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Original scientific paper

Fibre and polyphenols of selected fruits, nuts and green leafy vegetables used in Serbian diet

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Abstract: Fruits and vegetables are known as good sources of numerous bioactive compounds among which polyphenols and dietary fibre are considered essential because of their protective health effects. The aim of this study was to characterize the quality of selected plant foods of Serbia regarding the amount of total phenols, fibres and ratio of certain fractions of fibre. Fifteen samples of plant foods (green leafy vegetables, fruits and nuts) were evaluated for their total antioxidant activity, total phenolic content, total, soluble and insoluble fibre and fractions of fibre: β-glucans, arabinoxylan, cellulose and resistant starch. Generally, nuts were the richest sources of fibre and total phenols. However, when serving size was taken into consideration, it appeared that raspberry and blackberry were the richest in total, soluble fibre and cellulose. Furthermore, almonds and hazelnuts were particularly rich in insoluble fibre, while walnuts had the highest polyphenol content. The analyzed plant foods were poor sources of arabinoxylan and β-glucan. Data on the presence of resistant starch in cashew nut was the first confirmation that resistant starch could be found in significant amount in some nuts. The results give rare insight into the quality of selected plant foods regarding dietary fibre and polyphenols from the nutritive point of view.

Keywords: total fibre; fractions of fibre; total phenols; antioxidant activity.

INTRODUCTION

The importance of fruits and vegetables in human diet is well established. Plant foods are low in fats and energy; they are good sources of vitamins, minerals and polyphenols and provide a significant amount of fibre. All these components are considered to be bioactive ingredients according to a new definition proposed by Guaadaoui *et al.*[1] These properties make them highly recommended for daily diet. When consumed in a proper way, fruits and vegetables offer many health benefits, including reduction of body weight, reduction of the risks of type

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2 diabetes, cardiovascular disease and certain types of cancer.[2] The majority of noticed health benefits of fruits and vegetables are attributed to their bioactive ingredients and their specific combinations.

Total dietary fibre (TDF) is one of the bioactive compounds that are responsible for the protective effects of fruits and vegetables In their study, Ramulu & Rao[3] documented a significant amount of total, soluble and insoluble dietary fibres in fruits and vegetables. In terms of its chemistry, fibre is not a single defined compound but a combination of substances, such as cellulose, hemicelluloses, lignin, arabinoxylans, β-glucan, pectin, *etc*.[4] Different plant foods, even within the same food category, such as nuts, cereals, fruits, have different profiles of fibre fractions. Investigation of the profiles of food fibre is important because soluble and insoluble fibre, as well as individual specific fibre fractions, have distinct physiological effects. Soluble dietary fibre (SDF) reduces plasma glucose levels in diabetic patients, whereas insoluble fibre promotes laxative effects.[5] SDF derived from particular fruits and vegetables decrease serum cholesterol, thus lowering the risk of cardiovascular disease.[6] Soluble and insoluble dietary fibre (IDF) both play roles in cardiovascular risk reduction.[7,8]

Emerging evidence shows that different fibre fractions also have different physicochemical and physiological properties, and consequently express different protective effects. Cellulose is particularly known for its protective role in the development of colon cancer, while others, such as arabinoxylan and β-glucan, are effective as agents for reducing postprandial glucose response.[9] Pectins have hypolipidemic and hypoglycemic activity.[10,11]

Another important component of fruits and vegetables are polyphenols. Red wine, tea, coffee, chocolate and cereals are all sources of polyphenols in daily diet. Polyphenols exhibited anticancer, anti-inflammatory, antimicrobial, antimutagenic, anti-oxidant, and immunostimulant properties in numerous studies.[12]

A specific protective combination of polyphenols and fibres was defined by Saura-Calixto[13] as anti-oxidant dietary fibre (AODF), a natural product capable of combining the beneficial health effects of TDF and natural anti-oxidants, such as polyphenols. It seems that dietary fibre can entrap some polyphenols, thus protecting them from hydrolysis in the upper intestinal area. Such polyphenols entrapped in TDF easily reach the large intestine where they finally are fermented together with TDF. The end products of fermentation are metabolites such as phenylacetic, phenylpropionic, and phenylbutyric acids, which are easily absorbed and may exert systemic effects.[14] The remaining polyphenols that cannot be fermented and/or absorbed in the large intestine and remain unchanged may still contribute to a healthy antioxidant environment by acting as free radical scavengers and counteracting the pro-oxidants derived from food.[15] Foods and natural products that are rich in both fibre and polyphenols are considered to be of high nutritional and protective significance.

