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Essential Oils Impact on Elderberry Jam's Antioxidant and Sensory Profile

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Abstract

The utilization of *Sambucus nigra* L. fruits, owing to their complex biochemical profile encompassing a high content of antioxidants and other biologically active substances, is experiencing a notable increase in the food industry, particularly in the context of advanced natural formulations. This study aimed to produce and characterize five distinct elderberry jam formulations: a control sample (EJ) and four experimental samples incorporating essential oils of lemon (EJL), grapefruit (EJG), orange (EJO), and tangerine (EJT). The characterization encompassed the determination of ascorbic acid content (titrimetric analysis), total polyphenol concentration (Folin-Ciocalteu assay), antiradical activity (2,2-diphenyl-1-picrylhydrazyl free radical scavenging assay), proximate composition, and sensory attributes (5-point hedonic scale). The results highlighted that, concerning vitamin C content, there were no significant differences between the control sample and those with essential oils. However, the addition of citrus essential oils resulted in important increases in total polyphenols and antioxidant activity. Furthermore, the addition of essential oils led to a superior evaluation of the sensory attributes of the elderberry jam by the tasters, with the product containing grapefruit essential oil (EJG) being the most highly rated.

Keywords: elderberry, jam, essential oils, vitamin C, polyphenols, antioxidant activity.

1. Introduction

Jam is a non-jellied product obtained by boiling whole or cut fruits in a sugar syrup, with the goal of concentrating the product, which is then packaged in hermetically sealed and pasteurized containers. It is traditionally prepared from a single type of fruit and takes the name of the fruit used. To ensure preservation, the jam must reach a concentration of 70–75˚ Brix, achieved by the naturally occurring sugars in the fruit, but primarily by the added sugar. Traditionally, jam is made from various fruits as well as green tomatoes and carrots [1].

Elderberry (*Sambucus nigra* L.), a member of the *Adoxaceae* family, is widely distributed across subtropical and temperate regions, including Europe, North Africa, North America, and parts of Asia. While it is commonly found in the wild flora, several countries have recognized its value and engage in its commercial cultivation [2-3]. *Sambucus nigra* berries have been utilized for centuries in traditional medicine for their prophylactic and therapeutic properties against a range of ailments, including the common cold, upper respiratory tract infections, diabetes, obesity, constipation, hemorrhoids, and various dermatological conditions [4-5]. Recent investigations have demonstrated that *Sambucus nigra* extract possesses both antiviral and immunomodulatory activities [5]. The chemical composition of elderberries demonstrates that these fruits could be an interesting source of valuable

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bioactive compounds, responsible for their therapeutic effects: various phenolic compounds, such as anthocyanins (predominantly cyanidin-3-sambubioside and cyanidin-3-glucoside), flavonols (mainly quercetin-3-rutinoside and isoquercitrin), and phenolic acids chlorogenic acid, sinapic acid and cinnamic acid) [6-7].

Despite their high content of functional compounds, elderberries present a potential toxicological concern stemming from the presence of cyanogenic glycosides, specifically sambunigrin, prunasin, zierin and holocalin, as well as lectins, with higher concentrations typically observed in immature or unripe fruit. As these compounds are temperature-sensitive, thermal processing facilitates their degradation. Consequently, jam manufacturing serves as an effective preservation method and a reliable strategy for mitigating potential toxicity [8].

The widespread classification of Citrus essential oils (EOs) as Generally Recognized as Safe (GRAS) has led to their extensive application as natural food additives across various food and beverage formulations. Moreover, Citrus EOs function effectively as natural preservatives, owing to their diverse biological activities, notably their antimicrobial and antioxidant capacity. These potent antioxidative and antimicrobial properties are hypothesized to be conferred by the presence of key molecules, including terpenes, flavonoids, carotenes, and coumarins [9].

The primary objective of this work was to assess the impact of citrus essential oils (EOs) on the final antioxidant properties and sensory attributes of elderberry fruit jam. The experimental design involved formulating four distinct jams, each enriched with an EOs from either Lemon (EJL), Grapefruit (EJG), Orange (EJO), or Tangerine (EJT). These four experimental samples were then subjected to a comparative analysis against a control sample (EJ) containing no EOs. Key measurements included Vitamin C concentration, total polyphenol content, and DPPH scavenging activity, complemented by a five-point hedonic scale for sensory evaluation.

2. Materials and method

2.1. Elderberry jams preparation

For the preparation of the jam, the raw and auxiliary materials were used according to the recipes in Table 1. The elderberries, lemons, and raw sugar were sourced from the Romanian market, while the essential oils were provided by the Young Living company (pure essential oils - food supplement category, obtained by cold pressing).

