Fatty acid profiles, nutritional quality and sensory characteristics of unconventional oils and fats on the Slovenian market

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Summary

This study investigated nutritional value, oxidative status and sensory properties of 14 unconventional oils and fats, from flaxseed, sacha inchi, hemp seed, rapeseed, mustard seed, walnut, argan, grape seed, black cumin, camelina, peanut, poppy seed, coconut and ghee butter. Their fatty acid composition and peroxide values were determined, and their sensory profiles were evaluated by an expert panel. Data demonstrated unfavourable *n*-6/*n*-3 fatty acid ratios for grape seed, black cumin, peanut and poppy seed oils, which were otherwise rich in linoleic acid. Hemp seed, rapeseed, mustard seed and walnut oils had the most favourable *n*-6/*n*-3 fatty acid ratios. Oils with fatty acid composition close to that recommended were rapeseed oil, mustard seed oil (without erucic acid) and camelina oil. Erucic acid, which may be potentially harmful to health at high levels of chronic exposure, was detected in rapeseed, mustard seed and camelina oil. The oils and fats differed in intensities of their sweet taste and various descriptors of aroma. Sensory analysis rendered certain samples as unsuitable for human consumption due to the presence of fusty odour and aroma. In the majority of samples, lipid peroxide levels exceeded the maximum permitted levels and should be excluded from the market.

Keywords

unconventional oil; unconventional fat; fatty acid composition; sensory profile; nutritional value; erucic acid

Unconventional cold-pressed oils and fats are often expensive, although in recent years they have become an increasingly important part of the daily diet of Slovenians thanks to their popularity and marketing. From the consumer's point of view, the use of cold-pressed seed oils and fats mainly depends on nutritional quality as well as on the sensory characteristics. The nutritional quality of oils and fats is characterized by their fatty acid composition, where the parameters that are generally considered include the *n*-6/*n*-3 fatty acids ratio, the polyunsaturated/saturated fatty acids (PUFA/SFA) ratio, atherogenic index (*AI*), thrombogenic index (*TI*) [1] and the hypocholesterolemic/hypercholesterolemic fatty acid (*HH*) ratio [2].

The PUFA/SFA ratio is often used as an indicator of health-compatibility of the diet and its impact on cardiovascular health, with the assumption that diet with a higher PUFA/SFA ratio results in the greater reduction in plasma cholesterol. However, Ulbricht and Southgate suggested that the PUFA/SFA ratio is not specific enough and therefore unsuitable for assessing atherogenicity of foods. Instead, they suggested the use of *AI* and *TI* [1, 3]. These indices can be used to determine the potential effects of fatty acid composition of food on cardiovascular health. Diets with lower *AI* and *TI* have better nutritional quality and may therefore improve cardiovascular health. Another index that can more accurately describe the effects of fatty acid composition on cardiovascular health is the *HH* ratio [1–3].

However, the quality, stability and nutritional value of these oils and fats can deteriorate during storage due to oxidative changes [4]. Oxidation can damage the nutritional components of oils, which can result in changes in colour and viscosity, together with diminished oxidative stability, which will thus affect the sensory quality and shelf-life of the oil [5].

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Dietary fat for the healthy adult population should provide between 20 % and 35 % of their energy intake, with beneficial effects seen for increased consumption of *n*-3 fatty acids and limited intake of saturated and *trans* fatty acids. The Food and Agricultural Organisation also established an upper acceptable macronutrient distribution range for total PUFA at 11 % of energy intake. Among them, the acceptable distribution range for *n*-6 fatty acids was set at 2.5–9.0 % of energy intake. They also recommended total *n*-3 fatty acids intake of 0.5–2.0 % of energy intake, with a minimum requirement of > 0.5 % energy from α-linolenic acid (C18:3,*n*-3) to prevent deficiency, together with 250 mg eicosapentaenoic acid (C20:5,*n*-3) and docosahexaenoic acid (C22:6,*n*-3) a day for men and non-pregnant women [6].

Fatty acids are now defined less in terms of their general categories, such as saturated and unsaturated, because individual fatty acids within these categories have different structures and, therefore, different influences on health status and disease risk. Fatty acids not only serve as important energy sources and membrane components, but also have a more complex role in regulating energy homeostasis and metabolism. Consequently, fatty acids influence health, well-being and disease risk [7, 8]. For humans, the most important fatty acids are *n*-6 and *n*-3 fatty acids. Long-chain *n*-3 fatty acids may have the potential to prevent or reduce co-morbidities in older adults. In the body, *n*-3 fatty acids can modulate inflammation, hyperlipidemia, platelet aggregation and hypertension. They have an influence on brain function, the cardiovascular system, immune function, muscle performance and bone health, particularly in older adults. The *n*-3 fatty acids may also provide substantial benefits in terms of reduced risk of cognitive decline in older people [8].

Specific *n*-3 and *n*-6 fatty acids are essential nutrients and, as part of the overall fat supply, they can also affect the prevalence and severity of cardiovascular diseases, diabetes, cancer and age-related functional decline [9]. Among the *n*-3 fatty acids, α-linolenic acid is particularly important, as it is a precursor of eicosapentaenoic acid and docosahexaenoic acid. Among the *n*-6 fatty acids, the most important is linoleic acid (C18:2,*n*-6), which is a precursor for eicosatrienoic acid (C20:3,*n*-9) and arachidonic acid (C20:4,*n*-6) [6].

Erucic acid (C22:1,*n*-9) is considered an undesirable fatty acid, due to its negative effects on health, as it is known to cause myocardial lipidosis. Rapeseed oil is a well-known source of erucic acid. Other seed oils from *Brassica* genus are important sources of erucic acid, namely, mustard seeds and kale, as well as cabbage and turnip seeds [10]. According to European Commission Regulation (EU) 2019/1870, the maximum level of erucic acid should not exceed 20 $g\cdot kg^{-1}$ total fatty acids for vegetable oils and fats, and 50 $g\cdot kg^{-1}$ total fatty acids for camelina, mustard and borage oil. Tolerable daily intake of erucic acids represents 7 $mg\cdot kg^{-1}$ body weight [10, 11].

The oils and fats that form a part of the human diet can be selected based on their fatty acid composition and nutritional quality but sensory characteristics are very important for consumers [12]. Volatile compounds are generally responsible for characteristic odour and aroma of oils, which depend not only on the source but also on the treatment and storage conditions. These sensory properties are generally defined by panels of trained assessors, according to quantitative descriptive analysis (QDA) [13]. This allows identification of the aroma descriptors related to the oil source and quality, and can identify defects, which are most often due to oxidation.

The oils and fats selected for the present study are marketed as "healthy" oils with favourable fatty acid composition, and they are believed to represent alternatives to the more commonly used oils in Slovenia, such as olive oil or sunflower oil. They also exhibit particular odour and aroma characteristics, being consequently used in various culinary applications. However, because of their higher price, unconventional cold-pressed oils and fats tend to remain on retail shelves longer than conventional oils and fats. Storage under light and at room temperature in retail stores can promote oxidative deterioration of oils and fats, especially when stored in clear bottles. Different conditions during production, shelf-life and storage conditions at retail level may call into question the quality of the oils and fats. Therefore, the aim of this study was to determine the fatty acid composition of selected oils and fats, along with their nutritional value and sensory properties. Quality of the selected oils and fats, in terms of peroxide value, was also determined. By comparing the properties of selected oils and fats, we can better assess whether these oils and fats are a nutritionally superior alternative to more commonly used oils in the diet of Slovenians.