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The objective of the present work was to study the characteristics of the fruits and vegetables that are produced and used in daily diet in Serbia regarding their dietary fibre content and profile, as well as polyphenol content and anti-oxidant capacity. The obtained results may be useful in preparing dietary regimes for specific health conditions by enabling the best combinations to be chosen from a broad range of dietary sources of fibre and polyphenols.

EXPERIMENTAL

Plant material

Three independent samples of fresh broccoli, spinach, lettuce, cabbage, parsley, cherry, strawberry, raspberry, blackberry, blueberry, apple, walnut, almond, hazelnut, and cashew nuts were purchased from three open local markets in Belgrade, Serbia, and used for the research. The vegetables, fruits (2.0 kg each), and nuts (300 g each) were randomly sampled. Except for the cashew nuts, the other samples originated from Serbian region.

Preparation of vegetables and fruits samples

Before analysis, the fruit and vegetable samples were washed in deionised water and dried at room temperature. After removal of occasional stalks from the strawberries, raspberries and blackberries, and deseeding of the apples and cherries, all fruit samples were homogenized separately in a blender. Subsequently, the samples were kept at –20 °C until analysed. The nuts were homogenized immediately after purchase and kept at room temperature.

Methods

For the analysis of the total fibre, the fibre fractions, polyphenols and anti-oxidative activity, reliable methods that were adequate according to their accuracy and precision, and are usually employed in similar investigations were used.

Determination of total phenolics

About 1 g of homogenized sample was extracted with methanol (50 mL) using a mechanical shaker for 2 h. The mixture was centrifuged at 10000 rpm for 10 minutes and the supernatant removed and filtered through Whatman No. 1 filter paper. The clear extract was used for phenolic content and antioxidant activity evaluation. The amount of total phenolic content was determined using the Folin–Ciocalteu reagent, as described by Singleton & Rossi (1965).[16] The absorbance was measured at 765 nm against gallic acid as a reference standard. Five calibration curves were prepared for the working solutions of gallic acid (Acros Organic, Lot: A0325987) in the concentration range of 1–10 μg mL^{-1}. The least-squares method was applied to calculate the equations of the lines: $y = (0.087\pm0.001)x + (0.048\pm0.007)$, resulting in a correlation coefficient: 0.9971. The relative standard deviation (*RSD*) of the slopes was 1.84 %, and for 6 μg GA mL^{-1}, *RSD* = 1.46 %.

Results are expressed as mg gallic acid equivalents (mg GAE) per 100 g wet weight of the sample.

Determination of antioxidant activity

The ferric reducing antioxidant power (FRAP) was determined according to Benzie and Strain.[17] Methanol extract prepared in the same way as for determination of the total polyphenols was used. The procedure is based on reduction of the yellow-coloured 2,4,6-tri2--pyridyl-*s*-triazine (TPTZ) complex that yields a blue-coloured end product. The reaction is

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performed at pH 3.6 in order to preserve good iron solubility. The reduction was monitored by measuring the absorbance at 593 nm. A standard curve was constructed using ferrous sulphate solution. The results are expressed as μmol Fe(II) per100 g wet sample.

Five calibration curves were prepared for the working solutions of $FeSO_4$ (Panreac, Lot: 0000491691) in the concentration range of 200–1000 μmol L^{-1}. The least-squares method was applied to calculate the equations of the lines: $y = (0.0009\pm0.001)x + (0.058\pm0.003)$, resulting in a correlation coefficient: 0.9997. The *RSD* of the slopes was 1.20 %, and for 500 μmol L^{-1} $FeSO_4$, *RSD* = 0.98 %.

