Quality evaluation of cold-pressed oils and semi-defatted cake flours obtained on semi-industrial scale

JELENA KRULJ – LATO PEZO – JOVANA KOJIĆ – MARIJA BODROŽA SOLAROV – NEMANJA TESLIĆ

Summary

Mechanically pressed oils and the remaining semi-defatted cake flours obtained from fruit, vegetables and some of less utilized oilseeds have increasing trend on global oil market due to their health benefits and cost-effectiveness. Cold-pressed oils obtained from various plant seeds were evaluated in terms of physico-chemical properties, fatty acid composition and functional quality properties. Low oil yield was obtained for berry, red grape and sour cherry oils while moderate or high yield was obtained for other plant materials. Oil samples contained high amounts of unsaturated fatty acids, with linoleic and oleic acids as the major acids. Among all oils, flaxseed, raspberry and blackberry seed oils contained significant amounts of α-linolenic acid. In terms of functional quality indices, berry seed oils exhibited the highest quality of all obtained cold-pressed oils. Residual semi-defatted cake flours were examined in terms of basic proximal analysis. Poppy, sesame, flaxseed and both pumpkin flours had moderate or high contents of crude proteins and low content of fibres. Sour cherry, blackberry, raspberry and red grape flours had high fibre contents and relatively low content of proteins. A comprehensive study of oils and their residual cakes obtained from by-products of fruit and vegetable processing industry supports the concept of zero waste technology.

Keywords

mechanical pressing; semi-industrial scale; oil technology

Besides conventional oils, a variety of oils derived from vegetables, fruits or tree nut seeds have a significant presence in the market nowadays. The non-traditional oils are increasingly appreciated because of their nutritional quality and health benefits, which are linked to high contents of essential fatty acids and antioxidants with the high oxygen radical absorption capacity values [1]. The authenticity and origin of cold-pressed oil are important from the standpoint of both nutritional value and health aspects. Chemical composition and nutritional quality of oil as well as plant oil yield may be influenced by various factors such as species, geographical location of plant growing and processing technique. A lot of research studies dealt with health-promoting effects of various plant seed oils such as antiatherogenic, anti-thrombotic, anti-inflammatory, anti-arrhytmic and hypolipidemic effects [1, 2].

A change in consumer awareness has been mainly related to the increasing demand for "natural" and safe food, including oils and fats. In that regard, cold-pressed oils have attracted considerable interest in the last decade regrading their production process that is based on mechanical extraction involving neither heat nor chemical treatments. The cold pressing technique guarantees preservation of the aromatic profile and the contained macro- and micronutrients, as well as other bioactive constituents. In comparison with other techniques of oil extraction, cold pressing has capability of producing a high-quality product as well as lower energy requirements, easy-operating and environmental-friendly approach [3]. One of the significant advantages of this technique is that, after oil separation by cold pressing of seeds, a cake free of toxic solvents remains, which is rich in nutrients. Certain cakes have particularly high content of proteins, which could be up to 50 %, thus they can be further utilized as a raw material for production of various feed or food products [4]. Residual cakes could be also added in food

Jelena Krulj, Jovana Kojić, Marija Bodroža Solarov, Nemanja Teslić, Institute of Food Technology, University of Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad, Serbia.

Lato Pezo, Institute of General and Physical Chemistry, University of Belgrade, Studentski Trg 12–16, 11000 Belgrade, Serbia.

Correspondence author:

Jelena Krulj, e-mail: jelena.krulj@fins.uns.ac.rs

and feed products thanks to their functional properties as they are a good source of dietary fibres. Depending on the source of dietary fibres and their intake, they could have several health-promoting benefits including decrease in sugar and cholesterol levels in blood, suppression of cardiovascular diseases (coronary heart disease, stroke and hypertension), reduction of body weight, amelioration of insulin regulation and suppression of type 2 diabetes mellitus, improvement of immunity, suppression of breast cancer or amelioration of gastro-intestinal health by improved laxation and suppression of colon cancer [5].

Zero waste manufacturing is a concept enabling transition towards circular economy, and it is characterized by development and utilization of technologies that eliminate entire waste from production chains [6]. In that regard, chains of technological processes involving use of seed plants, which are by-products of fruit processing industry and winemaking industry (raspberry, blackberry, grape and other), for oil production or further use of residual oil cakes (pumpkin, sesame, flaxseed, grape and other) for feed and food production, generating minimum residual waste, are good directions towards such concept. Mechanically pressed oils obtained from various plant seeds such as sesame, raspberry, blackberry, grape, blue poppy or hazelnut, were already evaluated in terms of oil yield, fatty acid profile, peroxide value, acid value, oxidative stability, polyphenol, tocopherols and tocotrienols, carotenoids and squalene contents, and other quality parameters [2, 7, 8]. On the other hand, relatively small number of studies was focused on chemical composition of semi-defatted cake flours (e.g. blue poppy, flaxseed, pumpkin) remaining after mechanical pressing [9–11], particularly in case of semi-defatted flours obtained from nuts and fruit seeds. Furthermore, an integral study on cold-pressed oils and remaining cake flours is not available though such study could simultaneously provide valuable information about final product and by-product quality. It is noteworthy that many studies were performed with lab-scale pressing equipment mainly due to high cost of semi-industrial and industrial scale experiments. Even though, trials of oil pressing performed with lab-scale equipment surely provide relevant data, knowledge and conclusions about the technological process and product quality, experiments performed on a semi-industrial level may be favoured as they are executed in conditions closer to the industrial level, including comparable production capacity.

The value of mechanically pressed oils and potential for further use of residual oil cakes are strongly related to nutritional and functional quality. Thus, the aim of this study was characterization of mechanically pressed oils and cake flours of diverse plant origin obtained on a semi-industrial scale. Comparison of physico-chemical quality, fatty acid profile and functional quality properties of various cold-pressed oils and chemical composition of cake flours may provide a general view of their general quality and possible application in food, feed, cosmetics and nutraceutical industries.