MATERIALS AND METHODS

Samples

Based on a market overview, the most trending unconventional cold-pressed seed oils and fats were selected. The samples consisted of: three hemp seed (*Canabis sativa*) and argan (*Argania spinosa*) oils; two flaxseed (*Linum usitatissimum*), sacha inchi (*Plukenetia volubilis*), rapeseed (*Brassica napus*), mustard seed (*Brassica juncea*), walnut (*Juglans regia*), grape seed (*Vitis vinifera*), black cumin (*Nigella sativa*), camelina (*Camelina sativa*) and coconut (*Cocos nucifera*) oils; single peanut (*Arachis hypogaea*) and poppy seed (*Papaver somniferum*) oils; and ghee butter.

Samples were obtained from four supermarkets and some smaller specialist stores in Slovenia, and from three online stores. The more represented brands of these oils and fats were randomly selected from the shelf, and were purchased as if by ordinary consumers. Therefore, manufacturers were not aware of the choice of these oils and fats, and had no influence on their procurement and analysis. The obtained samples differed in terms of their shelf-life ranges (from 3 to 36 months) and once obtained, they were stored in a dark, dry place at room temperature at 21 ± 2 °C, to preserve their original properties as best as possible before they were analysed. All oil and fat samples were purchased in a store as they would have been by consumers. No special arrangements that would influence their quality took place prior to the purchase. All samples were processed and analysed within their recommended shelf-lives. Sensory analysis of the collected samples was done on the day of opening of the sample packages, while chemical analyses were performed within a few days after opening. If this was not possible, aliquots of the samples were stored in capped glass vials that were flushed with nitrogen and kept in the dark at –20 °C to prevent advancement of lipid oxidation, and analysed within a month.

Reagents and chemicals

The following chemicals and reagents were obtained for analysis of fatty acids: sodium hydroxide (Emsure; Merck, Darmstadt, Germany); methanol (Chromasolv; Honeywell, Riedel-de-Häen, Muskegon, Michigan, USA); dichloromethane (Lichrosolv; Merck); boron trifluoride (14%, in methanol; Sigma-Aldrich, St. Louis, Missouri, USA); hexane (Chromasolv; Honeywell); and quantitative fatty acid methyl ester standards (Nu-Chek Prep, Elysian, Minnesota, USA). The following chemicals were obtained for preparation of reagents for peroxide analysis: propanol (HPLC grade; Honeywell); *tert*-buthyl hydroperoxide (LuperoX TBH70X; Sigma-Aldrich); butylated hydroxytoluene (Sigma-Aldrich); ammonium iron(II) sulphate hexahydrate (Honeywell); xylenol orange (3,3'-*bis*[N,N-*bis*(carboxymethyl) aminomethyl]-*o*-cresolsulfonephtalein sodium salt, Sigma-Aldrich); *tert*-butyl hydroperoxide solution (Luperox TBH70X; from Sigma-Aldrich); and sulphuric acid (ACS reagent; from Honeywell).

Chemical analysis

The fatty acid composition of the oil samples was determined using gas chromatographic separation of fatty acid methyl esters (FAME), which were prepared using in situ transesterification [14]. FAME separation was carried out using a gas chromatography system 6890 (Agilent Technologies, Santa Clara, California, USA) equipped with an automatic liquid sampler 7683 series and flame ionization detector. FAME were separated using a capillary column Omegawax 320 (30 m × 0.32 mm × 0.25 μm; Supelco, Bellefonte, Pennsylvania, USA). Helium was used as the carrier gas. FAME were identified based on their retention times. The instrument was calibrated using the GLC 85, GLC 423, GLC 411 and GLC 68a FAME standards (Nu-Check Prep). The chromatographic data were analysed using the ChemStation A.08.03 software (Agilent Technologies).

The peroxides of the oil samples were analysed according to the PeroxyDetect Technical Bulletin procedure (Sigma Aldrich) for lipid peroxides. Briefly, oil samples (0.100 ± 0.006 g) were solubilized in 4 ml propanol with vortex-mixing for 5 min. Then, 100 μl solubilized sample (or propanol for the blank) or *tert*-butyl hydroperoxide (for calibration, as 1.0–8.0 nmol per reaction mixture) were mixed with 1 ml organic peroxide colour reagent (containing 125 $\mu mol \cdot l^{-1}$ xylenol orange, 4 $mmol \cdot l^{-1}$ butylated hydroxytoluene, in 90% methanol) and 10 μl ferrous ammonium sulphate reagent (25 $mmol \cdot l^{-1}$, in 2.5 $mol \cdot l^{-1}$ sulphuric acid; prepared fresh before analysis). The reaction mixtures were incubated at room temperature at 21 ± 2 °C for 30 min in the dark, and then absorbance at 560 nm was recorded for the samples, blank and standards using a UV-Vis spectrophotometer (Varian Cary 50; Agilent Technologies).

Calculation of nutritional indices

The following nutritional indices were calculated: *n*-6/*n*-3 ratio, PUFA/SFA ratio, *AI* [1], *TI* [1] and *HH* ratio [2]. *HH* ratio included lauric acid (C12:0) due to its high content in coconut oil.

The *n*-6/*n*-3 ratio was calculated using the sums of the *n*-6 and *n*-3 fatty acids, according to Eq. 1:

$$n\text{-}6/n\text{-}3 = \frac{C18{:}2, n\text{-}6 + C18{:}3, n\text{-}6}{C18{:}3, n\text{-}3 + C18{:}4, n\text{-}3} \quad (1)$$

where $C18{:}2, n\text{-}6$, $C18{:}3, n\text{-}6$, $C18{:}3, n\text{-}3$ and $C18{:}4, n\text{-}3$ represent the values of corresponding fatty acids.

Atherogenic index (*AI*) was calculated according to Eq. 2:

$$AI = \frac{C12:0 + 4 \cdot C14:0 + C16:0}{PUFA + C18:1 + MUFA} \quad (2)$$

where *C*12:0, *C*14:0, *C*16:0 and *C*18:1 represent the vaules of corresponding fatty acids, *PUFA* represents the sum of all PUFA, and *MUFA* represents the sum of all MUFA.

Thrombogenic index (*TI*) was calculated according to Eq. 3:

$$TI = \frac{C14:0 + C16:0 + C18:0}{0.5 \cdot MUFA + 0.5 \cdot n\text{-}6 + 3 \cdot n\text{-}3 + \frac{n\text{-}3}{n\text{-}6}} \quad (3)$$

where *C*14:0, *C*16:0 and *C*18:0 represent the values of corresponding fatty acids, *MUFA* represents the sum of all MUFA, *n*-6 represents the sum of all *n*-6 fatty acids, and *n*-3 represents the sum of all *n*-3 fatty acids.

