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Development, quality assessment, and antioxidant properties of fruit gels made from cornelian cherries

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Abstract

This research aimed to: a) explore how to produce fruit gels of consistent quality using cornelian cherry and different gelling agents, b) assess the nutritional and sensory qualities of the gels, and c) analyze their phenolic composition and antioxidant activity. Agar and pectin were tested as gelling agents to modify gel consistency. To achieve high-quality fruit gels, the study monitored the sensory attributes and quality parameters of the samples and adjusted the recipe accordingly. When the appropriate quality was achieved, the selected samples were subjected to more detailed analyses: basic chemical properties (moisture, soluble dry matter, total sugars, total ash, total acidity, and pH), sensory qualities (appearance, color, consistency, aroma, and taste), and the content of total polyphenols, flavonoids, flavonols, flavan-3-ols, anthocyanins, and antioxidant activity. The samples produced with 1.4% agar (GA4) and 1.2% pectin (GP3) had the highest quality with a moderately firm and homogeneous consistency suitable for bakery and confectionery applications. The agar-based fruit gel had significantly higher levels of total polyphenols, flavonoids, flavan-3-ols, and anthocyanins, as well as higher antioxidant activity compared to the pectin-based gel.

Keywords: cornelian cherry, gelling agents, quality, bioactivity

1. INTRODUCTION

Different consumers tastes, changes in their wishes, eating habits and needs, development of new technologies, and intense market competition represent guidelines for new food products development and the modification and improvement of existing ones. The new products development means complex and interconnected activities, which may include the development of a new recipes and the introduction of new technologies (Aramouni & Deschenes 2015). Consumers expect safe product with appropriate nutritional and sensory quality, but also affordable. Consumers demand for products with a positive impact on health is growing. Therefore, it is necessary that the new product has better nutritive composition, sensory, antioxidative and other properties compared to the existing ones (Grujić & Odžaković 2016). Cornelian cherry fruit is a significant source of bioavailable nutrients and phytochemicals, of which phenolic compounds make up about 37% (Szczepaniak, Kobus-Cisowska, Kusek, & Przeor 2019) including flavonoids, flavonols, anthocyanins, phenolic acids and other compounds that show a wide range of biological effects and contribute to the antioxidant activity of this fruit (Martinović & Cavoski 2020; Milenkovic-Andjelkovic et al. 2015; Odžaković et al. 2021). Antioxidant activity is a substantial factor in the evaluation of the nutritional value of fruit. In addition to biological activity and many protective effects, phenolic compounds contribute to the formation of certain sensory characteristics of cornelian cherry (Bajić-Ljubičić 2018), which significantly affects the sensory quality of products that can be made from this fruit. Despite the beneficial nutritive composition and suitability for processing, cornelian cherry is rarely and insufficiently used as a raw material in the food industry. Fruit gels stand out due to their specific consistency, which is achieved by using different gelling agents. Pectin is most often used in the food industry as a gelling agent, but agar, carrageenan, alginates and some other can also be used. In addition, sugar and acids, in

a certain ratio, are responsible for the formation of the appropriate gel consistency (Tsykhanovska, Yevlash, Trishch, Lazarieva, & Alexandrov 2021). The aim of this research was to: a) explore how to produce fruit gels of consistent quality using cornelian cherry and different gelling agents, b) assess the nutritional and sensory qualities of the gels, and c) analyze their phenolic composition and antioxidant activity.

2. MATERIALS AND METHODS

2.1. Ingredients and methodology of fruit gels preparation

For the production of gels, cornelian cherry fruit (harvested in Drvar, Bosnia and Herzegovina, altitude: 789 m; latitude: 44°31'1.30"; longitude: 16°28'30.7") blended into pulp, white table sugar, tap water and gelling agents: pectin (High methoxyl pectin E440i, Cagrill, Germany) and agar (Gelagar CH5+, B&V The Agar Company Hydrocolloids & food stabilizers, Parma, Italy) were used. The samples were produced in laboratory conditions, the necessary amounts of ingredients were weighed, solutions of gelling agents were prepared, fruit pulp and water were heated to boiling, and then pectin solution, i.e. agar solution and finally sugar were added. After the pasteurization of the product, the quality parameters were controlled (soluble dry matter and total acidity), then the samples were poured into jars and after cooling to room temperature, stored in the refrigerator at +4 °C. Gels with optimal quality selected based on the results of sensory analysis (fruit gel with agar and fruit gel with pectin) were prepared again and subjected to a more detailed quality analysis: determination of the basic chemical composition and descriptive sensory analysis. The content of biologically active components and the antioxidant activity of the selected samples were also determined.

