Phenol composition, DPPH radical scavenging and antimicrobial activity of Cornelian cherry (*Cornus mas*) fruit and leaf extracts

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Abstract

Fruit is rich in different phenolic compounds which are recognized as potential natural medicaments and have been used in folk medicine for centuries. In order to evaluate phenol composition, the Cornelian cherry (*Cornus mas*) fruit and leaf extracts were subjected to the spectrophotometric and HPLC analysis. The radical scavenging activity was estimated using DPPH test and antimicrobial activity by disc diffusion and microwell dilution tests. All extracts showed high phenol content from 89.89±0.45 to 117.34±1.40 mg of gallic acid equivalents GAE/g extract dry matter (DM), but different composition of phenol compounds. Flavonols, anthocyanins, flavan-3-ols and phenolic acids were the main phenol classes found in the investigated fruit and leaf extracts. All extracts showed significant radical scavenging activity and a correlation with total phenol content (R^2 = 0.9832). Significant antimicrobial activity was found against Gram-positive, followed by Gram-negative strains, and yeast in all tested extracts. Cornelian cherry fruit and leaf extracts, rich in phenolic content, with significant antiradical and antimicrobial activity, can be used as additives in food and medicaments.

Keywords: Cornelian cherry, phenols, anthocyanins, radical scavenging activity, antimicrobial activity.

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Phenolic compounds are produced by plants, both edible and inedible, as a response to the environmental stress and pathogens. They are present in all plant parts in different quantities, depending on the stage of plant development and the environment influence. Phenolic compounds are mainly represented by anthocyanins, phenolic acids, flavan-3-ols and flavonols. These compounds are recognized as potential antioxidant agents with possible applications as food and medical ingredients. Fruit is recognized as plants which are rich in different phenolic compounds and have been used in folk medicine for centuries [1–3].

Cornelian cherry was recognized as a medical plant from ancient times, mainly due to its astringent properties. Traditionally, the Cornelian cherry was applied for treatment of fevers (bark, shoots and root), diarrhea (fruit) and its leaves against diarrhea and diabetes [3]. Today, it can be used for various ailments: stomach aches and cramps, diarrhea, different skin infections, intestinal parasites and hemorrhoids.

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There have been many studies on antioxidant [4–17], anti-cancer, anti-inflammatory [18], antimicrobial activities [1,4,5,9] of berry fruit extracts which are rich in phenol content [1–13]. However, there is less research on antioxidant activity and phenol content of Cornelian cherry fruit [6,9,14,15] and leaf extracts [16,17] . Antimicrobial activity of Cornelian cherry fruit was partially described [9,18,19] and there are no research papers on Cornelian cherry leaf extracts.

The objectives of this study were first to identify phenolic compounds of Cornelian cherry (*Cornus mas*) berry fruit and leaf extracts from Southeast Serbia for two consecutive seasons and then to determine their radical scavenging and antimicrobial potentials.

MATERIALS AND METHODS

Samples

Cornelian cherry (*Cornus mas*) fruit and leaf samples were collected at the maturity stage of fruit from Southeast Serbia for two consecutive seasons (2012 and 2013). Fruit and leaf samples were washed and dried at 60 °C. Dried samples were crushed in a grinder for 2 min and then used for extractions.

Reagents and chemicals

Methanol, acetonitrile and formic acid of HPLC--grade were obtained from Merck (Darmstadt, Germany). The standard phenolic compounds and 2,2'--diphenyl-1-picrylhydrazyl (DPPH) free radical were supplied from Sigma Chemical Co. (St. Louis, MO). Nutrient agar and nutrient broth were purchased from Merck and all other chemicals from Sigma. The reagents used were of analytical quality.

Bacterial strains and yeast

The antimicrobial activity of the test samples was evaluated using the following laboratory control strains: *Clostridium perfringens* ATCC 19404, *Bacillus cereus* ATCC 8739, *Listeria monocytogenes* ATCC 7644, *Staphylococcus aureus* ATCC 8538, *Sarcina lutea* ATCC 9341 and *Micrococcus flavus* ATCC 40240 (Gram (+) bacteria), *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 9027, *Salmonella enteritidis* ATCC 13076, *Shigella sonnei* ATCC 25931, *Klebsiella pneumoniae* ATCC 10031 and *Proteus vulgaris* ATCC 8427 (Gram (–) bacteria) and *Candida albicans* ATCC 10231 (Yeast) obtained from the American Type Culture Collection. The inocula of the bacterial strains and yeast were prepared from overnight broth cultures, and the suspensions were adjusted to 0.5 McFarland standard turbidity (corresponding to 10^7–10^8 CFU/ml).

