuric acid solution (0.05 M)
s - consumption of sulphuric acid solution in ml (sample)
b - consumption of sulphuric acid solution in ml (blank = 0.2 ml)
w - sample weight

Then was calculate the % of crude protein according to the relation:
% CP = % N x 6,25
6.25 = conversion factor

Determination of ash content

Exactly 3 g of the sample was weighed on an analytical balance into the pre-annealed and after cooling weighed crucible. The sample was first carefully charred on the edge of a hot electric hotplate and allowed to burn freely with the flame. After the flame was extinguished, the crucibles were placed inside the muffle oven (KSL-1000X, USA). The furnace was closed, and the samples were allowed to burn at 900 °°C until all the organic fraction was burned. The ash should be uniformly light, with no black carbonaceous residue, which in our case took about 4 hours. Once the crucibles were completely burnt, they were removed from the kiln, placed in a desiccator where they were allowed to cool to a temperature of 18-20 °°C and then the weight was determined. The determination was done in two repetitions (*Muchová and Frančáková, 1992*).

The ash content in % was calculated according to the following formula:

$$A\ [\%] = \frac{\text{weight of crucible with ash} - \text{weight of empty crucible x 100}}{\text{weight of sample}}$$

The results were converted to 100% dry matter.

Sensory evaluation of cereal bars with the addition of edible flowers

A sensory panel of 30 panelists – 15 women and 15 men, aged 22 to 65 – determined the organoleptic properties of cereal bars. The panelists were asked to assess the overall acceptance, taste, smell, and overall appearance, aftertaste. A 9-point hedonic scale was used to rate the samples, with values ranging from 9 (like very much) to 1 (strongly dislike).

Statistical analysis

All experiments were carried out in triplicate and the mean of replicates was reported together with standard deviation. The experimental data were subjected to analysis of variance (Duncan's test) at the significance level of 0.05. Statistic calculations were performed using SAS (2009) software.

RESULTS AND DISCUSSION

Antioxidant activity by DPPH method

Edible flowers are increasingly attractive to consumers. In addition to enhancing the sensory properties and aesthetic value of food (*Fernandes et al*., 2017a), many studies have found them to be an excellent source of bioactive compounds. These compounds by their properties have beneficial effects on health *(Kumari et al., 2021).* They exhibit antioxidant activity *(Zheng et al., 2021),* and antimicrobial and anti-inflammatory properties *(Pires et al., 2017a; Pires et al., 2019b; Chen et al., 2020c).*

The antioxidant activity of the samples tested reveals a significant range, with values spanning from 0.834 to 3.15 mg TEAC/g (Tab. 1). The highest antioxidant activity was found in the rose-added bar, measuring 3.15 mg TEAC/g. This finding aligns with the research of *Kashefi et al. (2010),* which indicates that damascena rose has strong antioxidant properties, effectively scavenging free radicals *(Boskabady et al., 2011).* The second-highest antioxidant activity was observed in the lavender-added sample, which recorded a value of 2.02 mg TEAC/g. In contrast, calendula exhibited weaker antioxidant activity, consistent with the findings of *Benvenuti et al. (2016)*, who noted lower antioxidant values for calendula flowers. The control sample showed the lowest antioxidant activity in the study. Furthermore, *Młynarczyk et al. (2018, 2020*) demonstrated that elderberry flowers have a greater antioxidant capacity compared to their fruits, with values ranging from 0.304 to 0.444 mg TEAC/g dry weight. *Awika et al. (2003*) suggested a strong correlation between phenolic compounds and antioxidant activity. In support of this, *Shantamma et al. (2021)* emphasized the high antioxidant potential of flowers relative to fruits and vegetables. According to *Chen and Wei (2017b),* the antioxidant properties of edible flowers may play a role in providing anti-inflammatory, anti-cancer, and antimutagenic benefits. The elevated antioxidant activity observed in our results could also be attributed to the inclusion of dried raisins, which are known for their high antioxidant content *(Chen et al., 2022a; Fernandes et al*., 2018b*)*. Additionally, previous studies by *Alonso-Estaban et al. (2022)* and *Ilia et al. (2021)* highlighted the significant antioxidant content found in hemp seeds and honey, further supporting the overall findings regarding antioxidant activity in these samples.