Determination of D-xylose including xylan and arabinoxylan

D-Xylose, xylan and arabinoxylan were determined by a spectrophotometric method using the enzymatic assay kit K-XYLOSE (Megazyme, Bray, Ireland). The assay was performed according to the instruction manual of the kit producer. The measuring procedure is based on the interconversion of *α*-D-xylose to *β*-D-xylose. Interconversion of the *α*- and *β*-anomeric forms of D-xylose is catalysed by xylose mutarotase. The *β*-D-xylose is oxidised by NAD^+ to D-xylonic acid at pH 7.5 in the presence of *β*-xylose dehydrogenase. The amount of NADH formed in this reaction is proportional (directly correlated) to the D-xylose concentration and is measured by the increase in absorbance at 340 nm. The content of arabinoxylan is then calculated according to the formula:

$$\text{Arabinoxylan} = \text{Content of D-xylose (g/100 g)} \times 100/62 \text{ (g/100 g)}$$

Internal analytic quality control was conducted using reference materials: D-xylose control (Megazyme, Lot 90401a). The repeatability (*RSD*) and recovery of the method were 2.0 and 99.2 %, respectively.

Determination of cellulose guide

Cellulose was determined by the official AOAC 950.37method.[18] The procedure was performed by cooking the sample with alkaline and acidic agents. Cooking in strong acids hydrolyses starch and proteins from the sample while alkaline pH hydrolyses the remaining non-hydrolysed proteins and saponification occurs. Residual raw cellulose was filtered, dried and weighed. Analytical internal quality control was conducted using reference materials: T1061 (FAPAS). The repeatability (*RSD*) and recovery of the method were 2.4 and 98.2 %, respectively.

Determination of total, soluble and insoluble dietary fibre

Samples were analyzed for soluble and insoluble fraction according to an enzymatic––gravimetric procedure (AOAC method 985.29), as described by Prosky *et al.*[19] The method requires phosphate buffer, pH 6.0 and the following enzymes: heat stable *α*-amylase, protease and amyloglucosidase. Heat stable *α*-amylase depolymerises starch, protease depolymerises and dissolves proteins, while amyloglucosidase converts starch into glucose. The total fibre was calculated as the sum of the soluble and insoluble fibre. Analytical internal quality control was conducted using reference materials: T2454 (FAPAS). The repeatability (*RSD*) and recovery of the method were 2.6 and 98.0 %, respectively.

Determination of β*-glucan*

β-Glucan was quantified according to McCleary and Codd[20] by a spectrophotometric method using the enzymatic assay kit K-BGLU (Megazyme, Bray, Ireland). The samples were suspended and hydrated in a buffer solution of pH 6.5 and then incubated with purified lichenase enzyme and then filtered. Afterwards, an aliquot of the filtrate is hydrolysed to completion with purified *β*-glucosidase. The D-glucose produced was assayed using a glucose

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oxidase/peroxidase reagent and measuring the absorbance at 510 nm. Analytical internal quality control was conducted using reference materials: *β*-glucan control (Megazyme, Lot 60301). The repeatability (*RSD*) and recovery of the method were 2.1 and 98.4 %, respectively.

Determination of resistant starch and starch

Resistant starch was quantified according to McCleary and Monaghan[21] by a spectrophotometric method using the enzymatic assay kit RSTAR (Megazyme, Bray, Ireland). The samples are incubated in the presence of *α*-amylase and amyloglucosidase derived from pancreas for 16 h at 37 °C. By the synergistic action of the two enzymes, the non-resistant starch was solubilised and hydrolyzed to glucose. After addition of ethanol, the hydrolysate was centrifuged. The resistant starch (RS) was obtained as a pellet, while the supernatant was used for measurement of the soluble non-resistant starch. The pellet was dissolved in 2 M KOH and the solution was neutralized with acetate buffer. Using amyloglucosidase, the RS was subsequently quantitatively hydrolyzed to glucose, which was, in turn, assayed with glucose oxidase/peroxidase reagent (GOPOD). The absorbance was measured at 510 nm. The soluble non-resistant starch was determined from the supernatant at the same wavelength as the resistant starch. This method offers the results that most approximately reflect the proportion of resistant starch and non-resistant starch *in vivo* and thus could be physiologically relevant. Analytical internal quality control was conducted using reference materials: Resistant Starch Control (Megazyme, Lot: 50904). The repeatability (*RSD*) and recovery of the method were 2.4 and 97.2 %, respectively.