MATERIALS AND METHODS

Sample preparation and processing

Production of mechanically-pressed oils was performed in two ways: "oils" were extracted by pressing on screw press, while "virgin oils" were obtained by pressing of roasted seeds on a hydraulic press. Production was done during the year 2019. "Oils" extracted from pumpkin (*Cucurbita pepo*), muscat pumpkin (*Cucurbita moschata*), flaxseed (*Linum usitatissimum*), sesame (*Sesamum indicum*), walnut (*Juglans regia*), red grape (*Vitis vinifera*), blackberry (*Rubus fruticosus*), raspberry (*Rubu sidaeus*), sour cherry (*Prunus cerasus*) and blue poppy (*Papaver somniferum*), and "virgin oils" obtained from pumpkin (*Cucurbita pepo*), sesame (*Sesamum indicum*) and hazelnut (*Corylus avellana*) were kindly provided by Uljara Pan-Union (Novi Sad, Serbia). Also, semi-defatted cakes remaining after the oil separation by screw press from flaxseed (*Linum usitatissimum*), sesame (*Sesamum indicum*), muscat pumpkin (*Cucurbita moschata*), pumpkin (*Curcubita pepo*), red grape (*Vitis vinifera*), blackberry (*Rubus fruticosus*), raspberry (*Rubus idaeus*), sour cherry (*Prunus cerasus*) and blue poppy (*Papaver somniferum*) were kindly donated by Uljara Pan-Union.

Hydraulic pressing

Pre-treatment conditions and plant parts submitted to hydraulic pressing and single screw pressing are summarized for all samples in Tab. 1. Seeds were thermally processed (roasted) prior to hydraulic pressing, which gave to "virgin oils" specific roasty flavour compared to "oils", which had only flavour characteristic for plant seeds. Pressing was performed on semi-industrial hydraulic press (Lešnik Lenart, Zgornji Žerjavci, Slovenia). Processing parameters were determined by plant material: applied pressure (25–28 MPa); pressing capacity (40–45 kg of seeds per hour). "Virgin oil" extraction was performed at least three times for each plant material and yield of extracted oil was quantified. All the extracted oil was combined

Tab. 1. Pre-treatment conditions, type of used press and plant part submitted to cold-pressing.

Plant	Type of press	Pretreatment	Plant part submitted to pressing
Hazelnut (*Corylus avellana*)	Hydraulic press	Heated above 100 °C	Kernel
Sesame (*Sesamum indicum*)	Hydraulic press	Heated above 100 °C	Seed
Pumpkin (*Cucurbita pepo*)	Hydraulic press	Heated above 100 °C	Kernel (hull-less cultivar)
Pumpkin (*Cucurbita pepo*)	Single screw press	N/A	Kernel (hull-less cultivar)
Muscat pumpkin (*Cucurbita moschata*)	Single screw press	N/A	Hull and kernel
Walnut (*Juglans regia*)	Single screw press	N/A	Kernel
Flaxseed (*Linum usitatissimum*)	Single screw press	N/A	Seed
Sesame (*Sesamum indicum*)	Single screw press	N/A	Seed
Red grape (*Vitis vinifera*)	Single screw press	Separated from skin	Seed
Raspberry (*Rubus idaeus)*	Single screw press	N/A	Seed with neglectable amount of residual pulp
Blackberry (*Rubus fruticosus*)	Single screw press	N/A	Seed with neglectable amount of residual pulp
Sour cherry (*Prunus cerasus*)	Single screw press	N/A	Shell and kernel
Blue poppy (*Papaver somniferum*)	Single screw press	N/A	Seed

N/A – not applied.

and stored in a tank allowing sedimentation of fine particles. After few days of sedimentation, "virgin oils" were sampled from the upper part of the tank, transferred into amber glass bottles of 250 ml, filled up to the top (to exclude presence of O_2 as much as possible) and stored at 4 °C until the analysis for a maximum of 7 days.

Screw pressing

"Oils" were obtained by pressing on semi-industrial screw type expeller (Mikron, Temerin, Serbia). Processing parameters were dependent on plant matrix: frequency (10–30 Hz); nozzle internal diameter (7–14 mm); pressing capacity (5 kg to 50 kg of seeds per hour). Maximal temperature of oil at the exit of press was 45 °C. It was necessary to use whole seeds on this semi-industrial press (particularly in case of raspberry, red grape, blackberry and other seeds with similar dimensions), because grounded seeds would clog the press. Raw "oil" was collected during few hours for each plant material and yield of extracted oil was quantified. Afterwards, same procedure was performed as for "virgin oils". Semi-defatted cakes remaining after oil extraction on screw press were ground on a laboratory mill (Glen Mills, Clifton, New York, USA). Obtained flours were transferred into plastic bags and stored at 4 °C until the analysis for a maximum of 7 days.

Oil analysis and functional quality indices

Moisture content, insoluble solids, acid value, peroxide value, iodine value, unsaponifiable matter, saponification value, relative density and refractive index were determined according to AOAC official methods [12]. For easier determination, fatty acids from oil samples were derivatized to methyl esters using 14% boron trifluoride-methanol solution. Nitrogen was used for drying and solvent residues removal from fatty

Tab. 2. Mathematical formulas for calculation of functional quality indices.

Functional quality indices	Mathematical formula	Eq.
Hypocholesterolemic/ hypercholesterolemic ratio	$HH=\frac{(\mathrm{C18{:}1}n\text{–}9)+(\mathrm{C18{:}2}n\text{–}6)+(\mathrm{C20{:}4}n\text{–}6)+(\mathrm{C18{:}3}n\text{–}3)+(\mathrm{C20{:}5}n\text{–}3)+(\mathrm{C22{:}5}n\text{–}3)+(\mathrm{C22{:}6}n\text{–}3)}{\mathrm{C14{:}0}+\mathrm{C16{:}0}}$	1
Atherogenicity index	$AI=\frac{\mathrm{C12{:}0}+4(\mathrm{C14{:}0})+\mathrm{C16{:}0}}{\sum\mathrm{MUFA}+\sum(n-3)+\sum(n-6)}$	2
Thrombogenicity index	$TI=\frac{\mathrm{C14{:}0}+\mathrm{C16{:}0}+\mathrm{C18{:}0}}{0.5(\sum\mathrm{MUFA})+3\sum(n-3)+0.5\sum(n-6)+\frac{\sum(n-3)}{\sum(n-6)}}$	3

C18:1*n*–9 – oleic acid, C18:2*n*–6 – linoleic acid, C20:4*n*–6 – arachidonic acid, C18:3*n*–3 – α-linolenic acid, C20:5*n*–3 – eicosapentaenoic acid, C22:5*n*–3 – docosapentaenoic acid, C22:6*n*–3 – docosahexaenoic acid, C12:0 – lauric acid, C14:0 – myristic acid, C16:0 – palmitic acid, C18:0 – stearic acid, ΣMUFA – sum of monounsaturated fatty acids, Σ(*n*–3) – sum of polyunsaturated *n*–3 fatty acids, Σ*n*–6 – sum of polyunsaturated *n*–6 fatty acids.

Tab. 3. Yield and physico-chemical propertiesof mechanically pressed oils (hydraulic press and screw press).