Hypocholesterolemic/hypercholesterolemic fatty acid (*HH*) ratio was calculated according to Eq. 4:

$$HH = \frac{C18:1, n\text{-}9 + C18:2, n\text{-}6 + C18:3, n\text{-}6}{C12:0 + C14:0 + C16:0} + \frac{C18:3, n\text{-}3 + C18:4, n\text{-}3 + C20:4, n\text{-}6}{C12:0 + C14:0 + C16:0} \quad (4)$$

where *C*18:1,*n*-9, *C*18:2,*n*-6, C18:3,n-6, *C*18:3,*n*-3, *C*18:4,*n*-3, *C*20:4,*n*-6, *C*12:0, *C*14:0, *C*16:0 represent the values of corresponding fatty acids.

Sensory analysis

The sensory profiles of the oil samples were assessed by a seven-member panel of trained sensory assessors from the Biotechnical Faculty (University of Ljubljana, Ljubljana, Slovenia) using QDA [13]. The panellists included 4 women and 3 men aged 35–55. All panellists are regularly tested for sensory performance. A list of the sensory descriptors (i. e. attributes) for odour, aroma, taste and mouth feel was developed based on literature searches and pre-assessment by the sensory panel [15] to comparatively evaluate the sensory profiles of the samples from different sources. The final list comprised four descriptors for taste (sweet, sour, bitter, salty), three for mouth feel (pungency, astringency, coating) and 21 for odour and aroma (fruity, grassy, leafy, hay, herbal, woody, walnut, piquant, earthy, metallic, tart, winey, fusty, musty, soapy, rancid, yeasty, proteic, caramel, roast, burnt). For evaluation of the descriptor intensities, a scale from 0 (undetectable) to 5 (very intense) was applied [16]. The samples in the middle of their recommended shelf-life range were served at room temperature at 21 ± 2 °C in plastic cups with three-digit codes and were distributed to the assessors in a balanced presentation order, one at a time. The analysis lasted 2 h and was performed in duplicate. The assessors used tap water to neutralize their mouth between samples.

Statistical analysis

The QDA estimated means for each descriptor of the oil samples were calculated. Differences among samples for fatty acid composition, peroxide values, calculated indices and sensory profiles were analysed by ANOVA. Statistical analysis was carried out using SPSS Statistics for Windows Version 21.0 (IBM, SPSS Statistics, Armonk, New York, USA).

RESULTS AND DISCUSSION

Fatty acid composition

The data from the analysis of the fatty acid composition of the oils and fats are presented in Tab. 1. Most of these oils predominantly contained unsaturated fatty acids. In flaxseed oil, the most abundant fatty acid was α-linolenic acid (C18:3,*n*-3), followed by oleic acid (C18:1,*n*-9) and linoleic acid (C18:2,*n*-6). Similar levels of these were also reported previously [17]. Linoleic acid was the most abundant in hemp seed, walnut, grape seed, black cumin, poppy seed and peanut oil. Among these, grape seed oil contained the highest levels of linoleic acid, at over 70 %, with only a minor amount of α-linolenic acid (0.4 %, 0.5 %), which was similar to other studies [18, 19]. Oleic acid was the most abundant fatty acid in rapeseed oil (60.4 %, 61.3 %) and argan oil (43.6–47.4 %). Rapeseed oil also contained linoleic acid at levels of 18.9 % and 19.1 %, together with α-linolenic acid at levels of 8.6 % and 9.5 %. These data are in agreement with other studies [19, 20].

Hemp seed oil had a unique fatty acid composition, as it contained γ-linolenic acid (18:3,*n*-6) and stearidonic acid (C18:4,*n*-3). The content of γ-linolenic and stearidonic acid in hemp oil was 4.5 % and 1.5 %, respectively (Tab. 1). These data are in agreement with other studies [19, 21], although they included differences for the γ-linolenic acid and stearidonic acid levels, which ranged from 0.5 % to 4.6 % and from 0.3 % to 1.6 %, respectively [21].

Tab. 1. Fatty acid composition of oils and fats.