Table 1. Results of antioxidant activity in tested samples

Sample	**Antioxidant activity [mg TEAC/g]**
Cereal bar with elderberry flower	1.67 ±0.13^{c}
Cereal bar with calendula	1.30 ±0.12^{d}
Cereal bar with damascene rose	3.15 ±0.11^{a}
Cereal bar with lavender	2.02 ±0.14^{b}
Control bar	0.83 ± 0.01^{e}

TEAC – Trolox equivalent antioxidant capacity; mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Total polyphenols

Polyphenols are bioactive compounds found in various natural products, particularly within the flavonoid group. They are known for their antioxidant properties and potential health benefits. The quantification of polyphenolic content in plant products is commonly performed using a colorimetric method, with the Folin-Ciocalteu reagent being the most widely used. This method relies on the reaction between phenolic compounds and the reagent to produce a measurable color change, which correlates with the amount of phenolics present *(Ramirez-Sanchez et al., 2010*). In a recent evaluation, the highest polyphenol content was identified in a bar supplemented with damascene rose achieving a concentration of 3.39 mg GAE/g on a dry weight (Tab. 2). Additionally, research by *Dina et al. (2021)* found that rose extracts, derived from waste in essential oil production, exhibited a significant polyphenol content of 260 mg GAE/g. In contrast, a bar enriched with elderberry showed a polyphenol concentration of 1.45 mg GAE/g, followed by those containing calendula and a control sample, which had the lowest phenolic content. Further studies by *Mlynarczyk et al. (2020)* revealed that elderberry flowers contain higher levels of phenolic compounds compared to elderberry fruits, with a reported concentration of 10.22 mg GAE/g fresh weight. *Janarny et al. (2021*) documented the polyphenolic content in various edible flowers, ranging from 1.1 to 57.4 mg GAE/g on a dry weight basis. *Skrajda-Brdak et al. (2020)* also evaluated the phenolic content, noting values between 0.51 and 1.14 mg GAE/g fresh weight. *Nowicka and Wojdyło (2019)* provided a broader analysis of edible flowers, finding total polyphenol contents between 2.84 and 71.1 mg GAE/g on a dry matter basis, categorizing these flowers based on their phenolic content: Greater than 20 mg GAE/g dry weight (e.g., primrose, hawthorn), 10-20 mg GAE/g dry weight (e.g., lavender, daisy), 5-10 mg GAE/g dry weight (e.g., chamomile, mallow), less than 5 mg GAE/g dry matter (e.g., elderberry, cornflower). Despite the utility of the Folin-Ciocalteu method for quantifying polyphenolic compounds, *Milena et al. (201*9) cautioned that this method may not fully capture the complexity of polyphenolic profiles due to potential interference from other compounds such as sugars, organic acids, and aromatic amines, which could skew the results. This highlights the need for complementary methods to achieve a more comprehensive understanding of polyphenolic content in plant materials.

Table 2. Results of total polyphenols in tested samples

Sample	**Total polyphenols [mg GAE/g]**
Cereal bar with elderberry flower	1.45 ±0.22^{b}
Cereal bar with calendula	1.36 ±0.14^{c}
Cereal bar with damascene rose	3.39 ±0.25^{a}
Cereal bar with lavender	0.97 ±023^{d}
Control bar	0.91 ±0.11^{e}

GAE – gallic acid equivalent; mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Total phenolic acids

The results indicate that the addition of elderberry significantly enhances the phenolic acid content in the bars, reaching a notable 11.80 mg CAE/g, which is substantially higher than the control sample at 6.92 mg CAE/g (Tab. 3). This aligns with existing literature, particularly the findings of *Nowicka and Wojdyla (2019)*, who reported a baseline phenolic acid content of 0.78 mg CAE/g in a variety of edible flowers, with calendula (Asteraceae family) exhibiting the highest levels among the species studied. The identification of specific phenolic acids, such as gallic acid, syringic acid, *p*-hydrobenzoic acid, as well as derivatives of caffeic acid, including chlorogenic acid and caffeoylquinic acid, as highlighted by *Janarny et al. (2021*) is essential for understanding the potential health benefits associated with these compounds. The findings suggest that marigold and elderberry not only contribute to the overall phenolic acid content but may also offer unique health-promoting properties due to their specific phenolic profiles. The incorporation of elderberry and marigold into food products may enhance their functional properties, providing a richer source of beneficial phenolic acids, which could be advantageous for consumer health. Further studies could explore the bioavailability and the specific health effects of these phenolic compounds in various formulations.