Extraction procedures

The samples of dry berries and leaves (0.5 g DW) were extracted with 40 ml solvent system of methanol/acetone/water/formic acid (30/42/27.5/0.5) by stirring continuously at room temperature in the dark for 30 min, and then centrifuged for 10 min at 2500×*g*. The supernatants were collected and the precipitates were extracted again with the same solvent (40 ml). The extracts were centrifuged (10 min at 2500×*g*) and the supernatants were removed and combined with the previously collected supernatants and made up a final volume of the extracts. These extracts were evaporated under vacuum rotary evaporator and diluted in 10 ml methanol. Extracts were filtered through a 0.45 µm syringe filter before analysis.

Determination of phenols

Total phenols, hydroxycinnamoyl acids and flavonols in tested extracts were determined according to previously described spectrophotometric method [9]. Results were expressed as milligrams (mg) of gallic acid equivalents (GAE) for total phenols, mg of caffeic acid equivalents (CAE) for total hydroxycinnamoyl acids and mg of quercetin equivalents (QE) for total flavonols per g of extract dry matter (DM).

Total anthocyanins were determined also spectrophotometrically [11]. Malvidin-3-glucoside was employed as a calibration standard and results were expressed as mg malvidin-3-glucoside equivalents (ME) per g of extract DM.

Phenol composition of selected extracts was analyzed by high performance liquid chromatography (HPLC). The apparatus used for separation and determination of individual phenols from leaf extracts was an Agilent Technologies 1200 chromatographic system, equipped with an Agilent photodiode array detector (DAD) 1200 with RFID tracking technology for flow cells and UV lamp, an automatic injector, and ChemStation software. The column was thermostated at 30 °C. The separation was performed on an Agilent-Eclipse XDB C-18 4.6 mm×150 mm column. The HPLC method used was according to previously described [10] with some modifications. Briefly, the HPLC grade solvents used were formic acid/water (5:95, *V*/*V*) as solvent A and acetonitrile/formic acid/water (80:5:15, *V*/*V*) as solvent B. The elution gradient was linear as follows: from 0 to 10 min, 100% A + 0% B, from 10 to 20 min, 90% A + 10% B, from 20 to 30 min, 75% A + 25% B, from 25 to 35 min, 60% A + 40% B, from 35 to 40 min, 50% A + 50% B, from 40 to 45 min, 20% A + 80% B, and for last 10 min again 100% A + 0% B. The injection volume was 5 µl and the flow rate was 0.8 ml/min. The detection wavelengths were 280, 320, 360 and 520 nm for UV, and 275/322 nm ($\lambda_{Ex}/\lambda_{Em}$) for fluorescence-detection. The different phenolic compounds were identified by comparing their retention times and spectral characteristics with data of original reference standard compounds and with data given in the literature [9–11]. The calibration curves (five data points, n = 2) were linear with R^2 = 0.99. Results were expressed as mg/g extract DM.

DPPH test

The antioxidant activity of all investigated extracts was estimated determining the free radical scavenging activity of extracts by previously described DPPH test [11]. The radical scavenging activities of investigated extracts were expressed as median efficient concentrations (EC_{50}). This is the concentration of extract (mg/ml) necessary for a decrease in absorbance of DPPH solution to 50%.

Determination of antimicrobial activity

Preliminary antimicrobial tests were carried out by disc diffusion method [9] using 100 µl of bacterial suspension spread on Mueller–Hinton agar (MHA, Torlak, Serbia) in sterilized Petri dishes (90 mm in diameter). The discs (9 mm in diameter, HiMedia Laboratories Pvt. Limited) were impregnated with 50 µl of the testing samples, and placed on the inoculated agar (20 ml). The inoculated plates were incubated for 24 h at 37 °C. Reference antibiotic, tetracycline (30 µg/disc) served as a positive control, while the solvent (methanol, 50