Oil or fat sample	N°	Fatty-acid composition [%]												
		Caprylic C8:0	Capric C10:0	Lauric C12:0	Myristic C14:0	Palmitic C16:0	Stearic C18:0	Oleic C18:1, *n*-9	Linoleic C18:2, *n*-6	γ-Linolenic C18:3, *n*-6	α-Linolenic C18:3, *n*-3	Stearidonic C18:4, *n*-3	Arachidonic C20:4, *n*-6	Erucic C22:1, *n*-9
Flaxseed	#1					5.7 ± 0.0^{bc}	3.8 ± 0.0^{cd}	22.3 ± 0.1^{f}	15.6 ± 0.0^{c}		52.0 ± 0.2^{i}			
	#2			0.1 ± 0.0	0.1 ± 0.0^{a}	5.4 ± 0.0^{b}	3.8 ± 0.0^{cd}	22.7 ± 0.1^{f}	16.3 ± 0.0^{c}		51.0 ± 0.1^{i}			
Sacha inchi	#1					4.0 ± 0.0^{a}	2.9 ± 0.0^{c}	8.9 ± 0.0^{cd}	35.2 ± 0.0^{de}		48.3 ± 0.0^{h}			
	#2					4.1 ± 0.0^{a}	3.1 ± 0.0^{c}	10.1 ± 0.0^{d}	34.7 ± 0.1^{de}		47.3 ± 0.1^{h}			
Hemp seed	#1					6.1 ± 0.0^{c}	2.3 ± 0.0^{b}	10.8 ± 0.0^{d}	54.8 ± 0.0^{f}	4.5 ± 0.0	17.7 ± 0.0^{e}	1.5 ± 0.0		
	#2				0.1 ± 0.0^{a}	6.0 ± 0.0^{c}	2.5 ± 0.0^{b}	10.3 ± 0.0^{d}	54.6 ± 0.0^{f}	4.5 ± 0.0	18.4 ± 0.0^{e}	1.5 ± 0.0		
	#3					6.1 ± 0.0^{c}	2.5 ± 0.0^{b}	11.0 ± 0.0^{d}	54.7 ± 0.0^{f}	4.5 ± 0.0	17.4 ± 0.0^{e}	1.5 ± 0.0		
Rapeseed	#1				0.1 ± 0.0^{a}	4.6 ± 0.0^{b}	1.6 ± 0.0^{a}	60.4 ± 0.0^{i}	18.9 ± 0.0^{c}		8.6 ± 0.0^{c}			2.3 ± 0.0
	#2				0.1 ± 0.0^{a}	4.7 ± 0.0^{b}	1.6 ± 0.0^{a}	61.3 ± 0.0^{i}	19.1 ± 0.0^{c}		9.5 ± 0.0^{c}			0.5 ± 0.0
Mustard seed	#1				0.1 ± 0.0^{a}	4.2 ± 0.0^{a}	2.1 ± 0.0^{ab}	18.5 ± 0.1^{ef}	28.0 ± 0.2^{d}		6.8 ± 0.0^{b}			31.4 ± 0.3
	#2				0.1 ± 0.0^{a}	3.9 ± 0.0^{a}	2.5 ± 0.0^{b}	43.3 ± 0.0^{h}	31.3 ± 0.0^{d}		15.3 ± 0.0^{de}			
Walnut	#1					7.0 ± 0.0^{c}	2.6 ± 0.0^{bc}	16.7 ± 0.0^{e}	59.4 ± 0.0^{fg}		9.7 ± 0.0^{c}			
	#2					6.9 ± 0.0^{c}	2.3 ± 0.0^{b}	17.3 ± 0.0^{e}	60.4 ± 0.0^{fg}		12.5 ± 0.0^{d}			
Argan	#1				0.2 ± 0.0^{a}	12.8 ± 0.0^{fg}	5.6 ± 0.0^{e}	44.5 ± 0.0^{h}	35.3 ± 0.0^{e}		0.3 ± 0.0^{a}			
	#2				0.1 ± 0.0^{a}	9.4 ± 0.0^{de}	4.5 ± 0.0^{de}	43.6 ± 0.0^{h}	40.5 ± 0.0^{e}		0.1 ± 0.0^{a}			
	#3				0.2 ± 0.0^{a}	13.1 ± 0.0^{g}	5.4 ± 0.0^{e}	47.4 ± 0.0^{h}	32.4 ± 0.0^{de}		0.1 ± 0.0^{a}			
Grape seed	#1				0.0 ± 0.0^{a}	7.0 ± 0.0^{c}	3.7 ± 0.0^{cd}	14.8 ± 0.0^{e}	73.4 ± 0.0^{h}		0.5 ± 0.0^{a}			
	#2				0.1 ± 0.0^{a}	8.0 ± 0.0^{cd}	4.1 ± 0.0^{d}	15.6 ± 0.0^{e}	71.1 ± 0.0^{h}		0.4 ± 0.0^{a}			0.1 ± 0.0
Black cumin	#1				0.2 ± 0.0^{a}	12.8 ± 0.0^{fg}	3.0 ± 0.0^{c}	23.0 ± 0.0^{f}	57.4 ± 0.0^{f}		0.2 ± 0.0^{a}			
	#2				0.2 ± 0.0^{a}	9.7 ± 0.0^{e}	3.0 ± 0.0^{c}	32.1 ± 0.1^{g}	52.2 ± 0.1^{f}		0.2 ± 0.0^{a}			0.1 ± 0.0
Camelina	#1				0.1 ± 0.0^{a}	5.2 ± 0.0^{b}	2.2 ± 0.0^{b}	15.2 ± 0.1^{e}	17.7 ± 0.1^{c}		35.6 ± 0.2^{g}			3.0 ± 0.0
	#2				0.1 ± 0.0^{a}	6.0 ± 0.0^{c}	2.4 ± 0.0^{b}	18.2 ± 0.0^{e}	29.0 ± 0.0^{d}		26.5 ± 0.0^{f}			2.5 ± 0.0
Peanut	–					11.0 ± 0.0^{f}	4.0 ± 0.0^{d}	37.4 ± 0.0^{gh}	39.2 ± 0.0^{e}		0.5 ± 0.0^{a}			0.1 ± 0.0
Poppy seed	–				0.1 ± 0.0^{a}	8.1 ± 0.0^{cd}	2.5 ± 0.0^{b}	21.7 ± 0.0^{f}	66.2 ± 0.0^{g}		0.5 ± 0.0^{a}			
Coconut	#1	8.4 ± 0.1	5.7 ± 0.0	46.8 ± 0.2	19.9 ± 0.0^{d}	8.5 ± 0.0^{d}	2.8 ± 0.0^{bc}	6.2 ± 0.1^{bc}	1.5 ± 0.0^{ab}					
	#2	8.7 ± 0.0	6.9 ± 0.0	50.4 ± 0.1	17.9 ± 0.0^{c}	7.8 ± 0.0^{cd}	2.7 ± 0.0^{bc}	4.6 ± 0.0^{ab}	1.0 ± 0.0^{a}					
Ghee butter	–	1.2 ± 0.0	3.1 ± 0.1	3.9 ± 0.0	12.4 ± 0.0^{b}	33.3 ± 0.1^{h}	10.5 ± 0.0^{f}	22.7 ± 0.1^{f}	1.9 ± 0.0^{b}		0.4 ± 0.0^{a}		0.1 ± 0.0	

Data are mean ± standard deviation. Means with different letters in a column are significantly different ($p < 0.05$).
Empty cells – proportion of fatty acid lower than 0.04 %.

Among these samples, coconut oil and ghee butter are fats that are solid at room temperature as they predominantly contain saturated fatty acids. These comprise the prevailing lauric acid in coconut oil and palmitic acid (C16:0) in ghee butter. The ghee butter was found to contain more monounsaturated fatty acids than the coconut oil.

Nutritional value

Among the nutritional indicators, the *n*-6/*n*-3 and PUFA/SFA ratios, together with *AI* and *TI*, were calculated. For nutritional quality, a lower *n*-6/*n*-3 ratio is considered beneficial for human health. Therefore, n-6/n-3 ratios of 10 : 1 and greater are considered undesirable and not good for human health [22]. The oil with the highest *n*-6/*n*-3 ratio was black cumin seed oil (254.4, 281.4). The other oils with high *n*-6/*n*-3 ratios were the argan, grape seed, peanut and poppy seed oils (77.1–190.6; Tab. 2). On the other hand, the oils with the lowest *n*-6/*n*-3 ratio were those from flaxseed (0.3), hemp seed (3.0–3.2) and rapeseed (2.0, 2.2; Tab. 2). Other studies reported similar values for *n*-6/*n*-3 ratios, 0.3 for flaxseed oil, 3.29 for hemp seed oil [19] and 1.7–2.4 for rapeseed oil [20].

For both *AI* and *TI*, the highest values were seen for coconut oil (9.7, 12.7 and 8.1, 10.1, respectively), followed by the ghee butter, at 1.6 and 3.4, respectively (Tab. 2). For *TI*, all of the other values were similar. Similar results were previously obtained for other plant seed oils, such as flax and sesame seed oil, as well as olive oil [17].

The *HH* ratio describes the ratio between the hypocholesterolemic and hypercholesterolemic fatty acids, and hence higher values are more beneficial for human health. The lowest *HH* ratios were seen here for coconut oil and ghee butter (0.1 and 0.5, respectively). The *HH* ratio for olive oil was previously reported as 6.1 [17], and this corresponds to some of the *HH* ratios for the oils in the present study, namely, for argan oil (6.0–8.8), black cumin seed oil (6.2, 8.6) and peanut oil (7.0). All of the other oils here had higher *HH* ratios, with the highest seen for sacha inchi oil (22.2, 23.0) and for the mustard seed oil sample without erucic acid (22.3). Rapeseed and flaxseed oils also showed high *HH* ratios (18.9, 19.0 and 15.9, 16.7, respectively). Similar *HH* ratios were determined for flaxseed oil in other studies, as 13.2 [17] and 14.9 [23].

Consumers have long regarded coconut oil as a healthy alternative oil, mainly due to intensive marketing. However, the data here and from other studies now show that this appears not to be the case [24]. The main reason appears to be the content of medium-chain triglycerides in coconut oil, although studies that showed beneficial effects of commercial medium-chain triglycerides cannot be easily transposed to coconut oil. Therefore, coconut oil should be used with caution, as it contains high amounts of saturated fatty acids [25].