Table 3. Results of the total phenolic acid content in tested samples

Sample	**Phenolic acids [mg CAE/g]**
Cereal bar with elderberry flower	11.80 ±1.14^{a}
Cereal bar with calendula	9.80 ±0.89^{b}
Cereal bar with damascene rose	8.40 ±0.41^{c}
Cereal bar with lavender	7.70 ±0.23^{d}
Control bar	6.92 ±0.01^{e}

CAE – caffeic acid equivalent; mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Dry matter content

The high dry matter content of the samples, approximately 79 %, indicates a stable product that can be stored for an extended period (Tab. 4). However, studies by *Padmashree et al. (2012*) suggest that sensory attributes of the product decline over time, impacting consumer acceptance. One significant factor in the shelf life of cereal bars is the development of a hard texture, which is often viewed unfavorably by consumers. Additionally, *Padmashree et al. (201*3) highlighted the susceptibility of these bars to oxidation due to their elevated levels of unsaturated fatty acids. To mitigate these issues, the choice of packaging materials is crucial to maintain product quality throughout the storage period. Various packaging options, including polypropylene, paper-aluminum polyethylene laminate films, and matted polyester films, have been employed. Under these packaging conditions, the shelf life of the bars is generally maintained at around 3 to 4 months *(Padmashree et al., 2012; Janarny et al. 2021*). Therefore, proper packaging strategies are essential not only for preserving the texture and sensory quality of the bars but also for extending their overall shelf life.

Table 4. Results of dry matter content in tested samples

Sample	Dry matter [%]
Cereal bar with elderberry flower	78.90 ±0.12[a]
Cereal bar with calendula	79.01 ±0.14[a]
Cereal bar with damascene rose	79.71 ±0.11[a]
Cereal bar with lavender	78.83 ±0.12[ab]
Control bar	78.51 ±0.14[ab]

mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Total fat content

The highest percentage of fat is found in the bar with the addition of elderberry (17.62 %). The samples with calendula, rose and lavender followed with small differences (Table 5). The least fat (14.21 %) was found in the control bar, so we can conclude that the addition of edible flowers also achieves an increase in fat content. *Takashi et al. (2020)* found that calendula has a high content of unsaturated fatty acids (59.3 %). According to *Suksathan et al. (2021),* the fat content of edible flowers is at 2.6 % to 32 %. *Rivas-García et al. (2021)* found the following in their research. The lipid content of edible flowers is variable (0.1-10 %). Flowers such as hibiscus or pansy are among the species with the highest lipid content. Calendula and rose are the flowers that provide the highest amount of polyunsaturated (essential) fatty acids (linoleic acid, α-linolenic acid). According to *Domíngeuz et al. (2021),* the essential fatty acid content of edible flowers is high. For example, in elderberry, linoleic acid is the major fatty acid, accounting for up to 39 % of the total fatty acids. The second most abundant fatty acid in elderberry is α-linolenic acid, with 38 %. *Fernandes et al. (2018)* reported a fat content in the range of 3.6-5.6 % on a dry weight basis for calendula. The fat content of the bars with the addition of edible flowers is higher due to the hemp seeds. According to *Alonso-Esteban et al. (2022),* they contain a large amount of fat ranging from 25 to 30 %. Linoleic acid is dominant, accounting for up to 50 % of the total fatty acids. Butter was used in the mass for the preparation of the cereal bars, which contain a large amount of fat, which appears to be the case in the results.