µl/disc) was used as a negative control. Antibacterial activity was evaluated by measuring the zone of inhibition (in mm) against the test bacterial strains. A broth microdilution method [9] was used to determine the minimum inhibitory concentration (*MIC*) and minimum bactericidal concentration (*MBC*). Serial doubling dilutions of the testing samples were prepared in a 96/well microtiter plate over the range of 1500–0.25 µg/ml in inoculated nutrient broth (the final volume 100 µl and the final bacterial concentration was 10^6 CFU/ml in each well). Two growth controls consisting of medium with methanol (negative control) and medium with tetracycline (positive control) were also included. The microbial growth was determined by absorbance at 620 nm using the universal microplate reader (ThermoLabsystems, Multiskan EX, Software for Multiscan, ver. 2.6.). MIC was defined as the lowest concentration of test samples at which microorganisms showed no visible growth. The *MBC* is defined as the lowest concentration of the test samples at which 99.9% of inoculated microorganisms were killed.

Statistical analysis

All the experiments were performed in triplicate. Values are presented as means ± standard deviation. Significant differences were determined by analysis of variance (ANOVA), followed by the Tukey's test.

RESULTS AND DISCUSSION

Phenol content of fruit and leaf extracts

The results of the spectrophotometric analysis of Cornelian cherry fruit and leaf extracts are shown in Table 1.

Leaf extracts showed significant higher total phenol, hydroxycinnamoyl acid and flavonol content than fruit extracts. On the other hand fruit extracts were rich in anthocyanin content. Also, there were no significant differences in phenolic content during two consecutive seasons. Others also found significant phenol and anthocyanin content in Cornelian cherry fruits [14,15]. Some authors found higher total phenolic content [18] and others lower in Cornelian cherry leaf extracts [19]. This can be explained by different genotypes, environmental conditions and extraction procedures.

In order to determine more accurately phenolic content and composition in investigated extracts, the HPLC method was used. The selected method allows analysis of extracts without changing the chromatographic conditions by recording at 280, 320, 360 and 520 nm on DAD detector and at 275/322 nm (*Ex*/*Em*) on a fluorescent detector. Results (Table 2) are in good agreement with those obtained by spectrophotometric determination (Table 1). The results showed quite various phenolic compositions, which belong mainly to the following phenol classes: phenolic acids, flavonols, flavan-3-ols and anthocyanins (Table 2).

Few data exist about phenol acid, flavonol and anthocyanin composition [6,14,15] and there are no studies about flavan-3-ol composition in Cornelian cherry fruits except in previously described study for the acidified methanol extracts [9]. The (+)-catechin was predominant falavan-3-ol in fruit extracts, followed by (–)-epicatechin and procyanidin B2, while in leaf extracts (–)-epicatechin was predominant and procyanidin B2 was not found. The presence of these compounds was reported by Vagiri *et al*. in blackcurrant leaf extracts [20] and Buricova *et al*. in blackberry and raspberry leaf extracts [8].

Fruit extract showed slightly higher amount of phenol acids than leaf extracts. Ellagic acid was predominant phenol acid in all extracts, followed by chlorogenic and gallic acids. Others also reported the presence of gallic and ellagic acids in cornelian cherry fruit [6].

Leaf extracts showed significant higher amount of flavonol than fruit extracts. Flavonol compounds found in tested extracts were quercetin-3-glucoside, rutin, quercetin-3-galactoside, luteolin-3-glucoside and kaempferol-3-glucoside. Some authors reported the presence of quercetin and kaempferol derivates in Cornelian cherry fruit extracts [6,14]. The kaempferol-3--glucoside and rutin were predominant flavonols in fruit extracts while quercetin-3-glucoside was less abundant and luteolin-3-glucoside was not detected. On the other hand quercetin-3-glucoside was predominant flavonol in leaf extracts followed by rutin, kaempferol-3-glucoside and luteolin-3-glucoside. The high concentration of quercetin and kaempferol in leaves of *Rosa* L. species was reported [7] and also for *Rubus* L. [8,21].