2.2. Determination of basic chemical composition of fruit gels

For basic chemical composition of selected fruit gels, moisture content, soluble dry matter at 20 °C, total sugars and total ash content, total acidity and pH value were determined (AOAC 2000). All analyzes were performed with three replicates.

2.3. Sensory analysis of fruit gels

Sensory analysis of the samples, in which 12 trained evaluators participated, was performed in the laboratory for sensory analysis of foodstuffs at the Faculty of Technology of the University of Banja Luka. Descriptive sensory analysis was used for qualitative and quantitative determination of selected quality properties (appearance, color, consistency, aroma and taste) of fruit gels and according to the procedures defined by the respective standards (ISO 1994; 2003a; 2003b). The analyzed sensory properties were evaluated descriptively and using grades from 1 (unacceptable quality) to 5 (characteristic quality).

2.4. Preparation of fruit gel extracts

Extraction of fruit gels was obtained by double extraction according to a modified method (Ballesteros, Teixeira, & Mussatto 2014). For first extraction 5 grams of fruit gel samples was transferred with 25 ml of methanol solution (50%) into an Erlenmeyer flask and placed on a thermostratification in a dry thermostat (60 °C, 1h, with occasional stirring), after which the contents were filtered into a 50 ml volumetric flask. For second extraction the obtained precipitate was transferred to an Erlenmeyer flask with 25 ml of acetone solution (50%) and placed on thermostratification (60 °C, 1h, with occasional stirring) after which the contents were filtered. The extracts obtained in this way after the first and second extraction were combined in a 50 ml volumetric flask and the content was topped up with distilled water. The obtained extracts were used to determine the content of total phenols, flavonoids, flavonols and flavan-3-ol, as well as to determine the antioxidant activity of fruit gels with DPPH test and ABTS test. All measurements were performed by UV–vis spectrophotometry (Lambda 25, PerkinElmer, USA) with three replicates.

2.5. Determination of total phenols, flavonoids, flavonols and flavan-3-ol, monomeric and total anthocyanins content of fruit gel extracts

Total polyphenol content were determined by Folin-Ciocalteu spectrophotometric method (Wolfe, Wu, & Liu 2003). Absorbance was measured at a wavelength of 765 nm, and the content of total phenols was expressed as μg of gallic acid in one gram of extract (μg GAE/g of extract). The spectrophotometric pH differential method (Giusti & Wrolstad 2001) was used to determine monomeric and total (monomeric plus polymerized) anthocyanins. Two dilutions of the sample were prepared in 0.025M KCl solution and in 0.4 M sodium acetate solution adjusted respectively to pH 1.0 and 4.5 with HCl. The absorbance of each dilution was measured at 520 and 700 nm against a distilled water blank. The contents of total and monomeric anthocyanins were expressed as mg of cyanidin-3-glucoside per gram of extract (mg CyG/g

extract). Total flavonoids were determined by the spectrophotometric method (Ordonez, Gomez, Vattuone, & Lsla 2006). The yellow color of the solution indicates the presence of flavonoids, and its intensity was measured at a wavelength of 420 nm. Results were expressed as μg quercetin in one gram of extract (μg Qc/g extract). Total flavan-3-ols were determined by the vanillin test, which is based on the reaction of vanillin with free flavan-3-ols, during which a red-colored vanillin adduct is formed (Laličić-Petronijević et al. 2016). Absorbance was measured at a wavelength of 500 nm. The results are expressed as μg of catechin in one gram of extract (μg CAT/g of extract). The AlCl3 method was used to determine total flavonols (Kumaran & Karunakaran 2007). Absorbance was measured at a wavelength of 440 nm. The content of total flavonols is expressed as μg of quercetin in one gram of extract (μg Qc/g of extract).

2.6. Determination of antioxidant activity of fruit gel extracts

The reaction between the sample extracts and the DPPH radical was determined by the spectrophotometric method (Liyana-Pathirana & Shahidi 2005). This test is based on examining the ability of antioxidants to neutralize DPPH radicals. Absorbance was measured at a wavelength of 515 nm. The results are expressed as μg trolox in one gram of extract (μg TE/g extract).

A spectrophotometric method was used to test the ability of the tested samples to neutralize ABTS radicals (ABTS•+) (Re et al. 1999). Absorbance was measured at a wavelength of 734 nm The results are expressed as μg trolox in one gram of extract (μg TE/g extract).

2.7. Statistical analysis

For statistical processing of the results Statistica 12.0 software (StatSoft, Inc., Tulsa, OK, USA) was used. Independent t-test was conducted to assess the significance of differences between mean values, with significance set at $P < 0.05$.