Table 5. The results of total fat content in tested samples

Sample	Fat content [%]
Cereal bar with elderberry flower	17.62 ±1.02[a]
Cereal bar with calendula	16.81 ±1.11[a]
Cereal bar with damascene rose	15.83 ±0.99[a]
Cereal bar with lavender	15.35 ±0.84[ab]
Control bar	14.21 ±0.11[b]

mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Crude protein content

The findings indicate that the addition of elderberry and calendula significantly enhances the crude protein content of the bars, achieving the highest level at 12.42 % (Tab. 6). This is notably higher than the control bar, which had a crude protein content of 11.92 %. In comparison, the bars with lavender also showed increased protein levels, although specifics were not provided. The references to other studies highlight the variability of crude protein content in different edible flowers. For instance, *Takashi et al. (2020)* reported that rose, sunflower, and hibiscus had crude protein contents of 7.6 %, 10 %, and 2.7 %, respectively. Additionally, *Rop et al. (2012)* found *Rosa odorata* to have a crude protein content of around 2.7 %. *Cais-Sokolińska and Walkowiak-Tomczak (202*1) noted that yogurt with elderberry added had a crude protein content of 3.41 %. These findings suggest that incorporating certain edible flowers, particularly elderberry and marigold, can significantly enhance the nutritional profile of food products, particularly in terms of protein content. This could have implications for product development in the health food sector, especially for those targeting higher protein diets.

Table 6. The results of crude protein content in tested samples

Sample	Crude protein content [%]
Cereal bar with elderberry flower	12.42 ±0.13[a]
Cereal bar with calendula	12.42 ±0.14[a]
Cereal bar with damascene rose	11.92 ±0.25[a]
Cereal bar with lavender	12.21 ±0.11[a]
Control bar	11.90 ±0.01[b]

mean ±standard deviation; different letters in a column denote mean values that statistically differ one from anothe

Ash content

The study by *Mlynarczyk et al. (2020*) provides valuable insights into the composition of ash resulting from the complete combustion of materials, revealing that ash consists of both macro and microelements. In our research, we observed that the bar with calendula and lavender had the highest ash content at 2.02 %, followed closely by bars containing elderberry and rose, while the control bar exhibited the lowest ash content at 0.91 % (Tab. 7). *Mlynarczyk et al. (2020)* further highlighted that elderberry flowers contain approximately twice the ash content compared to black elderberry fruit, with notable variations in mineral content. Specifically, they reported calcium levels at 2.9 mg/g, iron at 0.5 mg/g, copper at 0.007 mg/g, zinc at 0.03 mg/g, and manganese at 0.04 mg/g, all measured per dry weight. *Suksathan et al. (2021)* investigated various edible flowers (*Bauhinia variegata, Shorea roxburghii, Viburnum inopinatum, Gmelina arborea, Glycyrrhiza glabra*) and found them to be rich sources of essential minerals, with calcium content ranging from 1.3 to 1.7 mg/g and iron between 0.044 to 0.075 mg/g. Their study also indicated significant potassium levels, from 7.9 mg/g to 23.7 mg/g. *Kumari et al. (2021)* identified potassium as the most abundant macronutrient in edible flowers, with a dry matter content of 30.03 mg/g, while iron emerged as the predominant micronutrient at 0.155 mg/g dry weight*. Rop et al. (2012)* emphasized the significance of mineral content in edible flowers for human nutrition, and findings regarding *Rosa odorata* revealed phosphorus at 0.225 mg/g, calcium at 0.275 mg/g, magnesium at 0.142 mg/g, potassium at 0.0019 mg/g, and sodium at 0.077 mg/g. In our results, we noted a distinct difference in ash content between bars with and without the addition of edible flowers. However, it is important to acknowledge the presence of hemp seeds in the bars, as reported by *Alonso-Esteban et al. (2022)*, which indicated that phosphorus is the most abundant mineral in the seeds, alongside potassium, magnesium, zinc, iron, sodium, and manganese. This suggests that the mineral composition of the bars is influenced not only by the edible flowers added but also by the inclusion of hemp seeds.