Table 1. Total phenol, hydroxycinnamoyl acid and flavonol contents (mg/g DM) and radical scavenging activity, EC_{50}, of Cornelian cherry fruit and leaf extracts determined by spectrophotometric analysis; Data are expressed as mean ± SD (n = 3); nd – not detected; means in the same column bearing different superscripts are significantly different (p < 0.05), as analyzed by the Tukey's test

Extract	Year	Total phenols	Hydroxy-cinnamoyl acids	Flavonols	Anthocyanins	EC_{50} / mg ml^{-1}
Fruit	2012	89.89±0.45^b	4.45±0.06^a	4.17±0.08^b	15.5±0.18^b	1.09±0.50^b
	2013	91.12±0.59^b	4.33±0.06^a	4.29±0.08^b	16.1±0.27^b	0.94±0.34^b
Leaf	2012	112.91±1.40^a	4.17±0.08^a	32.77±0.19^a	nd	0.58±0.13^a
	2013	117.34±1.40^a	4.23±0.16^a	35.19±0.32^a	nd	0.47±0.09^a

Table 2. Phenol composition (mg/g DM) of Cornelian cherry fruit and leaf extracts determined by HPLC analysis; data are expressed as mean ± SD (n = 3); nd – not detected; means in the same row bearing different superscripts are significantly different (p < 0.05), as analyzed by the Tukey's test

Phenolic compound	Fruit		Leaf	
	2012	2013	2012	2013
Gallic acid	0.57±0.08[a]	0.62±0.10[a]	0.41± 0.02[b]	0.37± 0.04[b]
Ellagic acid	2.08±0.15[b]	2.11±0.13[b]	2.55±0.04[a]	2.62±0.11[a]
Chlorogenic acid	0.87±0.14[a]	0.85±0.11[a]	0.28±0.03[b]	0.33±0.07[b]
Σ Phenolic acids	3.52±0.12[a]	3.58±0.11[a]	3.24±0.05[a]	3.32±0.08[a]
Quercetin-3-glucoside	0.22±0.06[b]	0.20±0.04[b]	9.28±0.21[a]	9.37±0.33[a]
Quercetin-3-galactoside	0.54±0.07[a]	0.57±0.09[a]	nd	nd
Rutin	0.76±0.11[b]	0.81±0.12[b]	6.11±0.11[a]	6.09±0.23[a]
Luteolin-3-glucoside	nd	nd	0.11±0.01a	0.15±0.04a
Kaempferol-3-glucoside	1.06±0.24[b]	1.11±0.20[b]	4.27±0.10[a]	4.37±0.19[a]
Σ Flavonols	2.58±0.16[b]	2.69±0.15[b]	19.77±0.11[a]	19.98±0.22[a]
(+)-Catechin	3.95±0.77[a]	3.91±0.68[a]	2.22±0.07[b]	2.28±0.11[b]
(–)-Epi-catechin	2.02±0.64[b]	2.11±0.71[b]	4.07±0.15[a]	4.15±0.14[a]
Procyanidin B2	1.61±0.34[a]	1.55±0.28[a]	nd	nd
Σ Flavan-3-ols	7.58±0.51[a]	7.57±0.42[a]	6.29±0.11[b]	6.43±0.13[b]
Cyanidin 3-galactoside	3.21±0.14[a]	3.27±0.12[a]	nd	nd
Pelargonidin 3-glucoside	10.16±0.94[a]	10.23±1.03[a]	nd	nd
Delphinidin-3-galactoside	0.49± 0.12[a]	0.53± 0.16[a]	nd	nd
Σ Anthocyanins	13.86±0.46[a]	14.03±0.67[a]	nd	nd

Cyanidin-3-galactoside, pelargonidin-3-glucoside and delphinidin-3-galactoside were anthocyanins which were found only in fruit extracts (Table 2). Our results of the anthocyanin qualitative composition were similar with those previously described [6,14]. Pelargonidin-3-glucoside was the predominant anthocyanin, followed by cyanidin-3-galactoside. Delphinidin-3-galactoside was the least abundant one and present only in 3%. The seasonal differences in the anthocyanin composition of fruit extracts can be explained by environmental conditions during the fruit development [11].