Plant	Yield [g·kg^{-1}]	Moisture and volatile content [g·kg^{-1}]	Insoluble solids content [g·kg^{-1}]	Acid value [g·kg^{-1}]	Peroxide value [mmol·kg^{-1}]	Iodine value [g·kg^{-1}]	Unsaponifiable matter [g·kg^{-1}]	Saponification value [g·kg^{-1}]	Relative density [g·cm^{-3}]	Refractive index
Virgin hazelnut	553.0 ± 17.8^{j}	0.90 ± 0.01^{g}	0.10 ± 0.00^{a}	1.38 ± 0.07^{b}	1.04 ± 0.03^{f}	877 ± 19^{a}	3.3 ± 0.1^{c}	188.8 ± 2.1^{a}	0.9165 ± 0.0008^{a}	1.468 ± 0.013^{a}
Virgin sesame	431.6 ± 11.5^{i}	0.20 ± 0.00^{b}	0.10 ± 0.00^{a}	1.83 ± 0.21^{d}	1.69 ± 0.04^{i}	1101 ± 22^{b}	10.7 ± 0.7^{j}	189.3 ± 0.8^{a}	0.9210 ± 0.0012^{d}	1.471 ± 0.004^{a}
Virgin pumpkin	327.8 ± 8.7^{f}	0.50 ± 0.01^{d}	0.10 ± 0.00^{a}	1.22 ± 0.04^{a}	4.97 ± 0.10^{k}	1080 ± 7.0^{b}	9.8 ± 0.2^{i}	189.1 ± 1.5^{a}	0.9198 ± 0.0001^{c}	1.471 ± 0.000^{a}
Pumpkin	337.6 ± 7.7^{f}	0.40 ± 0.00^{c}	0.20 ± 0.00^{b}	1.20 ± 0.03^{a}	5.04 ± 0.09^{k}	1104 ± 24^{b}	6.8 ± 0.0^{f}	190.6 ± 1.6^{ab}	0.9185 ± 0.0004^{b}	1.470 ± 0.001^{a}
Muscat pumpkin	281.7 ± 2.3^{e}	0.70 ± 0.00^{f}	0.10 ± 0.00^{a}	1.55 ± 0.09^{c}	1.54 ± 0.02^{g}	1136 ± 11^{c}	7.7 ± 0.4^{g}	191.1 ± 2.3^{b}	0.9224 ± 0.0000^{f}	1.471 ± 0.003^{a}
Walnut	548.9 ± 16.6^{j}	0.10 ± 0.00^{a}	0.10 ± 0.00^{a}	1.32 ± 0.00^{b}	1.61 ± 0.04^{h}	1507 ± 23^{g}	1.9 ± 0.1^{b}	190.3 ± 1.8^{ab}	0.9230 ± 0.0003^{f}	1.475 ± 0.003^{ab}
Flaxseed	343.2 ± 10.1^{f}	0.50 ± 0.00^{d}	0.10 ± 0.00^{a}	3.77 ± 0.09^{i}	0.74 ± 0.01^{c}	1863 ± 17^{j}	6.5 ± 0.3^{f}	192.7 ± 0.7^{b}	0.9360 ± 0.0004^{h}	1.479 ± 0.003^{b}
Sesame	409.8 ± 10.3^{h}	1.50 ± 0.01^{i}	0.20 ± 0.00^{b}	3.97 ± 0.17^{j}	0.76 ± 0.00^{d}	1060 ± 23^{b}	10.8 ± 0.4^{j}	188.0 ± 1.4^{a}	0.9208 ± 0.0010^{e}	1.471 ± 0.008^{a}
Red grape	110.1 ± 1.2^{d}	0.60 ± 0.00^{e}	0.30 ± 0.00^{c}	2.73 ± 0.05^{f}	0.84 ± 0.06^{e}	1383 ± 13^{f}	4.6 ± 0.1^{e}	194.4 ± 0.2^{c}	0.9205 ± 0.0003^{d}	1.471 ± 0.010^{a}
Raspberry	102.3 ± 3.0^{c}	1.50 ± 0.00^{i}	0.10 ± 0.00^{a}	2.04 ± 0.11^{e}	0.44 ± 0.01^{a}	1762 ± 15^{i}	9.8 ± 0.3^{i}	189.7 ± 1.2^{a}	0.9311 ± 0.0001^{h}	1.479 ± 0.001^{b}
Blackberry	90.5 ± 0.7^{b}	0.60 ± 0.00^{e}	0.20 ± 0.00^{b}	3.26 ± 0.15^{g}	3.72 ± 0.20^{j}	1596 ± 16^{h}	8.1 ± 0.1^{h}	188.7 ± 2.3^{a}	0.9331 ± 0.0005^{h}	1.477 ± 0.002^{b}
Sour cherry	23.0 ± 2.1^{a}	1.30 ± 0.00^{h}	0.10 ± 0.00^{a}	3.45 ± 0.09^{h}	0.56 ± 0.00^{b}	1255 ± 9^{d}	3.6 ± 0.0^{d}	191.5 ± 2.4^{b}	0.9233 ± 0.0000^{g}	1.479 ± 0.007^{b}
Blue poppy	364.5 ± 4.7^{g}	1.50 ± 0.00^{i}	0.10 ± 0.00^{a}	8.63 ± 0.20^{k}	5.47 ± 0.09^{l}	1302 ± 17^{e}	1.1 ± 0.0^{a}	192.1 ± 0.6^{b}	0.9215 ± 0.0000^{e}	1.472 ± 0.003^{a}

Results are expressed as mean ± standard deviation (n = 3). Values with different superscript letters in the same column are significantly different ($p < 0.05$), according to Tukey‘s HSD test. Yield is expressed per kilogram of seeds. Acid and saponification values are expressed as grams of KOH per kilogram of oil.

acid methyl esters. Instrumentation setup and conditions were described in detail elsewhere [13]. Functional quality indices of mechanically pressed oils were calculated from content of individual fatty acids. Ratio between hypocholesterolemic and hypercholesterolemic fatty acids (*HH*), atherogenicity index (*AI*) and thrombogenicity index (*TI*) were selected to evaluate oil functional quality and their suitability for human consumption. Indices were calculated according to the Eq. 1–3 given in Tab. 2.

Proximal analysis of semi-defatted cake flours

Moisture content, ash, total dietary fibres, protein, fat and total sugar content were determined according to AOAC official methods [12].

Statistical analyses

All determinations were made in triplicate, data were averaged and expressed as mean ± standard deviation (*SD*). The obtained data were statistically processed using Statistica 10.0 (StatSoft, Tulsa, Oklahoma, USA).

RESULTS AND DISCUSSION

Chemical composition of oils

Physico-chemical properties, including fatty acid composition and functional quality indices of cold-pressed oils obtained by either hydraulic press or screw press were examined in the present study. The physico-chemical properties of mechanically pressed oils are presented in Tab. 3.