Erucic acid is a natural plant toxin, being found at high contents mainly in the seeds of *Brassicaceae* species (e.g., rapeseed, mustard seed). It can induce myocardial lipidosis, although this effect is reversible and transient over prolonged exposure [10]. However, the EU Commission has set the maximum levels for erucic acid in vegetable oils and fats intended for human consumption at 20 $g \cdot kg^{-1}$, while for mustard and camelina oil this level was set at 50 $g \cdot kg^{-1}$ total fatty acids [11]. As there are considerable differences in the levels of erucic acid in the mustard and rapeseed oils available in Slovenia, and since this maximum permitted level of erucic acid was exceeded in one mustard seed oil (31.4 %) and one rapeseed oil (2.3 %), a more rigorous official monitoring scheme should be applied regarding it. Erucic acid was also found in camelina oil (2.5 %, 3.0 %), and these levels agree well with other studies (1.8–2.8 %) [26, 27]. However, it should be also noted that EFSA has established the tolerable daily intake of erucic acid of 7 $mg \cdot kg^{-1}$ body weight [10]. Accordingly, some varieties of rapeseed and camelina oil should not be consumed on a daily basis in amounts larger than approximately one serving (20 g) [10].

Quality

Lipid peroxides are the primary products of lipid oxidation, and their content in oils and fats is a widely used indicator for onset of lipid oxidation. This oxidation is induced by the presence of metal ions in the oils and fats, and by exposure of the oils and fats to light and increased temperatures [28]. The maximum permitted peroxide values of cold pressed oils and fats were set at 15 $meq \cdot kg^{-1}$, while for refined oils and fats, this was set at 10 $meq \cdot kg^{-1}$, which corresponds to 5 $mmol \cdot kg^{-1}$ [29]. In the present study, peroxide values greater than 15 $meq \cdot kg^{-1}$ were determined for two thirds of the analysed oil and fat samples. This finding was unexpected as the oils and fats included in the study belonged to a higher price range and were expected to be of high quality. Our findings thus indicate a clear need for a regular assessment of the quality of unconventional oils and fats on the Slovenian market.

Sensory quality

The sources of these oils and fats affected the sensory profiles determined by QDA. Tab. 3

Tab. 2. Nutritional quality parameters of oils and fats.