Statistical analysis

The analyses were performed in triplicate. The results are presented as the mean values with the standard deviations.

RESULTS AND DISCUSSION

In this study, 15 samples belonging to 3 food groups, *i.e.*, fresh fruit, green leafy vegetables, and nuts, were investigated for the presence of total dietary fibre, the fibre fraction profile and antioxidant capacity. These food groups were chosen for investigation as they are highly recommended for everyday diet. The analyzed fibre fractions were cellulose and arabinoxylans from the insoluble fibre, and *β*-glucan and resistant starch from the soluble fibre. Data on their presence in plant foods are scarce or non-existent, especially when it comes to food of Serbian origin. Pectins are an important part of fruit fibre, and information on their content and profile in Serbian fruit was previously published.[22] All the selected plant foods were of Serbian origin, except for the cashew nuts.

The results for the contents of fibres are presented in Table I. Although the samples between the groups differed in their water content, the results are presented on a fresh weight basis since it is much easier to use such data to calculate the fibre intake necessary for achieving the desirable physiological effects.

In general, all the analyzed samples proved to be significant sources of dietary fibre. The total fibre contents were within the wide range of 1.09 to 14.88 g 100 g^{-1}. As expected, the total fibre content was the highest in nuts, then in fruits and green leafy vegetables.

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TABLE I. Total, soluble, insoluble and fractional dietary fibre contents (g per 100 g fresh weight) in the analysed samples; n.d. – non detected; data are expressed on the original weight basis and presented as mean ± *SD* of three independent determinations. All values are given on a fresh weight basis

Sample	Arabinoxylan	Cellulose	*β*-glucan	RS	SDF	IDF	TDF	Moisture
Green leafy vegetables								
Spinach	0.02 ±0.01	0.90 ±0.16	n.d.	n.d.	0.78 ±0.21	2.03 ±0.35	2.81 ±0.26	92.62 ±1.02
Parsley	0.08 ±0.03	1.39 ±0.21	n.d.	n.d.	1.32 ±0.13	2.04 ±0.29	3.36 ±0.23	90.71 ±0.98
Lettuce	0.05 ±0.02	0.90 ±0.12	n.d.	n.d.	0.20 ±0.03	0.91 ±0.17	1.09 ±0.12	95.84 ±1.01
Cabbage	0.05 ±0.02	1.05 ±0.10	n.d.	n.d.	0.72 ±0.15	1.67 ±0.19	2.39 ±0.17	92.79 ±0.89
Broccoli	0.07 ±0.03	1.26 ±0.13	n.d.	n.d.	0.85 ±0.21	2.09 ±0.22	2.94 ±0.22	91.07 ±1.32
Fruits								
Apple (with skin)	0.11 ±0.03	0.49 ±0.11	n.d.	n.d.	0.60 ±0.13	1.66 ±0.10	2.26 ±0.12	86.72 ±2.18
Blueberry	0.07 ±0.04	0.79 ±0.09	n.d.	n.d.	0.8 1±0.21	2.11 ±0.17	2.90 ±0.19	85.22 ±1.43
Blackberry	0.11 ±0.04	1.93 ±0.19	n.d.	n.d.	1.77 ±0.23	3.36 ±0.26	5.13 ±0.25	88.14 ±1.65
Raspberry	0.15 ±0.03	1.21 ±0.22	n.d.	n.d.	2.88 ±0.27	2.62 ±0.21	5.50 ±0.24	85.39 ±0.99
Strawberry	0.14 ±0.05	0.71 ±0.26	n.d.	n.d.	1.06 ±0.10	1.14 ±0.17	2.20 ±0.14	90.25 ±1.58
Cherry	0.08 ±0.03	0.64 ±0.10	n.d.	n.d.	1.09 ±0.15	1.02 ±0.18	2.11 ±0.17	83.94 ±1.76
Nuts								
Almond	0.53 ±0.18	3.64 ±0.23	0.05 ±0.02	0.16 ±0.05	1.01 ±0.10	13.87 ±0.45	14.88 ±0.28	4.78 ±0.63
Hazelnut	0.44 ±0.13	2.67 ±0.43	0.04 ±0.02	0.17 ±0.06	1.37 ±0.32	8.09 ±0.51	9.46 ±0.42	3.39 ±0.76
Cashew nuts	0.21 ±0.10	1.02 ±0.20	0.02 ±0.01	0.93 ±0.23	0.95 ±0.26	4.21 ±0.29	5.16 ±0.27	3.97 ±0.48
Walnut	0.45 ±0.11	1.29 ±0.36	0.03 ±0.01	0.07 ±0.03	1.04 ±0.23	6.42 ±0.53	7.46 ±0.39	3.43 ±0.64