The oil yield obtained by cold pressing is usually lower than by hot pressing and solvent extraction, but cold pressing may preserve some thermolabile compounds and exclude use of toxic organic solvents. Total fat content of raw material used for oil pressing is presented in Tab. 4. The highest oil yield was achieved by pressing walnut and roasted hazelnut (548.9 g·kg^{-1} and 553.0 g·kg^{-1}, respectively). The oil yield of hazelnut ranged from 374 g·kg^{-1} to 566 g·kg^{-1} according to results in a study of Jokić et al. [14], while Martínez et al. [15] reported that oil yield of walnut varied from 610 g·kg^{-1}to 893 g·kg^{-1} depending on the process parameters during the screw pressing of nuts. The lowest oil yield values were obtained for sour cherry seed (23.0 g·kg^{-1}), and relatively low yield wasfrom blackberry, raspberry and red grape seed with the average oil yields of 90.5 g·kg^{-1}, 102.3 g·kg^{-1} and 80.1 g·kg^{-1}, respectively. These levels are close to the yield values reported by Lampi and Heinonen [16] for cold-pressed raspberry oil (107 g·kg^{-1}) and by Maier et al. [17] for red grape seed oil (from 76 g·kg^{-1} to 160g·kg^{-1}, depends on red grape variety).

Moisture and volatile content was found low in the samples, which is desirable for maintenance of the quality and good shelf life of the oils. Relative density and refractive index value were found to be within the acceptable range according to Codex Alimentarius [18]. The oxidative processes in oils belong to main reasons of the organoleptic and nutritional characteristics deterioration of foodstuffs.

The iodine value is a measure of susceptibility of the oil to oxidation (relates to the degree of unsaturation), while the saponification value is a measure of the average molecular weight of all the fatty acids present in oil as triacylglycerols. As presented in Tab. 3, grape and berry seed oils showed high iodine value, which indicated the presence of high percentage of unsaturated fatty acids. High iodine value was a pointer for the amount of double bonds present in the berry seed oils. These results are in accordance with the study of Van Hoed et al. [2] who reported that berry seed oils were highly susceptible to oxidation.

Saponification value (expressed as grams of KOH) of tested samples ranged from 188 g·kg^{-1} (sesame oil) to 194 g·kg^{-1} (red grape seed oil). Saponification value of cold-pressed oils was comparable to those of common vegetable oils. The relatively high saponification value can be caused by the very high content of low molecular weight triacylglycerols. The most commonly determined unsaponifiable matters in oils are sterols, waxes and hydrocarbons. The values of unsaponifiable matters of examined samples were in the range from 1.1 g·kg^{-1} for poppy seed to 10.8 g·kg^{-1} for sesame seed oils. Higher unsaponifiable matters values could be the result of the different oil extraction method and its higher effectiveness in the extraction of unsaponifiable matters.

The quality of fatty acids in the oil could be characterized by acid value, which presents the measure of the extent at which triacylglycerols in the oil or fat had been decomposed by lipase action. The higher acid value of oil, the more the fatty acid it contains, which makes it more exposed to the phenomenon of rancidity. According to Codex Alimentarius [18], the maximum acid value for edible non-refined oils is 4.0 g·kg^{-1}. The analysed oils were found to conform to the defined regulations. An exception was poppy seed oil, which had acid value of 8.63 g·kg^{-1}, together with a high peroxide value of 5.47 mmol kg^{-1}. High values of these parameters indicated the presence of peroxides and secondary products of oxidation in poppy seed oil. These results are consistent with research of Azcan et al. [19] who found that the poppy seed oil is highly unstable.

Tab. 4. Total fat content of raw materials used in the pressing process.

Sample	Total fat content [g·kg^{-1}]
Flaxseed	466.7
Sesame	571.2
Pumpkin	504.7
Muscat pumpkin	422.4
Red grape	169.3
Blackberry	149.6
Raspberry	157.7
Sour cherry	80.7
Blue poppy	498.0
Walnut	NA
Hazelnut	NA

Values present the sum of obtained oil yield and crude fat residue in semi-defatted oil cake expressed per kilogram of raw material.
NA – value not available.

Fatty acid composition and functional quality indices

The nutritional quality and oxidative stability of the edible oils mainly depend of their fatty acid composition. The fatty acid profile of the mechanically pressed oils is presented in Tab. 5. The cold-pressed oils from various plant seeds clearly differed in the degree of unsaturation. The differences in the fatty acid composition are primarily derived from the raw material, as well as location and/or climatic and growing conditions of the oilseed plant. Regarding the fatty acid composition, palmitic, oleic, linoleic and α-linolenic acid were detected in all analysed samples. It was also noted that blackberry seed oil did not contain stearic acid, which was present in all other samples. The most represented unsaturated fatty acids in examined oil samples were oleic acid, linoleic acid and α-linolenic acid.

Generally, vegetable oils are considered a rich source of monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids. It was found that the saturation followed the order: PUFA > MUFA > saturated fatty acids (SFA). Exceptionally, the greater content of MUFA compared to PUFA was determined in virgin hazelnut oil with an oleic acid content of 834.5 g·kg^{-1}. This was in agreement with the results obtained in a study of Ozulku et al. [20] who reported the oleic acid content in virgin hazelnut oil to range from 785 g·kg^{-1} to 835 g·kg^{-1}. This parameter is of nutritional significance, as it was recognized that MUFA-enriched diets can re-

Tab. 5. Fatty acid composition of mechanically pressed oils (hydraulic press and screw press).