Oil or fat sample	N°	Nutritional quality parameter										
		SFA [%]	MUFA [%]	PUFA [%]	*n*-3 [%]	*n*-6 [%]	*n*-6/*n*-3 ratio	PUFA/SFA ratio	Atherogenic index	Thrombogenic index	*HH* ratio	*PV* [mmol·kg^{-1}]
Flaxseed	#1	9.8 ± 0.1^{b}	22.6 ± 0.1^{e}	67.6 ± 0.2^{i}	52.0 ± 0.2^{l}	15.6 ± 0.0^{c}	0.3 ± 0.0^{a}	6.9 ± 0.1^{jk}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	15.9 ± 0.0^{gh}	6.4 ± 0.4^{bc}
	#2	9.6 ± 0.0^{b}	23.1 ± 0.1^{e}	67.3 ± 0.1^{i}	51.0 ± 0.1^{kl}	16.3 ± 0.0^{c}	0.3 ± 0.0^{a}	7.0 ± 0.0^{k}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	16.7 ± 0.0^{gh}	7.3 ± 0.1^{c}
Sacha inchi	#1	7.1 ± 0.0^{a}	9.3 ± 0.0^{c}	83.6 ± 0.0^{jk}	48.3 ± 0.0^{kl}	35.2 ± 0.0^{ef}	0.7 ± 0.0^{a}	11.8 ± 0.0^{p}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	23.0 ± 0.1^{i}	20.8 ± 1.1^{gh}
	#2	7.4 ± 0.0^{a}	10.5 ± 0.0^{c}	82.1 ± 0.0^{jk}	47.3 ± 0.1^{k}	34.8 ± 0.1^{ef}	0.7 ± 0.0^{a}	11.1 ± 0.0^{o}	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	22.2 ± 0.0^{i}	11.0 ± 0.9^{d}
Hemp seed	#1	10.0 ± 0.0^{b}	11.4 ± 0.0^{c}	78.6 ± 0.0^{j}	19.2 ± 0.0^{h}	59.4 ± 0.0^{g}	3.1 ± 0.0^{a}	7.9 ± 0.0^{n}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	14.5 ± 0.0^{g}	29.4 ± 0.3^{j}
	#2	10.1 ± 0.0^{b}	11.0 ± 0.0^{c}	79.0 ± 0.0^{j}	19.9 ± 0.0^{h}	59.1 ± 0.0^{g}	3.0 ± 0.0^{a}	7.9 ± 0.0^{n}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	14.6 ± 0.1^{g}	23.7 ± 0.1^{hi}
	#3	10.2 ± 0.0^{b}	11.6 ± 0.0^{c}	78.2 ± 0.0^{j}	18.9 ± 0.0^{h}	59.3 ± 0.0^{g}	3.2 ± 0.0^{c}	7.7 ± 0.0^{m}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	14.6 ± 0.0^{g}	77.2 ± 0.1^{p}
Rapeseed	#1	7.4 ± 0.0^{a}	65.0 ± 0.0^{k}	27.6 ± 0.0^{c}	8.6 ± 0.0^{f}	19.0 ± 0.0^{d}	2.2 ± 0.0^{a}	3.7 ± 0.0^{d}	0.0 ± 0.0^{a}	0.1 ± 0.0^{a}	19.0 ± 0.0^{h}	14.2 ± 0.1^{e}
	#2	7.5 ± 0.0^{ab}	63.9 ± 0.0^{k}	28.7 ± 0.0^{c}	9.5 ± 0.0^{f}	19.2 ± 0.0^{d}	2.0 ± 0.0^{a}	3.8 ± 0.0^{de}	0.0 ± 0.0^{a}	0.1 ± 0.0^{a}	18.9 ± 0.0^{h}	20.2 ± 0.3^{fg}
Mustard seed	#1	8.2 ± 0.7^{b}	56.0 ± 0.5^{j}	35.8 ± 0.2^{d}	7.0 ± 0.0^{e}	28.8 ± 0.2^{e}	4.2 ± 0.0^{a}	4.4 ± 0.4^{f}	0.0 ± 0.0^{a}	0.1 ± 0.0^{a}	12.4 ± 0.1^{f}	64.5 ± 5.3^{o}
	#2	7.8 ± 0.0^{ab}	45.5 ± 0.0^{i}	46.8 ± 0.0^{f}	15.3 ± 0.0^{gh}	31.5 ± 0.0^{e}	2.1 ± 0.0^{a}	6.0 ± 0.0^{i}	0.0 ± 0.0^{a}	0.1 ± 0.0^{a}	22.3 ± 0.1^{i}	16.9 ± 1.4^{ef}
Walnut	#1	9.9 ± 0.0^{b}	18.7 ± 0.0^{d}	71.4 ± 0.1^{i}	9.7 ± 0.0^{f}	59.6 ± 0.0^{g}	6.1 ± 0.0^{a}	7.2 ± 0.0^{l}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	12.2 ± 0.0^{f}	5.5 ± 0.4^{abc}
	#2	9.4 ± 0.0^{b}	17.7 ± 0.0^{d}	72.9 ± 0.0^{ij}	12.5 ± 0.0^{g}	60.4 ± 0.0^{g}	4.8 ± 0.0^{a}	7.8 ± 0.0^{mn}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	12.9 ± 0.0^{f}	39.2 ± 1.5^{k}
Argan	#1	19.3 ± 0.0^{d}	45.0 ± 0.0^{i}	35.7 ± 0.0^{d}	0.4 ± 0.0^{cd}	35.3 ± 0.0^{ef}	85.1 ± 1.1^{c}	1.9 ± 0.0^{b}	0.1 ± 0.0^{a}	0.5 ± 0.0^{e}	6.2 ± 0.0^{c}	3.2 ± 0.3^{ab}
	#2	15.0 ± 0.0^{c}	44.0 ± 0.0^{i}	40.9 ± 0.0^{e}	0.2 ± 0.0^{b}	40.5 ± 0.0^{f}	190.6 ± 2.8^{g}	2.7 ± 0.0^{c}	0.1 ± 0.0^{a}	0.3 ± 0.0^{c}	8.8 ± 0.0^{d}	26.1 ± 0.3^{i}
	#3	19.4 ± 0.0^{d}	48.0 ± 0.0^{i}	32.6 ± 0.0^{d}	0.3 ± 0.0^{b}	32.4 ± 0.0^{e}	123.9 ± 4.8^{d}	1.7 ± 0.0^{b}	0.1 ± 0.0^{a}	0.5 ± 0.0^{e}	6.0 ± 0.0^{c}	3.1 ± 0.1^{ab}
Grape seed	#1	11.0 ± 0.0^{bc}	15.1 ± 0.0^{d}	73.9 ± 0.0^{ij}	0.5 ± 0.0^{cd}	73.5 ± 0.0^{i}	162.9 ± 0.2^{e}	6.7 ± 0.0^{j}	0.1 ± 0.0^{a}	0.2 ± 0.0^{b}	12.5 ± 0.0^{f}	82.7 ± 0.7^{r}
	#2	12.4 ± 0.0^{c}	16.0 ± 0.0^{d}	71.6 ± 0.0^{ij}	0.4 ± 0.0^{c}	71.2 ± 0.0^{i}	183.5 ± 2.8^{f}	5.8 ± 0.0^{gh}	0.1 ± 0.0^{a}	0.3 ± 0.0^{c}	10.9 ± 0.0^{e}	138.4 ± 3.7^{s}
Black cumin	#1	16.3 ± 0.0^{c}	23.6 ± 0.0^{e}	60.1 ± 0.0^{h}	0.2 ± 0.0^{b}	59.9 ± 0.0^{g}	281.4 ± 0.6^{i}	3.7 ± 0.0^{d}	0.1 ± 0.0^{a}	0.4 ± 0.0^{d}	6.2 ± 0.0^{c}	17.9 ± 0.5^{fg}
	#2	13.6 ± 0.0^{c}	32.6 ± 0.1^{g}	53.7 ± 0.1^{g}	0.2 ± 0.0^{b}	53.5 ± 0.1^{g}	254.4 ± 11.3^{h}	3.9 ± 0.0^{e}	0.1 ± 0.0^{a}	0.3 ± 0.0^{c}	8.6 ± 0.0^{d}	61.7 ± 4.5^{o}
Camelina	#1	9.4 ± 0.0^{b}	34.8 ± 0.0^{g}	55.9 ± 0.1^{g}	36.0 ± 0.2^{j}	19.9 ± 0.1^{d}	0.6 ± 0.0^{a}	6.0 ± 0.0^{i}	0.1 ± 0.0^{a}	0.1 ± 0.0^{a}	12.9 ± 0.1^{f}	3.9 ± 0.0^{abc}
	#2	10.1 ± 0.0^{b}	32.4 ± 0.0^{g}	57.4 ± 0.0^{gh}	26.9 ± 0.0^{i}	30.6 ± 0.0^{e}	1.1 ± 0.0^{a}	5.7 ± 0.0^{g}	0.1 ± 0.0^{a}	0.8 ± 0.0^{f}	12.1 ± 0.0^{f}	58.4 ± 3.6^{n}
Peanut	–	21.7 ± 0.0^{d}	38.6 ± 0.0^{h}	39.8 ± 0.0^{e}	0.5 ± 0.0^{cd}	39.2 ± 0.0^{f}	77.1 ± 0.5^{b}	1.8 ± 0.0^{b}	0.1 ± 0.0^{a}	0.4 ± 0.0^{d}	7.0 ± 0.0^{c}	46.1 ± 1.1^{l}
Poppy seed	–	11.3 ± 0.0^{bc}	22.0 ± 0.0^{e}	66.8 ± 0.0^{i}	0.5 ± 0.0^{d}	66.2 ± 0.0^{h}	123.2 ± 0.1^{d}	5.9 ± 0.0^{hi}	0.1 ± 0.0^{a}	0.2 ± 0.0^{b}	10.9 ± 0.0^{e}	50.7 ± 2.8^{m}
Coconut	#1	92.3 ± 0.0^{f}	6.2 ± 0.1^{b}	1.5 ± 0.0^{a}		1.5 ± 0.0^{a}		0.0 ± 0.0^{a}	9.7 ± 0.1^{c}	8.1 ± 0.1^{h}	0.0 ± 0.0^{a}	2.0 ± 0.1^{a}
	#2	94.4 ± 0.0^{f}	4.6 ± 0.0^{a}	1.0 ± 0.0^{a}		1.0 ± 0.0^{a}		0.0 ± 0.0^{a}	12.7 ± 0.0^{d}	10.1 ± 0.1^{i}	0.1 ± 0.0^{a}	1.8 ± 0.1^{a}
Ghee butter	–	69.8 ± 0.1^{e}	27.0 ± 0.1^{f}	3.2 ± 0.0^{b}	0.5 ± 0.0^{d}	2.2 ± 0.0^{b}	4.2 ± 0.0^{a}	0.1 ± 0.0^{a}	1.6 ± 0.0^{b}	3.4 ± 0.0^{g}	0.5 ± 0.0^{b}	5.4 ± 0.1^{abc}

Data are mean ± standard deviation. Means with different letters in a column are significantly different ($p < 0.05$; ANOVA).
SFA – sum of saturated fatty acids, MUFA – sum of mono-unsaturated fatty acids, PUFA – sum of polyunsaturated fatty acids, *n*-3, *n*-6 – defined position of double bond in fatty acid; *HH* ratio – hypocholesteroaemic/hypercholesterolaemic fatty acid ratio; *PV* – peroxide value (expressed as millimoles of *tert*-butyl hydroperoxide).

Tab. 3. Sensory descriptors for the taste, aroma and mouthfeel parameters of oils and fats.