Samples from the nut group were particularly rich in insoluble fibre, but contained soluble fibre as well (the ratio of IDF to SDF was from 4:1 to 14:1). Such a dominance of IDF in nuts was previously reported.[23] The IDF was the dominant fibre fraction in the analyzed fruits and vegetables. The descending sequence of the IDF content in the analyzed fruits was as follows: blackberry > raspberry > blueberry > apple > strawberry > cherry. The lowest SDF fraction in TDF was found in apple (26 %), whereas the highest was measured in raspberry

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(52 %). Similar amounts of total fibre and IDF to SDF ratios were found in fruits collected from markets in North Carolina area, USA.[24] Among the green leafy vegetables, lettuce was the poorest source, while parsley and broccoli were the best sources of total, SDF and IDF. The green leafy vegetable samples examined in the present study demonstrated higher IDF and TDF contents than the vegetables of Canadian origin analyzed by Mongeau and Brassard.[25] IDF and SDF have different physiological properties and their balanced intake is of great nutritional importance. Since several studies found that the daily diets in European countries[26] and in Serbia[27] especially are low in SDF, the obtained data on the SDF content in the selected plant foods is important as an indicator for choosing appropriate food for increasing SDF.

The majority of published data reports the total, IDF and SDF fibre content of fruits and vegetables, while particular fibre fractions are hardly ever mentioned. Since individual fibre fractions often have specific and unique physiological effects, it is important to investigate fibre profile of regularly consumed foods. In the present study, several fibre fractions were investigated that were not previously studied in fruits and vegetables of Serbian origin: cellulose, arabinoxylan, β-glucan and resistant starch. Cellulose, classified as an insoluble fibre, was found in high percentages in all samples. Among the nuts, the highest cellulose content was detected in almonds (3.64 g 100 g^{-1}), while blackberry was the richest in cellulose (1.93 g 100 g^{-1}) in the fruit group. Parsley was the best source of cellulose in the green leafy vegetable group. The cellulose portion in nuts was about 20 % of the TDF, in fruits 20–40 %, and 40 % in green leafy vegetables, except for lettuce in which cellulose comprised up to 80 % of the TDF. Besides the common physiological properties ascribed to IDF, cellulose was specifically accredited as a protective agent in colon cancer.[8] Arabinoxylan is another insoluble fibre fraction, but unlike cellulose, it was present in very small quantities in 100 g of analyzed samples – from several milligrams in the fruits and vegetables to half gram in the nuts. Arabinoxylans are supposed to have influence on postprandial glucose response and insulin sensitivity.[28] The best dietary sources of arabinoxylans, according to the literature, are cereals[29] and the present results show that fruits, vegetables and nuts are not appropriate for increasing the daily intake of arabinoxylan.