Plant	Myristic acid [g·kg^{-1}]	Palmitic acid [g·kg^{-1}]	Palmitoleic acid [g·kg^{-1}]	Stearic acid [g·kg^{-1}]	Oleic acid [g·kg^{-1}]	Linoleic acid [g·kg^{-1}]	α-Linolenic acid [g·kg^{-1}]
Virgin hazelnut	nd	55.0 ± 1.4^{c}	2.2 ± 0.1^{c}	18.5 ± 0.7^{b}	834.5 ± 30.7^{g}	87.6 ± 2.4^{a}	2.2 ± 0.0^{a}
Virgin sesame	0.2 ± 0.0^{a}	94.3 ± 2.8^{f}	nd	50.2 ± 2.8^{g}	418.1 ± 20.1^{f}	429.6 ± 12.0^{c}	7.6 ± 0.0^{g}
Virgin pumpkin	1.1 ± 0.0^{d}	121.3 ± 5.7^{g}	nd	63.1 ± 3.1^{i}	384.1 ± 22.1^{e}	427.6 ± 14.4^{c}	2.8 ± 0.1^{c}
Pumpkin	1.1 ± 0.0^{d}	120.8 ± 5.1^{g}	nd	63.9 ± 1.8^{i}	373.3 ± 17.2^{e}	438.0 ± 17.5^{c}	2.9 ± 0.1^{c}
Muscat pumpkin	1.2 ± 0.1^{d}	152.1 ± 8.5^{h}	nd	56.6 ± 2.3^{h}	239.9 ± 14.4^{d}	546.7 ± 11.0^{f}	2.5 ± 0.0^{b}
Walnut	0.3 ± 0.0^{b}	69.4 ± 2.4^{e}	nd	20.7 ± 0.6^{c}	174.7 ± 8.1^{bc}	620.9 ± 13.9^{g}	114.0 ± 1.4^{h}
Flaxseed	0.3 ± 0.0^{b}	62.1 ± 2.8^{d}	nd	46.7 ± 2.4^{f}	176.9 ± 10.3^{bc}	136.0 ± 8.2^{b}	578.0 ± 12.3^{k}
Sesame	nd	97.4 ± 3.1^{f}	1.6 ± 0.0^{a}	46.2 ± 1.6^{f}	412.3 ± 19.2^{f}	435.1 ± 13.6^{c}	7.3 ± 0.0^{f}
Red grape	0.5 ± 0.0^{c}	72.3 ± 4.2^{e}	1.9 ± 0.0^{b}	34.3 ± 0.6^{e}	188.5 ± 10.5^{c}	697.4 ± 20.5^{h}	5.1 ± 0.0^{d}
Raspberry	nd	26.2 ± 0.0^{a}	nd	9.4 ± 0.3^{a}	121.4 ± 6.8^{a}	523.2 ± 1.5^{e}	319.8 ± 7.4^{j}
Blackberry	nd	35.5 ± 1.4^{b}	17.7 ± 0.0^{e}	nd	161.6 ± 7.9^{b}	624.6 ± 23.1^{g}	160.7 ± 3.3^{i}
Sour cherry	nd	64.6 ± 1.4^{d}	3.8 ± 0.1^{d}	22.2 ± 0.8^{d}	406.7 ± 16.7^{f}	478.6 ± 3.3^{d}	5.4 ± 0.2^{e}
Blue poppy	nd	97.9 ± 4.9^{f}	1.9 ± 0.1^{b}	22.0 ± 0.8^{d}	238.5 ± 14.0^{d}	632.5 ± 18.8^{g}	7.3 ± 0.4^{f}

Results are expressed as mean ± standard deviation ($n = 3$). Values with different superscript letters in the same column are significantly different ($p < 0.05$), according to Tukey's HSD test.
nd – not detected

Tab. 6. Functional quality indices of mechanically pressed oils (hydraulic press and screw press).

Plant	*SFA* [g·kg^{-1}]	*MUFA* [g·kg^{-1}]	*PUFA* [g·kg^{-1}]	*UFA* [g·kg^{-1}]	*PUFA/SFA*	*n*–6/*n*–3	*AI*	*TI*	*HH*
Virgin hazelnut	73.5 ± 2.1^{b}	836.7 ± 30.8^{h}	89.8 ± 2.4^{a}	926.5 ± 33.2^{b}	1.22 ± 0.00^{a}	39.82 ± 1.09^{e}	0.0594 ± 0.0006^{c}	0.1567 ± 0.0010^{e}	16.80 ± 0.17^{k}
Virgin sesame	144.7 ± 5.7^{f}	418.1 ± 20.1^{f}	437.2 ± 12.0^{b}	855.3 ± 32.1^{ab}	3.02 ± 0.03^{e}	56.53 ± 1.48^{f}	0.1112 ± 0.0009^{h}	0.3238 ± 0.0010^{j}	9.05 ± 0.07^{f}
Virgin pumpkin	185.5 ± 8.7^{g}	384.1 ± 22.1^{e}	430.4 ± 14.5^{b}	814.5 ± 36.6^{a}	2.32 ± 0.03^{b}	152.72 ± 1.02^{j}	0.1543 ± 0.0001^{j}	0.4477 ± 0.0010^{k}	6.65 ± 0.01^{b}
Pumpkin	185.8 ± 6.9^{g}	373.3 ± 17.5^{e}	440.9 ± 17.6^{b}	814.2 ± 35.2^{a}	2.37 ± 0.01^{c}	151.03 ± 0.15^{j}	0.1538 ± 0.0004^{j}	0.4483 ± 0.0026^{k}	6.68 ± 0.01^{c}
Muscat pumpkin	209.9 ± 10.7^{h}	239.9 ± 14.4^{d}	549.2 ± 11.0^{c}	789.1 ± 25.5^{a}	2.62 ± 0.08^{d}	218.68 ± 3.18^{k}	0.1988 ± 0.0040^{k}	0.5236 ± 0.0100^{l}	5.15 ± 0.012^{a}
Walnut	90.4 ± 3.0^{c}	174.7 ± 8.1^{b}	734.9 ± 15.3^{f}	909.6 ± 23.3^{b}	8.13 ± 0.10^{j}	5.45 ± 0.05^{d}	0.0776 ± 0.0007^{f}	0.1219 ± 0.0015^{d}	13.05 ± 0.12^{h}
Flaxseed	109.1 ± 5.2^{d}	176.9 ± 10.3^{b}	714.0 ± 20.5^{e}	890.9 ± 30.8^{b}	6.54 ± 0.13^{i}	0.24 ± 0.01^{a}	0.0711 ± 0.0007^{d}	0.0564 ± 0.0014^{c}	14.28 ± 0.15^{j}
Sesame	143.6 ± 4.7^{f}	413.9 ± 19.2^{f}	442.4 ± 13.6^{b}	856.3 ± 32.8^{ab}	3.08 ± 0.01^{f}	59.60 ± 1.86^{g}	0.1137 ± 0.0007^{i}	0.3216 ± 0.0014^{i}	8.77 ± 0.06^{d}
Red grape	107.1 ± 4.8^{d}	190.4 ± 10.5^{c}	702.5 ± 20.5^{e}	892.9 ± 31.0^{b}	6.56 ± 0.10^{i}	136.75 ± 4.02^{i}	0.0832 ± 0.0020^{g}	0.2332 ± 0.0027^{g}	12.25 ± 0.29^{g}
Raspberry	35.6 ± 0.3^{a}	121.4 ± 6.8^{a}	843.0 ± 8.9^{h}	964.4 ± 15.7^{c}	23.68 ± 0.03^{l}	1.64 ± 0.03^{b}	0.0272 ± 0.0004^{a}	0.0276 ± 0.0003^{a}	36.81 ± 0.60^{m}
Blackberry	35.5 ± 1.4^{a}	179.3 ± 7.9^{b}	785.3 ± 26.3^{g}	964.6 ± 34.2^{c}	22.12 ± 0.14^{k}	3.89 ± 0.06^{c}	0.0368 ± 0.0002^{b}	0.0400 ± 0.0005^{b}	26.68 ± 0.10^{l}
Sour cherry	75.8 ± 2.3^{b}	465.4 ± 20.1^{g}	441.5 ± 3.5^{b}	906.9 ± 23.5^{b}	5.57 ± 0.13^{h}	88.63 ± 2.68^{h}	0.0722 ± 0.0002^{e}	0.1883 ± 0.0006^{f}	13.79 ± 0.01^{i}
Blue poppy	119.9 ± 5.8^{e}	240.4 ± 14.1^{d}	639.8 ± 19.2^{d}	880.2 ± 33.3^{b}	5.34 ± 0.10^{g}	86.72 ± 2.46^{h}	0.1112 ± 0.0014^{h}	0.2615 ± 0.0025^{h}	8.98 ± 0.11^{e}