Radical scavenging activity of fruit and leaf extracts

Radical scavenging activity of investigated extracts was estimated by the DPPH test. The results are shown in Table 1, expressed as EC_{50} values (mg/ml). Lower EC_{50} values correspond to higher radical scavenging activity of extracts. All extracts showed strong radical scavenging activity, ranged from 0.47±0.09 for leaf to 1.09±0.50 mg/ml for fruit extracts. Leaf extracts showed higher radical scavenging activity than fruit extracts. Strong radical scavenging activity of leaf extracts, corresponding to their high phenol content, suggests that the phenolic compounds at least partially are responsible for the strong radical scavenging activity of these extracts. The significant correlation was found between radical scavenging activity and total phenol content (R^2 = 0.9832). The literature data also confirm the presence of correlation between radical scavenging activity and total phenol content of Cornelian cherry extracts [6,15–17]. We also found correlation between radical scavenging activities and the individual classes of phenols, but lower than with total phenol content (flavonols) and negative correlation for flavan-3-ols and phenolic acids. The HPLC analysis showed that extracts of fruit and leaf are a wide mixture of phenolic, and other compounds such as ascorbic acid and carotenoids not identified in this study. It is possible that these constituents may interact to produce synergistic or antagonistic antioxidant effects with each other and with other compounds [7,22].

Antimicrobial activity of fruit and leaf extracts

The antimicrobial activity data for all investigated extracts and tetracyclin – antibiotic (positive control) against 13 microbial species are given in Tables 3 and 4 (inhibition zones and *MIC*/*MBC* values). Methanol (negative control) did not show any inhibitory effects on the 13 microbial species. All extracts tested by disc diffusion method showed significant antimicrobial activity against Gram-positive, Gram-negative strains and yeast (Table 3). The leaf extracts showed higher antimicrobial activity than fruit extracts. Antimicrobial activity of these extracts can be connected with their high total phenol content. The existing correlation between total phenol content and antimicrobial activity of plant extracts also was reported by others [3–5]. There are some reports about quite different antimicrobial acti-

Table 3. Antimicrobial activities (inhibition zone diameters, mm) of fruit leaf extracts (50 µl/disc) and reference antibiotics (30 µg/disc) against Gram-positive strains, Gram-negative strains and yeast; data are expressed as mean ± SD (n = 3); Te. – tetracyclin; nd – not detected

Strain	Fruit		Leaf		Te.
	2012	2013	2012	2013	
Gram-positive strains					
Clostridium perfringens	14.4±2.0	14.7±1.3	19.2±1.3	19.5±1.2	29.0±2.0
Bacillus cereus	15.3±1.2	15.9±1.0	18.8±1.3	18.7±1.1	23.9±1.0
Staphylococcus aureus	16.5±2.0	16.7±1.4	18.2±1.2	18.6±1.1	18.5±1.3
Listeria monocytogenes	15.1±1.8	15.5±1.1	16.1±1.3	16.7±1.4	18.7±1.2
Sarcina lutea	16.7±1.8	16.9±1.7	17.0±1.4	17.5±1.2	20.0±1.2
Micrococcus flavus	14.3±1.8	14.1±1.5	15.2±1.1	15.9±1.3	23.6±0.7
Gram-negative strains					
Escherichia coli	13.8±0.9	14.2±0.5	14.1±1.2	14.5±0.9	23.2±1.2
Pseudomonas aeruginosa	12.6±2.4	12.7±1.4	15.6±1.3	15.9±1.2	20.8±1.5
Salmonella enteritidis	14.3±3.1	14.6±2.3	15.2±1.1	15.2±1.5	23.3±1.3
Shigella sonnei	15.4±2.5	15.8±2.0	17.6±1.3	17.8±1.1	31.1±0.8
Klebsiella pneumoniae	12.49±1.1	13.01±1.3	16.6±1.1	16.9±1.2	23.6±0.6
Proteus vulgaris	14.4±1.9	14.6±1.5	16.0±1.2	16.3±1.1	16.0±1.2
Yeast					
Candida albicans	14.7±2.2	14.7±2.2	15.1±1.0	15.3±1.1	19.2±0.5

vity of Cornelian cherry fruit extracts in different solvent [18,19]. This can be explained by using different extraction conditions and also with the fact that the disc diffusion test can give us approximate results of antimicrobial activity of these extracts. In order to know *MIC*/*MBC* values of (Table 4) we used a more precise broth microdilution method. Investigated extracts were meanly more sesitive on Gram-positive strains compared to Gram-negative strains and yeast, which is in agreement with literature data [9,18,19]. *Sarcina lutea, Listeria Monocytogenes* and *Staphylococcus aureus* were the most sensitive Gram-positive strains, and *Shigella sonnei* and *Salmonella enteritidis* Gram-negative strains for the most investigated Cornelian cherry fruit and leaf extracts.