Two fractions of soluble fibre, resistant starch and β-glucan, were analyzed for the first time in the chosen plant foods. The analyzed fruits and vegetables have low levels of starch, thus no resistant starch was detected in them, but it was found exclusively in the nuts. Resistant starch is defined as “the sum of starch and the products of starch degradation not absorbed in the small intestine of healthy individuals”.[30]

Starch is not a major component in almonds, hazelnuts and walnuts but cashew nuts are rich in starch. The starch contents in the analyzed nuts were as

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follows: 10.11±1.42 g/100 g in cashew nuts; 2.51±0.22 g/100 g in hazelnuts; 1.35±0.31 g/100 g in almonds; 0.97±0.34 g/100 g in walnuts (the results not shown in the table). Consequently, the values for resistant starch decreased in the same manner: the highest content was measured in cashew nut, the lowest in walnuts. Resistant starch share in total fibre was 1–18 %. Resistant starch has been proven to induce satiety, and intake of 15 g/day increased insulin sensitivity.[30,31] The obtained results confirmed that the analyzed fruit, vegetables, and nuts are generally not good sources of resistant starch, while the evidenced presence of resistant starch in cashew nut is the first confirmation that resistant starch could be found in significant amounts in some nuts.

β-Glucans are considered to be a very important class of fibres with proven hypocholesterolemic and hypoglycemic effects, but the analyzed fruits and vegetables contained no *β*-glucans.

The total polyphenol contents of the fruit, vegetable and nut samples were estimated using the Folin–Ciocalteu method and methanol as the extraction solvent. In the group of green leafy vegetables, by far the highest content was measured in broccoli, berries had the highest content in comparison with apples and cherries among the fruits and within the nut group, walnuts had 3.5–5 times more polyphenols than other analyzed nuts. The differences in polyphenol content that could be found in the literature largely depended on the plant family, genus and species, but were also dependent on the type of the used extraction agent and standards, which makes comparison of the present results with those of other authors difficult. Wu *et al.*[32] used acetone/water/acetic acid as an extraction solvent for fruit and nut samples purchased from 12 cities in United States. The results presented herein are in agreement with those of this previous study, with the exception for walnuts, where a lower content detected. However, in the vegetable group, lettuce had a higher phenolic content compared to previous studies.[32,33]

A broad spectrum of methods has been developed to measure antioxidant capacity. The methods are based on various anti-oxidative mechanisms, such as scavenging and inhibition of free radicals or chelating metallic ions which would otherwise lead to free radical formation. The FRAP test is based on electron transfer detection[34] and the assumption that the reducing capacity of a sample is directly proportional to its anti-oxidative capacity. The FRAP assay was used in the reported study to evaluate the anti-oxidant capacity of the analyzed fruits and vegetables and the results are given in Table II. As expected, all samples had high antioxidant capacity. In the group of green leafy vegetables, the highest FRAP value was found for spinach (1.61 mmol Fe^{2+} 100 g^{-1}), then broccoli (1.20 mmol Fe^{2+} 100 g^{-1}), while cabbage showed the lowest FRAP value (0.36 mmol Fe^{2+} 100 g^{-1}). In the group of fresh fruits, blueberries had the highest antioxidant capacity (FRAP value 4.98 mmol Fe^{2+} 100 g^{-1}), and apples the smallest

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(0.98 mmol Fe^{2+} 100 g^{-1}). By far the highest FRAP value among all the analyzed samples was found for walnuts (13.24 mmol Fe^{2+} 100 g^{-1}).

TABLE II. Total antioxidant capacity and total phenolics in the analyzed samples; data are expressed on the original weight basis and presented as mean ± *SD* of three independent determinations. All values are given on a fresh weight basis

Samples	Total phenolic content mg GAE 100 g^{-1}	Antioxidant capacity (FRAP) mmol Fe^{2+} 100 g^{-1}
Green leafy vegetables		
Spinach	230±23	1.61±0.34
Parsley	190± 78	1.10±0.04
Lettuce	140±54	0.42±0.09
Cabbage	170±39	0.36±0.12
Broccoli	376±67	1.20±0.41
Fruits		
Apple with skin	103±43	0.98±0.33
Blueberry	310±76	4.98±0.51
Blackberry	259±23	3.54±0.61
Raspberry	262±41	2.98±0.23
Strawberry	305±54	2.69±0.37
Cherry	198±38	1.97±0.32
Nuts		
Almond	408±49	0.54±0.21
Hazelnut	772±03	0.90± 0.34
Cashew nuts	269±87	0.24±0.09
Walnut	1456±235	13.24±1.99