Results are expressed as mean ± standard deviation ($n = 3$). Values with different superscript letters in the same column are significantly different ($p < 0.05$), according to Tukey's HSD test.
SFA – saturated fatty acids, *MUFA* – monounsaturated fatty acids, *PUFA* – polyunsaturated fatty acids, *UFA* – unsaturated fatty acids, *n*–6/*n*–3 – *n*–6/*n*–3 polyunsaturated fatty acids ratio, *AI* – atherogenicity index, *TI* – thrombogenicity index, *HH* – hypocholesterolemic/hypercholesterolemic fatty acids ratio.

duce atherosclerosis development [21]. Oils from tree nuts are mainly used in nutraceutical, pharmaceuticals and cosmetics industry due to their high contents of MUFA. In particular, hazelnut oil may serve as cooking oil in various dishes due to its unique flavour.

Oil samples were predominantly characterized by high contents of PUFA suggesting that the cold-pressed oils may serve as a potential dietary source of fatty acids with positive health effects. The essential fatty acids cannot be synthesized within a human organism and it is necessary to obtain them through diet. Linoleic acid was the most abundant fatty acid in cold-pressed grape seed oils (697.4 g·kg^{-1}). The results were aligned with a previous study whereas results reported for linoleic acid were in the range between 660 g·kg^{-1} and 753 g·kg^{-1} of total fatty acid in grape seeds [22]. Flaxseed oil had the greatest level of a essential *n*–3 PUFA, α-linolenic acid (578.0 g·kg^{-1}), among all tested oil samples, followed by the raspberry (319.8 g·kg^{-1}) and blackberry oil (160.7 g·kg^{-1}). Flaxseed oil is an excellent natural source of α-linolenic acid and its content ranges from approximately 400 g·kg^{-1} to 600 g·kg^{-1} of the total fatty acids in this oil [23]. Also of note is that the ratio of *n*–6 and *n*–3 PUFA was 0.24 for flaxseed oil. Low *n*–6/*n*–3 PUFA ratio in the flaxseed oil makes it attractive and suitable for functional foods and nutraceuticals applications. The recommended *n*–6/*n*–3 PUFA ratio is estimated to be 4, while the current *n*–6/*n*–3 PUFA ratio in present Western diets has been assessed to be 15–20. Berry seed oils have a favourable *n*–6/*n*–3 PUFA ratio, which is better compared with some other fruit and vegetable oils. These ratios were 1.64 and 3.89 for raspberry and blackberry seed oils, respectively (Tab. 6). Slightly higher ratio (5.45) was noticed for walnut oil. The increased content of *n*–6 PUFA and/or a reduced content of *n*–3 PUFA resulted in an increased *n*–6/*n*–3 PUFA ratio in other oil samples, which may have contributed to the current prevalence of many chronic diseases. The appropriate *n*–6/*n*–3 PUFA ratio might play a role in reducing the risks of cancer and heart diseases [24].

The most important health benefit attributed to pumpkin seed oil consumption is preventing the urinary dysfunction in human [25]. Pumpkin seed oil is generally one of the most commonly preferred salad oils, giving the prepared foods (e.g. dressings, soups, scrambled eggs or ice cream) a dark-green colour and typical aroma. The incorporation of plant seed oils in food, pharmaceutical and cosmetic products is mostly based on their nutritional properties and possible health benefits [2].

The potential to reduce the risk of increased blood cholesterol is related to the ratio of polyunsaturated/saturated fatty acids (PUFA/SFA) higher than 0.45 [26]. The highest values for PUFA/SFA ratio were obtained for raspberry and blackberry oils, which confirmed the advantageous nutritional quality of these oils. Additionally, numerous aromatic compounds provide special "berry/cherry flavours" and add to the value of creams, bath oils, gels and other cosmetic products. The high *HH* value is directly related to the benefit given to cholesterol metabolism and formation of high density lipoproteins, unlike the *AI* and *TI* indices, which should be reduced, making the oil suitable for human consumption. The *AI* of the oil samples was recorded below 0.2000 in all examined samples (Tab. 6). The *TI* ranged from 0.0276 (raspberry oil) to 0.5236 (muscat pumpkin oil). Similar values of *TI* were reported for cold-pressed raspberry oil (0.060) [13], red grape (0.257) and white grape seed oil (0.269) obtained by supercritical CO_2 extraction [27]. *TI* values for all oil samples were below 1 which is the limit suitable for a healthy diet [28]. *HH* values were in the range from 5.15 determined in muscat pumpkin oil to 36.81 in raspberry oil. Similar results were noticed in study of Marić et al. [13], who obtained high *HH* values in raspberry seeds oil in the range from 31.36 to 39.09 depending on the process variables of supercritical fluid extraction.

Chemical composition of semi-defatted cake flours

The semi-defatted cake flours (SDCF) of various plant seeds (flax, sesame, muscat pumpkin, pumpkin, red grape, blackberry, raspberry, sour cherry and blue poppy) remaining after oil separation by screw press were subjected to proximal analysis of moisture content, ash, crude protein, crude fat, total sugar and dietary fibres contents (Tab. 7). Chemical composition of SDCF could vary to a great extent and it is strongly determined by characteristics of raw material (plant species, plant nutrition, climate conditions and others). Differences in oilseed pre-treatment technology (e.g. impurity removal and dehulling) are greatly contributing to this variability. As for example, dehulling pre-treatment separates the high dietary fibre fraction (hull) from the high-oil and high-protein fraction (central part of the oilseed). Type of processing technology applied for oil separation (mechanical pressing or solvent extraction) and efficiency of oil recovery from seeds is also in close relation to chemical composition of SDCF, as the higher oil yield results in higher content of other constituents in SDCF.