CONCLUSION

Both methods, spectrophotometric and HPLC confirmed high phenol content in all examined Cornelian cherry fruit and leaf extracts. There were no significant differences in phenolic content during two consecutive seasons. These compounds are responsible for significant antioxidant and antimicrobial activities of fruit and leaf extracts. In this paper, flavan-3-ols were reported for the first time in both, fruit and leaf extracts of Cornelian cherries as well as antimicrobial activity of leaf extracts against 13 species of bacteria strains and yeast. Extracts of the leaves contain considerably more flavonols than fruit extracts. Leaf extract showed higher phenolic content, antiradical and antimicrobial activity than fruit extracts. This allows further work on the combination of different extracts, *i.e.*, phenol compounds in order to obtain the extract with a stronger antimicrobial and antioxidant potential. Simple extraction procedure of these compounds from fruit and leaves opens the possibility for application in the food and pharmaceutical industry.

Table 4. Antibacterial (MIC)/bactericidal (MBC) activities (µg/ml) of fruit berry leaf extracts and reference antibiotic against Gram-positive strains, Gram-negative strains and yeast; Te. – tetracyclin

Strain	Fruit		Leaf		Te.
	2012	2013	2012	2013	
Gram-positive strains					
Clostridium perfringens	63/125	63/63	31/31	16/31	0.9/0.9
Bacillus cereus	31/63	31/63	31/63	31/31	0.9/0.9
Staphylococcus aureus	63/63	31/63	16/31	16/31	0.12/0.9
Listeria monocytogenes	63/63	63/63	16/16	16/16	0.46/0.9

Table 4. Continued

Strain	Fruit		Leaf		Te.
	2012	2013	2012	2013	
Gram-positive strains					
Sarcina lutea	31/31	31/31	16/31	16/31	0.06/0.06
Micrococcus flavus	125/125	63/125	63/63	63/63	0.4/0.9
Gram-negative strains					
Escherichia coli	125/250	125/250	125/250	125/250	3.8/7.5
Pseudomonas aeruginosa	250/250	250/250	63/125	63/125	7.5/7.5
Salmonella enteritidis	63/125	63/63	63/125	63/125	0.9/1.9
Shigella sonnei	125/125	125/125	31/125	31/63	0.06/0.12
Klebsiella pneumoniae	125/125	63/125	63/125	63/125	0.9/1.9
Proteus vulgaris	125/250	125/250	63/125	63/63	0.9/1.9
Yeast					
Candida albicans	250/500	250/500	125/250	125/250	16/16

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IZVOD

FENOLNI SASTAV, AKTIVNOST HVATANJA DPPH RADIKALA I ANTIMIKROBNA AKTIVNOST EKSTRAKATA VOĆA I LIŠĆA DRENA (*Cornus mas*)

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Voće je bogato različitim fenolnim jedinjenjima, koja su prepoznata kao potencijalni prirodni lekovi i koriste se u narodnoj medicini vekovima. U cilju procene fenolnog sastava, ekstrakti voća i lišća drena (*Cornus mas*) podvrgnuti su spektrofotometrijskoj i HPLC analizi. Aktivnost hvatanja (neutralizacije) DPPH radikala procenjena je pomoću DPPH testa, a antimikrobna aktivnost korišćenjem disk difuzionog testa i testa mikro-razblaženja. Svi ekstrakti su pokazali visok sadržaj fenola od 89,89±0,45 do 117,34±1,40 mg/GAE g SM ekstrakta, ali različiti sastav fenonih jedinjenja. Flavonoli, antocijani, flavan-3-oli i fenolne kiseline su bile najzastupljenije klase fenola nađene u ispitivanim ekstraktima voća i lišća. Svi ekstrakti su pokazali značajnu aktivnost hvatanja radikala i značajnu korelaciju sa ukupnim fenolnim sadržajem (R^2 = 0,9832). U svim ispitivanim ekstraktima nađena je značajna antimikrobna aktivnost u inhibiciji gram-pozitivnih, gram-negativneih sojeva i kvasca. Ekstrakti voća i lišća drena bogati fenolima, sa značajnom antiradikalnom i antimikrobnom aktivnošću, mogu se koristiti kao aditivi u hrani i lekovima.

Ključne reči: Dren • Fenoli • Antocijani Aktivnost hvatanja radikala • Antimikrobna aktivnost