Berry fruits are known for their high contents of phenolic acid and flavonoids, such as anthocyanins,[35] hence they demonstrate high antioxidant activity.[36] The present results for the antioxidative capacity obtained by the FRAP method for the berry fruit samples were in overall agreement with previous reports and the deviations that were found may be the consequence of the distinct geographic region and the altitude from where the cultivar samples originated.[37,38]

Fruits and vegetables are proven sources of multiple bioactive compounds, among which dietary fibre and polyphenolic antioxidants are of great importance. These two classes of plant ingredients and their physiological effects are usually studied separately. Saura-Calixto[13] was the first to combine the protective properties of fibre and polyphenols and to introduce the concept of anti-oxidant dietary fibre (AODF) – a natural product capable of combining the beneficial health effects of DF and natural antioxidants, such as polyphenols. Although this expression is not used for natural products but for functional ingredients derived from natural plant sources, it brought attention to the importance of combined and interrelated effects of these bioactive compounds. Epidemiological studies

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suggest that regular consumption of fruits and vegetables is negatively associated with the risk of several serious chronic diseases.[39,40] Five to seven daily portions or a minimum of 400 g of fruit and vegetables was proposed as population goals.[41,42] Simultaneously, several recommendations for individual phytonutrient intake, such as fibre and polyphenols, was also proposed. It is considered beneficial to consume >25 g day^{-1} of dietary fibre;[43] 6 g day^{-1} of arabinoxylan; 5 g day^{-1} cellulose[44] and >1 g day^{-1} of total polyphenols[45] as a part of ordinary daily diet. Similarly, the intake of 1 g SDF is considered important, since each additional gram of SDF in the diet was found to decrease serum total and LDL cholesterol concentration by 0.03 mmol L^{-1}.[46] One of the aims of this study was to evaluate the potential of selected plant foods as combined sources of anti-oxidative polyphenols and dietary fibre. These data could help in reaching dietary recommendations by choosing the best combinations from broad range of fibre and polyphenol dietary sources.

The best dietary sources of fibre and polyphenols among the analysed fruits and vegetables, expressed per average portion of original food item, are listed in Table III. The portion sizes were estimated according to the Dutch and Swiss dietary guidelines[42] since no estimates of Serbian standard portions exist. The criterion used for inclusion in the list of best dietary sources (Table III) was based on the potential of the analyzed plant foods to contribute in a significant way to the recommended intake of bioactive plant ingredients.

TABLE III. The best dietary sources of fibre and polyphenols among analysed fruits and vegetables (in descending order, expressed per one portion); 1 portion of fruit and vegetables, 100 g; 1 portion of nuts, 30 g. Serving size from Agundo, 2005[42]

Total fibre[a] g/portion	Soluble fibre[b] g/portion	Insoluble fibre[c] g/portion	Cellulose[d] g/portion	Polyphenols[e] mg GAE/portion	Polyphenol +total fibre[f] (g/portion)/(mg GAE/portion))
Raspberry (5.5)	Raspberry (2.9)	Almond (4.2)	Blackberry (1.9)	Walnut (437)	Raspberry (5.5 / 262)
Blackberry (5.1)	Blackberry (1.8)	Hazelnut (2.4)	Raspberry (1.2)	Blueberry (310)	Blackberry (5.1 / 259)
Blueberry (2.9)	Cherry (1.1)	Blackberry (3.4)	Almond (1.1)	Strawberry (305)	Blueberry (2.9 / 310)
Almond (4.5)	Strawberry (1.1)	Raspberry (2.6)	Parsley (1.4)	Raspberry (262)	Broccoli (2.9 / 376)
Hazelnut (2.8)	Parsley (1.3)	Blueberry (2.1)	Broccoli (1.3)	Blackberry (259)	Spinach (2.8 / 230)
Parsley (3.4)		Broccoli (2.1)	Cabbage (1.1)	Broccoli (376)	Hazelnut (2.8 / 232)
Broccoli (2.9)		Parsley (2.0)		Hazelnut (232)	
Spinach (2.8)		Spinach (2.0)		Spinach (230)	