Table 7. Results of ash content in tested samples

Sample	Ash content [%]
Cereal bar with elderberry flower	1.90 ±0.01[a]
Cereal bar with calendula	2.02 ±0.02[a]
Cereal bar with damascene rose	1.80 ±0.01[a]
Cereal bar with lavender	2.01 ±0.02[a]
Control bar	0.91 ±0.01[b]

mean ±standard deviation; different letters in a column denote mean values that statistically differ one from another

Sensory evaluation of cereal bars with the addition of edible flowers

According to *Rop et al. (2012),* sensory properties are the main criteria for evaluating the quality of edible flowers. The cereal bar with the addition of lavender (Figure 1) had the strongest aroma, while the taste of the sample with rose was rated the highest, receiving a score of 7.3. The cereal bar with added calendula had a flavor reminiscent of fig. An aftertaste was present in all samples; the most intense aftertaste was from the lavender, which was often described as herbal, bitter, and even unpleasant. The aftertaste of elderflower was characterized as mealy, while marigold had an earthy, herbaceous aftertaste, and rose had a sweet aftertaste. The highest scores for overall appearance were given to the cereal bars with lavender and calendula. Overall acceptability was satisfactory for all samples, with the rose scoring 7.35 due to its sweet taste. The lowest score was for the bar with lavender, which was rated as very aromatic but bitter to unpleasant. The flavors of the samples were characteristic of their respective flowers; the consistency was satisfactory, and the herbal aftertaste was present in all samples.

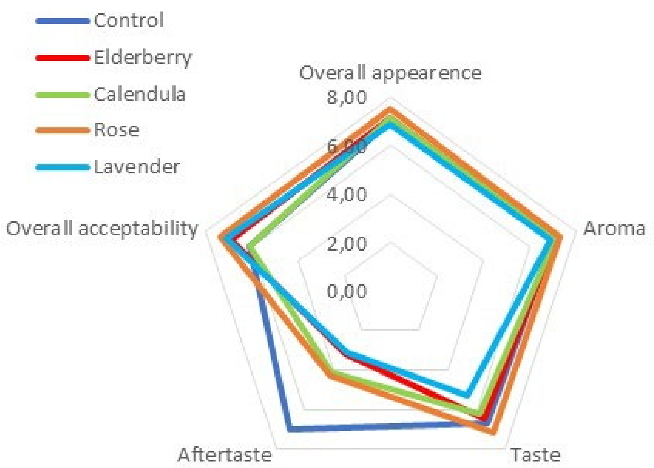

Fig. 1. Results of sensory analysis (sum of all evaluators) of tested samples

CONCLUSION

In conclusion, the integration of edible flowers into food products not only elevates their aesthetic appeal but also enhances their sensory qualities and nutritional profile. Rich in bioactive compounds, these flowers offer a range of health benefits, including antioxidant, antimicrobial, and anti-inflammatory properties that can aid in reducing the risk of chronic diseases. Our study demonstrated that the antioxidant capacities of edible flowers varied significantly, with rose, lavender, calendula, elderberry, and the control sample exhibiting antioxidant activity levels between 0.83 and 3.15 mg TEAC/g. Additionally, total polyphenol content was highest in rose, followed by elderberry and calendula, indicating a strong correlation between flower type and nutritional value. The analysis of phenolic acids further confirmed the potential health benefits of these flowers, with elderberry leading in concentration. The consistency in dry matter content coupled with the varying fat and protein levels highlights the unique nutritional profiles of each flower, suggesting varied culinary applications. Given these findings, we recommend that the food industry consider the incorporation of edible flowers not only as a means to enhance visual appeal but also as a strategic approach to developing functional foods that cater to the growing health-conscious consumer market. To maximize the potential of edible flowers, food manufacturers should explore innovative product formulations that leverage their unique flavors and health benefits. Collaborating with horticulturists to ensure sustainable sourcing and quality control will also be essential. Furthermore, consumer education initiatives highlighting the health benefits and culinary uses of edible flowers can drive market demand. By embracing this trend, the food industry can create exciting new offerings that align with contemporary consumer preferences for health and wellness, ultimately contributing to a more vibrant and health-oriented food landscape.

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