Table 1. Recipes used to make elderberry jams

Jam assortment	**EJ**	**EJL**	**EJG**	**EJO**	**EJT**
Elderberries (%)	51	51	51	51	51
Raw sugar (%)	44	44	44	44	44
Water (%)	3	3	3	3	3
Lemon juice (%)	2	1.9	1.9	1.9	1.9
Lemon EOs (%)	-	0.1	-	-	-
Grapefruit EOs (%)	-	-	0.1	-	-
Orange EOs (%)	-	-	-	0.1	-
Tangerine EOs (%)	-	-	-	-	0.1

Initially, the elderberries were separated from their clusters, and only sound and fully ripened fruits were subjected to thorough washing. Concurrently, a sugar and water syrup was prepared by boiling for 6 minutes. Subsequently, the prepared elderberries were introduced into the boiling syrup and simmered for an initial 6-minute period. Lemon juice was then incorporated, and the mixture continued to boil for an additional 2 minutes. Upon completion of the boiling phase, the vessel was covered with a damp gauze and allowed to cool to ambient temperature. Following the cooling stage, the designated essential oil was uniformly incorporated into the jam matrix. Finally, the resultant jam was aseptically filled into pre-sterilized jars and sealed to ensure product integrity. Subsequently, representative samples were collected from each distinct product type for both physicochemical and sensory analysis.

The resulting elderberry jam are visually presented in Figure 1.

Figure 1. - Elderberry jam

2.2. Assessment of vitamin C, total polyphenol content, antiradical activity, proximate composition and sensory analysis

Ascorbic acid determination was performed utilizing the modified iodometric method, as previously described by Dumbrava *et al*. (2016) [10]. Assessment of the total polyphenol content (TPC) in finished products was conducted using the Folin-Ciocalteu assay. Additionally, the sensory evaluation of the elderberry jams was performed via the 5-point hedonic scale method. The TPC assay, proximate composition determination and the sensory evaluation adhered to the protocols presented by Dumbrava *et al*. (2020) [11]. The DPPH free-radical scavenging activity (RSA) was determined following the spectrophotometric protocol detailed by Dumbrava *et al*. (2022) [12].

2.3. Statistical analysis

The data obtained for TPC and RSA were subjected to statistical analysis utilizing Excel software (Microsoft Office 2010). Descriptive statistics, specifically the mean values and standard deviations of all replicates, were subsequently computed.

3. Results and discussion

3.1. Vitamin C and total polyphenol content

The results regarding the content of Vitamin C and total polyphenols in the elderberry jam samples are presented in Table 2.

Table 2. Levels of vitamin C and total polyphenols in the elderberry jam samples

Sample	Vitamin C (mg/100g)	Total polyphenols content (mg GAE/g)
EJ	18.65±0.06	166.48±0.38
EJL	18.58±0.16	195.47±0.44
EJO	18.62±0.08	178.35±0.21
EJG	18.59±0.14	238.28±0.37
EJT	18.52±0.10	188.21±0.37

Vitamin C concentration remained stable across all jam formulations supplemented with essential citrus oils (18.58±0.16, 18.62±0.08, 18.59±0.14, and 18.52±0.10 mg/100g, for EJL, EJO, EJG, and EJT, respectively), exhibiting no significant difference compared to the EJ (18.65±0.06 mg/100g).

The observed increase in TPC is attributed to the inherent presence of these compounds within the cold-pressed citrus essential oils, a finding consistent with previous research by Tavallali *et al*. (2021) [13] and Farahmandfar *et al*. (2020) [14].

The plain jam (EJ) demonstrated a TPC of 166.88±0.38 mg GAE/g. The incorporation of orange essential oil (EJO) resulted in a 6.87% increase in this compounds (178.35±0.21 mg GAE/g), while the addition of lemon essential oil (EJL) yielded an even greater enhancement, reporting a 17.13% increase (195.47±0.44 GAE/g). The highest TPC, 238.28±37 mgGAE/g, was recorded in the EJG sample, representing a 42.79% increase relative to the plain jam (EJ).

Regarding elderberry jam formulations, Nistor *et al*. (2025) [15] published TPC values contingent upon the sweetener utilized. The preparation incorporating white sugar resulted in a TPC of 9.70±0.33 mg GAE/g DM, equivalent to 55.49 mg GAE/g on a wet-weight basis. A comparatively higher TPC of 15.97±0.90 mg GAE/g DM (91.36 mg GAE/g of jam) was recorded for the formulation prepared with stevia sweetener. All cited Total Polyphenol Content (TPC) values are lower than those determined in the present study.

3.2. Radical scavenging activity

Table 3 provides the RSA results, which was experimentally measured for the elderberry jam samples following a 1:100 dilution.

Table 3. DPPH Radical Scavenging Activity (RSA)

Sample	Dilution	RSA (%)
EJ	1:100	59.80±0.23
EJL	1:100	78.43±0.18
EJO	1:100	64.01±0.28
EJG	1:100	86.32±0.33
EJT	1:100	61.82±0.21

From the results regarding the DPPH free radical scavenging activity for the jam samples diluted 1:100, it is evident that the control sample (EJ) exhibited the lowest activity (59.80±0.23%). Conversely, the highest activity was recorded for sample EJG (86.32±0.33%), followed by EJL (78.43±0.18%). Consequently, the incorporation of citrus essential oils into the elderberry jam significantly enhanced its antiradical activity. Analysis suggests that the RSA results are directly correlated with the TPC across the evaluated jam samples.