[a]Contributes > 2.5 g / portion; [b]contributes > 1 g/portion; [c]contributes > 2 g/portion; [d]contributes > 1 g/portion; [e]contributes > 200 mg GAE/portion; [f]contributes: polyphenol > 200 mg GAE/portion and total fibre > 2.5 g/portion

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When dietary goal is increasing the total, IDF, and cellulose intake, the best choices among the analyzed food would be berries, almonds, parsley, and broccoli. The best dietary choices for SDF would be berries, cherries, and parsley. Although walnuts have by far the highest polyphenol content, when the combination of polyphenols and total fibre is considered, other plant foods could be of more importance. The best sources of combined polyphenols and total fibre was shown to be berries, hazelnut, broccoli, and spinach.

CONCLUSIONS

Based on the results presented in this paper, it is evident that daily consumption of 400 g of the analyzed fruits and vegetables would provide the quantity of dietary fibre and polyphenols that could be expected to give positive physiological effects. The combination of 100 g each of raspberry, blackberry, broccoli and spinach, per example, ensures an amount of 16.4 g day^{-1} TDF, approximately 1.2 g day^{-1} polyphenols, and 5.3 g day^{-1} cellulose. These are precisely the quantities that are being recommended for protective purposes.

In conclusion, the obtained data clearly demonstrate that no single food contains each and all the non-nutritive components relevant to human health. The analyzed plant foods of Serbian origin are rich sources of polyphenols and total, insoluble and soluble fibres, while some specific fibre fractions, such as arabinoxylans, β-glucans and resistant starch were only present in insignificant amounts. The analysis of individual fibre fractions should be encouraged, with aim of ensure proper and more knowledgeable food combinations that would help to supply a diet with the necessary ingredients. Possible synergistic effects of polyphenols and fibres are not well known and need further investigation in well-designed clinical studies.

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И З В О Д

ПРОФИЛ ВЛАКАНА И САДРЖАЈ ПОЛИФЕНОЛА У ОДАБРАНОМ ВОЋУ И ПОВРЋУ

МАРГАРИТА ДОДЕВСКА, СЛАЂАНА ШОБАЈИЋ и БРИЖИТА ЂОРЂЕВИЋ

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Воће и поврће је познато као добар извор бројних биолошки активних једињења у које спадају и полифеноли и дијетна влакана. За ове састојке постоје докази да повољно утичу на смањење ризика од неких врста канцера, дијабетес, гојазност и хипертензију. Циљ овог рада био је да се провери квалитет биљних намирница са нашег подручја у погледу количине укупних фенола, влакана и односа појединих фракција влакана. Петнаест узорака зеленог лиснатог поврћа, воћа и језграстог воћа је испитивано на укупну антиоксидантну активност, укупан садржај фенола, укупна, растворљива и нерастворљива влакна и следеће фракције влакана: β-глукан, арабиноксилан, целулоза и резистентан скроб. Језграсто воће је било најбогатије у влакнима и укупним фенолима, међутим када је узета у обзир величина порције, бобичасто воће је било најбољи извор уку-

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пних, растворљивих влакана и целулозе, лешници и бадеми су најбољи извор нерастворљивих влакана, док су ораси остали најбољи извор полифенола. У анализираним биљним намирницама нису нађене значајније количине арабиноксилана и β-глукана. Податак о присуству резистентног скроба у индијским орасима је прва потврда да резистентан скроб може да се нађе у значајној количини у језграстом воћу. Ови резултати дају редак приказ дијетарног значаја воћа и поврћа које се конзумира у Србији у смислу садржаја влакана и полифенола.

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