Moisture content is a relevant factor for seeds storage longevity. For most of the seeds with moisture content in the range 50–130 g·kg^{-1}, an increase in moisture content for 10 g·kg^{-1} diminishes seed shelf life by half. Even higher reduction rate of storage longevity occurs with seed moisture content above 130 g·kg^{-1}, which is connected to activity of fungi and increased heat production due to respiration processes. Thus, moisture content is also a relevant quality factor for obtained SDCF. It ranged from 32.6 g·kg^{-1} to 88.7 g·kg^{-1}. Since moisture content in some SDCF was below the recommended storage values [29], i.e. for full-fat flaxseed (80–90 g·kg^{-1}), pumpkin seed (80–90 g·kg^{-1}) [30] and poppy seed (80–100 g·kg^{-1}), it could be considered that moisture content of the obtained flours was acceptable for at least short-term storage (for a few months).

Quantity of inorganic minerals, which are determined after ignition or total oxidation of organic matter in food samples, refers to ash content. The mineral elements are often classified as macroelements (Ca, P, Na etc.) and microelements (Fe, Co, Cu, K, Mg, Mn, Zn etc.). Minerals have numerous functions in human, plant and animal tissues, which were thoroughly reviewed by Soetan et al. [31]. Sour cherry, raspberry, blackberry and red grape flours exhibited low quantity of inorganic minerals (9.6–25.1 g·kg^{-1} dry weight, dw, Tab. 7). Ash content determined in flaxseed, sesame and in both pumpkin SDCF was moderate and in the range from 49.9 g·kg^{-1} to 69.5 g·kg^{-1} dw. Ash content in whole pumpkin kernels flour (32.1 g·kg^{-1} dw) [32], sesame press cake (86 g·kg^{-1} wet basis) [33], yellow and brown linseed press cake (61.9 g·kg^{-1} and 63.0 g·kg^{-1} dw, respectively) [11] was reported by other studies as well. It should be highlighted that the lower value of ash content in whole pumpkin kernel flour (32.1 g·kg^{-1} dw) determined in a study by El-Adawy and Taha [32], comparing to pumpkin flour in the present study (69.5 g·kg^{-1} dw), was mainly due to fat content, which was reduced at pressing (Tab. 3, Tab. 7).

Proteins are important constituents in a wide spectrum of products from agri-food sector due to their complementary bio- and techno-functionality. Bio-functionality is linked to nutritional and physiological characteristics of proteins, while techno-functionality is linked to physico-chemical characteristics, which incorporated proteins provide in food systems (e.g. foaming, emulsifying and gelling agents). Low crude protein content was determined in sour cherry, raspberry, grape and blackberry SDCF (60–132 g·kg^{-1} dw), moderate content was observed in flax and blue poppy flours (322.8 g·kg^{-1} and 354.1 g·kg^{-1} dw, respectively), while relatively high crude protein content was obtained for pumpkin, muscat pumpkin and sesame SDCF (418.1–509.6 g·kg^{-1} dw). This determined moderate to high protein content in sesame, pumpkin, blue poppy and linseed cakes is in line with other studies [19, 33, 34]. Apart from obvious variation in crude protein content between different plant families, there is also a difference among cultivars. Higher crude protein content was determined in SDCF obtained from pumpkin comparing to muscat pumpkin. Depending on flax variety, crude protein content can range from 105 g·kg^{-1} to 310 g·kg^{-1}, thus this value in flax SDFC may vary significantly as well [34].

Dietary fibre is defined as an edible part of plants which is resistant to the digestion process mediated by endogenous enzymes in the small human bowel but susceptible to partial or full fermentation process in the large bowel. Dietary fibre has several promoting benefits on human health including laxation and positive reduction of cholesterol and glucose levels in blood. Dietary fibre is commonly divided into two major groups: soluble (gums, oligosaccharides, pectins, β-glucans, water-soluble arabinoxylans and others) and insoluble (cellulose, lignins, water-insoluble arabinoxylans and others) [5]. Content of total dietary fibres exhibited the highest variability between the SDCF samples, as it was in the range of 137.3–797.3 g·kg^{-1} dw. The lowest dietary fibre content was determined in pumpkin and sesame flours, while muscat pumpkin, linseed and blue poppy flours exhibited moderate content of fibres. Blackberry, raspberry, red grape and sour cherry SDCF had the lowest crude protein content, but exhibited the highest total natural fibres content (620.9–797.3 g·kg^{-1} dw). This was due to presence of shells in sour cherry flour obtained in the present study, which resulted in higher dietary fibre content compared to flours obtained from sour cherry kernels. This indicated that variability of fibre content in flours obtained from red grape, pumpkin and sour cherry could be higher compared to other flours as they could have incorporated skin, shell or hull. Thus, lower or higher amount of skin, shell or hull significantly alters fibre content in these flours. Furthermore, recovery of oil by mechanical pressing is less effective when hull is completely removed from seeds (e.g. in case of pumpkin). This is due to formation of less elastic reactive forces in the pressing medium with high oil and low fibre content, which leads to clogging of oil drain paths. Thus, certain amount of hulls is desirable in order to increase efficiency of oil extraction, which will result in higher fibre content in oil cakes.

Since seeds can be used as a raw material for oil production, it is desirable that crude fat content in flours is as low as possible when oilseed are utilized for this purpose. Oil separation by mechanical pressing enables complete exclusion of organic solvents (e.g. hexane), use of which is hazardous and for human health and environment. On the other hand, even with extensive mechanical pressing, it is not possible to reduce oil content in cakes to lower than 50 g·kg^{-1}, which can be achieved only by oil separation techniques involving organic solvents. Thus, certain amount of crude fat content in oil cakes obtained by mechanical pressing is always present. The lowest quantities of crude fat content were determined in raspberry, sour cherry, blackberry and red grape (57.3–65.0 g·kg^{-1} dw), while higher contents were obtained in all other flours (135.2–181.0 g·kg^{-1} dw). Similar or higher content of residual oil in cakes obtained from grape seeds (24–61 g·kg^{-1} dw) [8], blue poppy seeds (30 g·kg^{-1} dw) [9], flaxseeds (76–124 g·kg^{-1} dw) [11] and sesame seeds (approximately 270 g·kg^{-1} wet basis) obtained with mechanical pressing was achieved in others studies [7]. To increase the process efficiency, the oil remaining after mechanical pressing could be successfully isolated with organic solvents [7].