Nistor *et al.* (2025) [15] previously determined the RSA of elderberry jam to be in the range of 80.96% to 82.61%, though these results were derived from samples with a dilution factor of only 1:7.

3.3. Proximate composition and energy value of elderberry jam

The results concerning the proximate composition and energy value of the elderberry jam are presented in Table 4.

Table 4. Proximate composition and energy value of elderberry jams

Parameters	EJ, EJL, EJO, EJG, EJT
Moisture (g/100g)	26.18±0.85
Total carbohydrates (g/100g)	67.11
- Sugars (g/100g)	60.05±1.64
- Dietary fiber (g/100g)	14.45±0.32
Protein (g/100g)	6.71±0.12
Energy value (kcal/100g)	295

The proximate composition was observed to be consistent across all assayed elderberry jam varieties. As anticipated, total carbohydrates constituted the predominant fraction (67.11 g/100g). A detailed breakdown revealed that sugars accounted for (60.05±1.64 g/100g and dietary fiber contributed 14.45±0.32 g/100g. Notably, the protein content was substantial for this product category, registering a mean value of 6.71±0.12 g/100g.

3.4. Sensory analysis

The sensory properties of the elderberry jam varieties, obtained following the analysis performed by 20 non-specialized tasters, are presented in Figure 2.

The entire range of jam varieties received strong positive ratings from the non-specialized tasters, with mean scores from 4.5 and above, across all measured sensory characteristics.

A high degree of uniformity was observed in the appraisal of fundamental attributes, with appearance, color, and fruit consistency registering mean scores of 4.55, 4.65, and 4.60, respectively, across all samples. Furthermore, the inclusion of essential oils significantly enhanced the perceived quality; these variants demonstrated superior scores in taste, flavor, odor, and general acceptance compared to the control (EJ).

The assortment EJG was the highest-rated product, achieving mean scores of 4.70 (taste), 4.80 (odor), 4.85 (flavor), and 4.80 (overall acceptability).

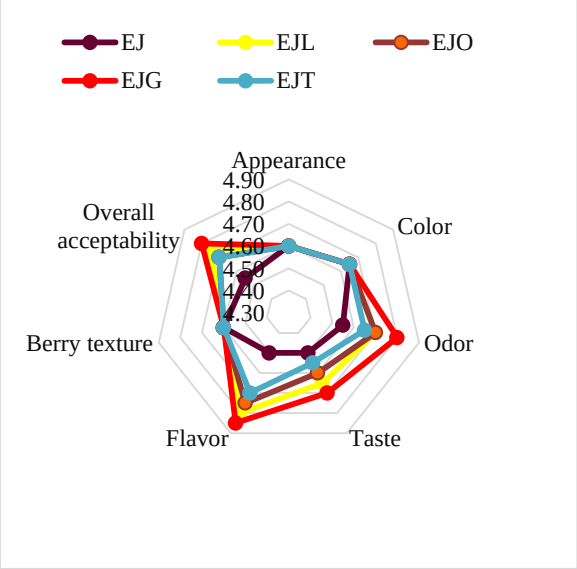

Figure 2. - The global values of the sensory evaluation of elderberry jams

4. Conclusion

Five distinct elderberry jam formulations were developed for this study: a control sample (EJ, plain) and four experimental variants supplemented with various citrus essential oils—lemon (EJL), orange (EJO), grapefruit (EJG), and tangerine (EJT). The resultant products underwent comprehensive analysis, including the assessment of vitamin C concentration, total polyphenol content, DPPH radical scavenging activity (RSA), proximate composition, energy value, and sensory attributes.

No significant inter-sample differences were observed concerning ascorbic acid concentration. However, the total polyphenol content was significantly elevated in all variants incorporating essential oils. The most substantial increase was documented in the EJG, followed by EJL.

Furthermore, RSA exhibited a direct proportional correlation with the total polyphenol content. All essential oil-enriched samples registered higher RSA values compared to the control (EJ). The most pronounced antiradical activity was recorded in EJG, with EJL variant demonstrating the second highest activity.

The findings derived from the sensory analysis indicated a consistently high degree of acceptability across all jam variants for every characteristic evaluated. Specifically, the variants supplemented with essential oils significantly outperformed the control, achieving the highest scores. These preference ratings established a clear hierarchy

among the experimental samples, observed in descending order as follows: EJG > EJL > EJO > EJT.

Enhancing elderberry jam with citrus essential oils not only deepens its flavor profile but also significantly increases its polyphenol content and antioxidant capacity. Consequently, the incorporation of these oils is recommended to yield an elderberry jam exhibiting enhanced organoleptic properties and superior health benefits compared to traditional formulations. It is noteworthy that the grapefruit essential oil exhibited the most pronounced positive impact on the improvement of the final product's antioxidant and organoleptic characteristics.

Conflicts of interest / Competing interests: No conflict of interest

Ethics approval: No ethic situation.

Availability of data and material: The data have been reviewed depending on the literature.

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