3. RESULTS AND DISCUSSION

In the first part of this experiment, samples of fruit gels were made using agar as a gelling agent in order to achieve the appropriate consistency of the product. To make the first sample GA1, the ingredients were used in the amount shown in Table 1. The soluble dry matter of the obtained product was 39.9%, and the acidity was 0.83%. Based on the descriptive sensory analysis, it was established that the consistency of the sample was too soft, inappropriate for the intended purpose of the product, and the sweetness was too pronounced compared to the acidity. The recipe was modified and GA2 was prepared with a higher content of fruit and a lower content of sugar compared to the first sample. Sample GA2 had almost the same content of soluble dry matter and higher acidity (0.92%). Although the fruit content was increased to 30%, the consistency of the sample was still too soft.

Sample GA3 was prepared according to a modified recipe (Table 1) and had higher soluble dry matter (50.70%), and the acidity was 0.82%. This sample had a firm but plastic consistency and the fruit aroma was less pronounced. After the production of sample GA4, the highest values of soluble dry matter (53.6%) and acidity (0.94%) were established. By correcting the ratio of fruit and sugar, a harmonious ratio of acidity and sweetness was achieved, which resulted in a moderately sweet and refreshing sour taste and the corresponding pleasant aroma of the fruit. Descriptive sensory analysis showed that sample GA4 had a fine, shiny homogeneous structure, an intense red color characteristic for the ripe cornelian cherry color. The consistency of the sample was described as moderately firm, elastic and homogeneous.

In the second part of this experiment, samples of fruit gels were made using pectin as a gelling agent (Table 2). The first sample GP1 was produced with 1.20% pectin. Sensory analysis revealed that sweetness is more pronounced than acidity (acidity = 0.87%), the fruit aroma was mild and insufficiently expressed, and the consistency of the sample was too soft (soluble dry matter = 54.50%). In order to achieve the appropriate consistency, the pectin content was reduced (1.00%) and the sugar content was increased (53.75%), considering that highly esterified pectin was used, which gels with a larger amount of sugar. However, the consistency of this sample (GP2) was also too soft. During the production of the sample GP3, the content of pectin and sugar was corrected, while the amounts of fruit and water remained unchanged (Table 2). Based on the results of the sensory analysis, it was established that the obtained gel was homogeneous with a shiny surface and an intense, full and clear red color. The consistency of the sample was moderately firm and homogeneous. The aroma was assessed as pleasant, pronounced and characteristic. The taste of the product was full, refreshing with a harmonious balance between acidity and sweetness.

Fruit gels with the best quality were selected for more detailed analysis which included determination of basic chemical composition, sensory analysis with 12 selected and trained panelists and determination of polyphenolic compounds content and antioxidant activity of selected samples GA4 and GP3. After new production and conditioning of samples (24 hours at room temperature ~20

Table 1. Quality parameters of cornelian cherry fruit gels with agar.

Samples	Cornelian cherry (%)	Sugar (%)	Agar (%)	Water (%)	Realized quality parameters	
					Soluble dry matter (%)	Acidity (%)
GA1	25.0	33.75	1.0	50.25	39.9	0.83
GA2	30.0	32.3	1.0	56.7	39.8	0.92
GA3	25.0	43.35	1.4	40.25	50.7	0.82
GA4	30.0	47.3	1.4	31.3	53.6	0.94

Table 2. Quality parameters of cornelian cherry fruit gels with pectin.

Samples	Cornelian cherry (%)	Sugar (%)	Pectin (%)	Water (%)	Realized quality parameters	
					Soluble dry matter (%)	Acidity (%)
GP1	25.00	48.55	1.20	35.25	54.50	0.87
GP2	25.00	53.75	1.00	30.25	57.70	0.78
GP3	25.00	53.55	1.20	30.25	58.70	0.88

Table 3. Basic chemical composition of selected cornelian cherry fruit gels.

Samples	Moisture (%)	Soluble dry matter (%)	Total sugars (%)	Total ash (%)	Total acidity (%)	pH value
GA4	46.41 ± 0.40	52.73 ± 0.06	51.66 ± 0.05	0.15 ± 0.01	0.92 ± 0.02	2.85 ± 0.01
GP3	40.16 ± 0.36	58.92 ± 0.21	57.91 ± 0.05	0.14 ± 0.00	0.87 ± 0.02	2.89 ± 0.01
t value	-20.045	40.746	160.192	-1.502	-4.899	-2.500
P value	0.000	0.000	0.000	0.207	0.008	0.067

Data are presented as mean ± standard deviation. $P < 0.05$ - the means in the same column are significantly different according to *t*-test.