Oil or fat sample	Flaxseed	Sacha inchi	Hemp seed	Rapeseed	Mustard seed	Walnut	Argan	Grape seed	Black cumin	Camelina	Peanut	Poppy seed	Coconut	Ghee butter
Descriptors for taste														
Sweet	1.8 ± 0.5^{bc}	2.1 ± 0.4^{c}	1.7 ± 0.5^{bc}	1.5 ± 0.5^{abc}	1.1 ± 0.4^{ab}	1.8 ± 0.7^{bc}	1.6 ± 0.5^{bc}	0.9 ± 0.6^{a}	1.5 ± 0.5^{abc}	1.6 ± 0.7^{bc}	1.5 ± 0.6^{abc}	1.8 ± 0.5^{bc}	3.0 ± 0.5^{d}	1.8 ± 0.5^{bc}
Sour	0.1 ± 0.4	0.6 ± 0.5	0.8 ± 0.5	1.0 ± 0.9	0.5 ± 0.5	0.1 ± 0.4	0.6 ± 0.5	2.8 ± 0.7	0.9 ± 0.8	0.5 ± 0.5	0.3 ± 0.5	0.0 ± 0.0	0.3 ± 0.5	0.3 ± 0.5
Bitter	2.4 ± 1.1	1.3 ± 0.5	1.3 ± 0.7	1.1 ± 0.6	1.5 ± 0.5	1.6 ± 0.7	1.2 ± 0.4	1.8 ± 0.7	1.9 ± 0.8	1.1 ± 0.4	0.8 ± 0.5	2.5 ± 0.6	0.3 ± 0.5	0.3 ± 0.5
Salty	0.1 ± 0.4	0.0 ± 0.0	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.4	0.3 ± 0.5
Mouth feel descriptors														
Pungency	2.4 ± 0.7	0.8 ± 0.5	1.3 ± 0.5	1.3 ± 0.5	1.6 ± 0.5	0.3 ± 0.5	1.2 ± 0.4	2.9 ± 0.6	3.0 ± 0.0	1.6 ± 0.5	0.8 ± 0.5	1.8 ± 0.5	0.4 ± 0.5	0.3 ± 0.5
Astringency	0.8 ± 0.7	0.3 ± 0.5	0.8 ± 0.5	0.8 ± 0.5	1.4 ± 0.5	1.0 ± 0.9	0.5 ± 0.5	1.3 ± 0.5	1.0 ± 0.8	0.9 ± 0.4	0.3 ± 0.5	1.3 ± 0.5	0.1 ± 0.4	1.0 ± 0.0
Coating	1.1 ± 0.4	0.9 ± 0.4	0.8 ± 0.4	1.4 ± 0.5	1.0 ± 0.5	0.8 ± 0.5	0.6 ± 0.5	1.4 ± 0.5	0.8 ± 0.5	0.6 ± 0.5	0.8 ± 0.5	1.5 ± 0.6	1.1 ± 0.8	1.0 ± 0.0
Odour and Aroma descriptors														
Fruity	0.6 ± 0.5	1.5 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	0.0 ± 0.0	0.9 ± 0.8	0.9 ± 0.5	0.8 ± 0.9	0.4 ± 0.5	0.5 ± 0.5	0.8 ± 0.5	0.3 ± 0.5	2.9 ± 1.6	0.0 ± 0.0
Grassy	2.4 ± 1.1	1.8 ± 0.5	1.8 ± 0.6	1.5 ± 0.5	1.3 ± 0.7	1.1 ± 0.8	0.8 ± 0.5	1.0 ± 0.5	2.0 ± 0.5	1.3 ± 0.5	1.0 ± 0.0	0.8 ± 0.5	0.3 ± 0.5	0.5 ± 0.6
Leafy	2.5 ± 0.5^{e}	1.9 ± 0.6^{cde}	2.2 ± 0.6^{de}	2.4 ± 0.5^{de}	1.8 ± 0.5^{cd}	0.6 ± 0.5^{ab}	1.0 ± 0.6^{b}	1.0 ± 0.5^{b}	1.3 ± 0.5^{bc}	2.5 ± 0.5^{e}	1.8 ± 0.5^{cd}	1.8 ± 0.5^{ab}	0.6 ± 0.5^{ab}	0.3 ± 0.5^{a}
Hay	1.8 ± 0.5^{d}	0.9 ± 0.4^{bc}	1.3 ± 0.7^{bcd}	1.5 ± 0.5^{cd}	1.4 ± 0.5^{cd}	1.5 ± 0.5^{cd}	1.5 ± 0.5^{cd}	0.8 ± 0.5^{ab}	1.8 ± 0.5^{d}	1.8 ± 0.5^{d}	1.3 ± 0.5^{bcd}	1.3 ± 0.5^{bcd}	0.3 ± 0.5^{a}	0.8 ± 0.5^{ab}
Herbal	2.3 ± 0.7	1.6 ± 0.5	1.8 ± 0.5	1.0 ± 0.0	3.4 ± 0.5	1.5 ± 0.5	1.3 ± 0.8	1.4 ± 0.5	3.0 ± 0.5	2.4 ± 0.5	1.5 ± 0.6	0.8 ± 0.5	0.4 ± 0.5	0.3 ± 0.5
Woody	0.8 ± 0.5^{abc}	0.9 ± 0.4^{bcd}	1.1 ± 0.5^{cde}	1.6 ± 0.5^{e}	1.1 ± 0.4^{cde}	1.4 ± 0.5^{cde}	1.3 ± 0.6^{cde}	1.0 ± 0.8^{cde}	0.8 ± 0.5^{abc}	0.9 ± 0.4^{bcd}	1.5 ± 0.6^{de}	1.0 ± 0.0^{cde}	0.4 ± 0.5^{ab}	0.3 ± 0.5^{a}
Walnut	1.3 ± 0.5	0.9 ± 0.4	1.0 ± 0.0	1.6 ± 1.1	0.9 ± 0.4	3.4 ± 0.7	1.5 ± 0.5	0.4 ± 0.5	0.5 ± 0.5	0.8 ± 0.5	1.3 ± 0.5	1.3 ± 0.5	0.3 ± 0.5	0.8 ± 0.5
Piquant	2.1 ± 0.6	1.0 ± 0.0	1.3 ± 0.5	1.1 ± 0.6	1.9 ± 0.6	1.0 ± 0.5	1.7 ± 0.7	1.3 ± 0.5	4.4 ± 0.5	2.1 ± 0.8	0.8 ± 0.5	1.8 ± 0.5	0.0 ± 0.0	0.3 ± 0.5
Earthy	0.3 ± 0.5	0.5 ± 0.5	0.8 ± 0.6	1.3 ± 0.7	0.8 ± 0.5	0.6 ± 0.5	0.4 ± 0.5	1.0 ± 0.0	0.0 ± 0.0	0.8 ± 0.5	0.5 ± 0.6	0.5 ± 0.6	0.0 ± 0.0	0.0 ± 0.0
Metallic	0.5 ± 0.5	0.5 ± 0.5	0.7 ± 0.5	0.6 ± 0.5	0.6 ± 0.5	0.6 ± 0.5	0.5 ± 0.5	0.8 ± 0.5	0.4 ± 0.5	0.6 ± 0.5	0.8 ± 0.5	0.5 ± 0.5	0.1 ± 0.4	0.0 ± 0.0
Tart	3.3 ± 0.9^{j}	0.9 ±0.6^{abcd}	1.3 ±0.8^{cdef}	1.1±0.6^{bcde}	1.5 ± 0.5^{def}	0.8 ± 0.7^{abc}	1.7 ± 0.5^{efg}	1.9 ± 0.4^{fgh}	2.6 ± 0.5^{ij}	1.6 ± 0.5^{efg}	2.3 ± 0.5^{ghi}	2.5 ± 0.6^{hi}	0.3 ± 0.5^{a}	0.5 ± 0.6^{ab}
Winey	0.0 ± 0.0	0.3 ± 0.5	0.1 ± 0.3	0.8 ± 0.7	0.9 ± 0.8	0.0 ± 0.0	0.6 ± 0.8	4.0 ± 0.9	0.0 ± 0.0	0.1 ± 0.4	0.3 ± 0.5	0.0 ± 0.0	0.8 ± 0.9	0.3 ± 0.5
Fusty	0.6 ± 0.5^{ab}	0.8 ± 0.5^{ab}	1.3 ± 0.7^{bc}	1.8 ± 0.5^{cd}	1.3 ± 0.7^{bc}	0.6 ± 0.7^{ab}	1.1 ± 0.5^{bc}	2.4 ± 0.5^{d}	0.3 ± 0.5^{a}	1.1 ± 0.8^{bc}	0.8 ± 0.5^{ab}	1.8 ± 0.5^{cd}	0.6 ± 0.7^{ab}	0.3 ± 0.5^{a}
Musty	0.1 ± 0.4	0.0 ± 0.0	0.3 ± 0.5	0.1 ± 0.4	0.4 ± 0.5	0.0 ± 0.0	0.1 ± 0.3	1.0 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.5	0.5 ± 0.6	0.0 ± 0.0	0.0 ± 0.0
Soapy	0.0 ± 0.0	0.1 ± 0.4	0.0 ± 0.0	0.4 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.5	1.3 ± 0.9	2.0 ± 0.0	0.0 ± 0.0	1.0 ± 0.0	0.0 ± 0.0	0.8 ± 0.9	0.3 ± 0.5
Rancid	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.5	0.1 ± 0.4	1.0 ± 1.1	0.5 ± 0.5	0.5 ± 0.5	2.8 ± 1.4	0.3 ± 0.5	0.1 ± 0.4	0.3 ± 0.5	4.5 ± 0.6	0.1 ± 0.4	0.0 ± 0.0
Yeasty	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.5	0.1 ± 0.4	0.0 ± 0.0	0.3 ± 0.5	0.4 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Roquefort	0.3 ± 0.5	0.0 ± 0.0	0.5 ± 0.5	0.8 ± 0.5	0.5 ± 0.5	0.3 ± 0.5	1.6 ± 0.7	0.5 ± 0.5	0.0 ± 0.0	0.4 ± 0.5	0.3 ± 0.5	0.5 ± 0.6	0.3 ± 0.5	0.8 ± 0.5
Caramel	0.3 ± 0.5	0.0 ± 0.0	0.3 ± 0.5	0.3 ± 0.5	0.5 ± 0.5	0.9 ± 0.4	0.3 ± 0.5	0.1 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.8 ± 0.9	1.0 ± 0.0
Roasty	0.1 ± 0.4	0.0 ± 0.0	0.3 ± 0.5	0.4 ± 0.5	0.5 ± 0.5	0.5 ± 0.5	1.3 ± 0.6	0.3 ± 0.5	0.3 ± 0.5	0.4 ± 0.5	0.3 ± 0.5	1.0 ± 0.0	0.0 ± 0.0	1.0 ± 0.0
Burnt	0.4 ± 0.5	0.0 ± 0.0	0.2 ± 0.4	0.1 ± 0.4	0.8 ± 0.5	1.5 ± 1.6	1.7 ± 0.8	0.5 ± 0.5	0.0 ± 0.0	0.1 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.7	0.0 ± 0.0