The term sugars generally refers to mono- and disaccharides, which are the simplest forms of carbohydrates constituted of one or two monomeric units, respectively. Once sugars are digested in human body, they mainly serve as a source of energy. It is well known that excessive consumation of food with a high sugar content (especially with added sugar) could lead to several health issues such as dental caries, obesity, type 2 diabetes, cardiovascular diseases and certain cancers. Therefore, due to the relatively low content of total sugars (or naturally present sugars), SDCF could be interesting for diets with low sugar contents. The lowest total sugar content was determined in sesame flour (19.5 g·kg^{-1} dw), while flour obtained from raspberry seeds exhibited the highest content (83.4 g·kg^{-1} dw).

Blue poppy, sesame, flaxseed and both pumpkin samples were characterized as flours with moderate or high content of ash, crude proteins and remaining crude fat, and with low content of fibres. Thus, due to the relatively high content of protein, the flours could be further used as raw material for production of protein isolates used as food and beverage supplements, or protein-based biodegradable film, which serves as a gas barrier coating. Highly nutritive cake flours could be also directly added to food products such as oil cake based spread [10], fortified breads [30], biscuits,

Tab. 7. Chemical composition of semi-defatted cake flours obtained from selected plant seeds by screw press.

Plant	Moisture [g·kg^{-1}]	Ash [g·kg^{-1}]	Crude protein [g·kg^{-1}]	Crude fat [g·kg^{-1}]	Total sugar [g·kg^{-1}]	Dietary fibre [g·kg^{-1}]
Flaxseed	86.8 ± 0.4^{h}	49.9 ± 1.2^{e}	354.1 ± 16.5^{e}	135.2 ± 5.4^{d}	40.6 ± 3.1^{d}	372.5 ± 17.8^{e}
Sesame	48.2 ± 0.2^{d}	60.9 ± 3.4^{f}	471.5 ± 20.6^{g}	169.6 ± 6.6^{f}	19.5 ± 0.3^{a}	154.8 ± 5.4^{b}
Pumpkin	76.9 ± 0.5^{g}	69.5 ± 1.8^{h}	509.6 ± 24.1^{h}	181.0 ± 6.3^{g}	50.3 ± 2.4^{e}	137.3 ± 8.6^{a}
Muscat pumpkin	58.5 ± 0.4^{e}	65.9 ± 3.2^{g}	416.1 ± 12.6^{f}	149.4 ± 4.0^{e}	78.8 ± 4.5^{g}	234.6 ± 12.0^{c}
Red grape	88.7 ± 0.3^{i}	25.1 ± 1.1^{d}	127.9 ± 8.7^{c}	65.0 ± 2.3^{c}	28.9 ± 1.6^{b}	746.1 ± 35.0^{h}
Blackberry	39.8 ± 0.0^{c}	18.5 ± 0.8^{c}	132.0 ± 10.2^{c}	61.5 ± 0.8^{b}	73.6 ± 0.9^{f}	620.9 ± 9.5^{f}
Raspberry	32.6 ± 0.1^{a}	17.5 ± 0.6^{b}	105.5 ± 8.6^{b}	57.3 ± 2.0^{a}	83.4 ± 2.3^{h}	716.5 ± 17.4^{g}
Sour cherry	35.1 ± 0.3^{b}	9.60 ± 1.5^{a}	61.4 ± 3.2^{a}	59.8 ± 3.2^{a}	36.2 ± 0.5^{c}	797.3 ± 42.0^{i}
Blue poppy	74.4 ± 0.0^{f}	9.08 ± 1.5^{i}	322.8 ± 13.3^{d}	144.2 ± 4.7^{e}	73.0 ± 3.5^{f}	$357.6 \pm 16.0t^{d}$

Results are expressed per dry weight as mean ± standard deviation (n = 3). Values with different superscript letters in the same column are significantly different (p < 0.05), according to Tukey's HSD test.
Ash, crude protein, crude fat, total sugar and dietary fibre contents are expressed per kilogram of dry weight.

pasta, maize extrudates [33], or to feed. These flours could be also used as a substrate for solid-state fermentation or as a supplement in growth media at microbial production of enzymes, antibiotics or biopesticides.

On the other hand, sour cherry, blackberry, raspberry and red grape flours were separated as flours with high fibre content and relatively low content of aforementioned compounds. These flours may be further utilized as a raw material for production of functional foods rich in fibres, or for production of feed. Residual grape oil cake may also be used as a raw material for extraction of fermentable sugars and phenolic compounds. Oil cakes obtained by cold-pressing of blackberry, raspberry and sour cherry seeds or kernels and their potential use in food industry as a raw material for functional foods is rarely studied even though certain health benefits were observed in rats, when their diet was fortified with fibres from defatted blueberry and raspberry seeds [35]. A recent study evaluated functional properties of raspberry fibres from entire fruit and concluded that fibre fractions could be used as functional and prebiotic ingredient in novel functional foods. It is reasonable to expect that certain amount of fibres in samples from aforementioned research had originated from seeds, as semi-defatted raspberry seeds could contain 716.5 $g \cdot kg^{-1}$ dw of fibres (Tab. 7), and that seed fibres could contribute to the properties evaluated by the authors. Thus, future research could be more focused on formulation of functional food made from these valorized fibre-rich flours and on assessment of their potential benefits on human health.

CONCLUSIONS

Waste-streams of fruit and vegetable food processing industry have a great importance in the development of novel waste-to-value products. Mechanical pressing as an eco-friendly technique that excludes use of toxic and hazardous organic solvents provides also preservation of aromatic profiles, macronutrients, micronutrients and bioactive components in plant oils, as well as in the residual cakes. Mechanically pressed plant oils and semi-defatted cake flours exhibited significant differences in terms of composition and functionality, which facilitate a variety of applications of these products. Regarding the fatty acid composition, oil samples were predominantly characterized by high contents of PUFA. Flax and berries seed oils contained significant levels of α-linolenic acid as an essential fatty acid belonging to the n–3 PUFA group. The virgin hazelnut oil contained a high proportion of MUFA, particularly oleic acid (834.5 $g \cdot kg^{-1}$), which gave it high stability and nutritional value. Relatively low-yielding berries, red grape, sour cherry and flax seed oils can be considered to have nutritional potential due to high functional quality indices. Oil cakes obtained by cold-pressing of blackberry, raspberry and sour cherry seeds were characterized as fibre-rich flours, while poppy, sesame, flaxseed and both pumpkin samples as flours with moderate or high contents of crude proteins. Utilization of cold-pressed oils and remaining cake flours in food and pharmaceutical products may enhance the profitability of vegetables, fruits and tree nut production and processing industries.

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