°C), they were stored in a refrigerator at +4 °C until analysis. Results of chemical analysis (Table 3) showed that cornelian cherry fruit gel with agar (GA4) had significantly higher content of moisture and significantly lower content of total sugars ($P < 0.05$) compared to fruit gel with pectin (GP3). The sugar content primarily comes from added sugar and partially from sugar from cornelian cherry. Total acidity was significantly higher ($P < 0.05$) in GA4 sample. Acidity of samples comes exclusively from cornelian cherry. By modifying the ratio of fruit and sugar, a harmonious taste of acidity and sweetness was achieved. Cornelian cherry is rich in acids and has high acidity (2.71 – 4.03%) (Odžaković et al. 2022), therefore, it was not necessary to add citric acid for correction. The total ash content was approximately equal in both samples ($P > 0.05$).

According to the results of the descriptive sensory analysis (Table 4), both cornelian cherry fruit gel with agar and cornelian cherry fruit gel with pectin were evaluated as samples with excellent quality and in accordance with the defined quality. The color of the product takes special attention because it is the first characteristic that consumers notice and on which it often depends whether the product will be consumed or not. Sensory analysis revealed that both samples retained the pure, full and intense red color of the fresh cornelian cherry fruit, without undesirable darkening. The moderately firm and homogeneous consistency imbued with a fine shine has determined the purpose of these products for filling and decoration in the bakery and confectionary industry. The aroma was pleasant, characteristic for cornelian cherry fruit and slightly more pronounced in GA4 sample ($P > 0.05$). The harmonious ratio of acidity and sweetness influenced the pleasant and refreshing impression in the mouth during the evaluation of both samples.

Sample GA4 had statistically higher ($P < 0.05$) content of total polyphenol, total flavonoid and total flavan-3-ol comparing to sample GP3 (Table 5). The content of monomeric and total anthocyanins was also statistically higher ($P < 0.05$) in the fruit gel produced with agar compared to the fruit gel produced with pectin. On the other hand, the content of total flavonol was statistically higher ($P < 0.05$) in sample GP3. Both samples showed higher antioxidant activity measured by the DPPH test compared to the ABTS test. Sample GA4 had higher antioxidant activity ($P > 0.05$) than sample GP3 according the results of both tests.

Table 4. Descriptive sensory analysis of selected cornelian cherry fruit gels.

Samples	Appearance	Color	Consistency	Aroma	Taste
GA4	4.60 ± 0.42	4.75 ± 0.45	4.54 ± 0.40	4.88 ± 0.31	4.63 ± 0.48
GP3	4.88 ± 0.23	4.96 ± 0.14	4.71 ± 0.45	4.67 ± 0.39	4.79 ± 0.26
t value	1.915	1.520	1.000	-1.449	0.983
P value	0.069	0.143	0.328	0.161	0.336

Data are presented as mean ± standard deviation. $P < 0.05$ - the means in the same column are significantly different according to *t*-test.

Table 5. Content of polyphenolic components and antioxidant activity of cornelian cherry fruit gel extracts.

Parameters	GA4 extract	GP3 extract	*t* value	*P* value
Total polyphenol content (μg GAE/g of extract)	1060.899 ± 75.45	927.857 ± 17.01	2.793	0.049
Monomeric anthocyanin content (μg CyG/g of extract)	97.299 ± 4.45	73.475 ± 3.72	-7.119	0.002
Total anthocyanin content (μg CyG/g of extract)	122.681 ± 7.02	94.404 ± 4.45	-5.898	0.004
Total flavonoid content (μg Qc/g of extract)	85.284 ± 5.65	68.366 ± 4.45	3.536	0.024
Total flavan-3-ol content (μg CAT/g of extract)	0.982 ± 0.16	0.663 ± 0.04	3.339	0.029
Total flavonol conтent (μg Qc/g of extract)	20.08 ± 0.14	20.57 ± 0.15	0.935	0.016
DPPH (μg TE/g of extract)	1153.16 ± 81.22	1051.55 ± 44.92	-1.896	0.131
ABTS (μg TE/g of extract)	1035.22 ± 61.09	936.57 ± 17.06	-2.693	0.054

Data are presented as mean ± standard deviation. $P < 0.05$ - the means in the same row are significantly different according to *t*-test.

4. CONCLUSION

The study demonstrated that high-quality fruit gel can be produced from cornelian cherry fruit by adding either agar (sample GA4) or pectin (sample GP3), keeping in mind that specific recipe parameters were carefully balanced. By adjusting the ratios of the basic ingredients, a moderately firm and uniform fruit gel structure was achieved, making these gels suitable for use in bakery and confectionery applications for filling and decoration. The gels offer a full, refreshing aroma and well-balanced taste of acidity and sweetness that can enhance bakery and confectionery products. Notably, fruit gel made with agar contains less sugar and more fruit compared to the pectin-based gel. Additionally, the agar-based gel has significantly higher levels of total polyphenols, flavonoids, flavan-3-ols, and both monomeric and total anthocyanins, along with greater antioxidant activity compared to the pectin-based gel.

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