Data are mean ± standard deviation. Means with different letters in a row are significantly different ($p < 0.05$).

presents the mean values of the intensities of the descriptors. The six descriptors for which statistically significant differences among oils and fats were confirmed were marked with different letters. Significant differences were seen across these samples for the intensity of the sweet taste ($p < 0.001$), but not for the other tastes. The sweetness was judged to be of medium intensity in the coconut oil (3.0), and mild to very mild in the other samples (0.9–2.1). A sour taste of medium intensity was only perceived for the grape seed oil, while very mild acidity was noted in the hemp seed, rapeseed and black cumin seed oils. The bitter taste was highest for the poppy seed oil, followed by the flaxseed and black cumin seed oils; however, these differences did not reach statistical significance. This might be related to the type of pre-treatment, before the cold pressing and the type of oil [30]. The bitter taste was absent or barely detectable in the coconut oil, walnut oil and ghee butter. A salty taste was not perceived for the assessed samples. The other significant discriminators regarding these types of oil were some of the descriptions for the odour and aroma profile, as leafy, hay, woody, tart and fusty (all $p < 0.001$). A leafy odour and aroma was most clearly seen for the camelina seed oil (2.5), followed by the rapeseed (2.4) and hemp seed (2.2) oils, which was in line with descriptions from another study [31]. The most intense hay odour and aroma were detected in flaxseed, black cumin and camelina oils (all 1.8). The woody note was the most intense, although mild, for rapeseed oil (1.6), followed by peanut oil (1.5), as was reported previously [16, 31]. The tart odour and aroma were significantly most intense in flaxseed oil (3.3) and black cumin oil (2.6). The fusty odour and aroma, which are considered a defect in oils [16], were detected at medium intensities in the grape seed (2.4), rapeseed (1.8) and poppy seed (1.8) oils. This indicates that these samples were of inferior sensory quality, therefore not suitable for human consumption and should be disqualified as edible products.

Certain notes of odour and aroma were perceived only in individual oil types. The nutty odour and aroma were characteristic of walnut seed oil (3.4), but not of the other samples. Black cumin oil was significantly more piquant (4.4) than the other samples, while a winey odour and aroma were intensively expressed only in the grape seed oils (4.0). The proteic (i.e. like Roquefort cheese) odour and aroma were characteristic of argan oil (1.6), as also reported previously [32], while it was not, or only barely, detected in the other samples. The sensory attributes were low for coconut oil and ghee butter. The ghee butter was characterized by a slightly sweet taste, together with caramel and roasty odour and aroma, while for the coconut oil, the sweetness was of medium intensity and was the most pronounced across all of the samples. Similar descriptors for the latter two fats were reported previously [33, 34].

Differences in the sensory profiles between samples of the same type of oil or fat might indicate different quality levels. Indeed, all of the quantitative sensory profiles between samples of the same type showed some significant differences, except for the sacha inchi oil. The two samples of coconut oil significantly differed in intensity of mouth coating ($p = 0.017$) and the fruity odour and aroma ($p < 0.001$). The two samples of flaxseed oil differed significantly in the intensities of the bitter taste ($p = 0.004$) and astringency ($p = 0.030$), grassy ($p = 0.004$) and herbal ($p = 0.030$) aroma, while the two rapeseed oil samples had significantly different intense sour tastes ($p = 0.005$), walnut aroma ($p = 0.004$) and earthy aroma ($p = 0.030$). The two samples of mustard seed oil significantly differed in their intensities of winey ($p = 0.017$), fusty ($p = 0.030$) and grassy ($p = 0.030$) odour and aroma. The two walnut oil samples showed one that was significantly more astringent ($p = 0.005$) and tart ($p = 0.030$), which had lower peroxide value than the other, which had a significantly more pronounced sweet taste ($p = 0.030$), fruity odour and aroma ($p = 0.017$) and grassy odour and aroma ($p = 0.017$). Between the two samples of grape seed oil, the one with a higher peroxide value was significantly more bitter ($p = 0.030$), but significantly less sour ($p = 0.030$) and winey ($p = 0.005$). The sample of the two black cumin oils that had a higher peroxide value was significantly more bitter ($p = 0.017$) and significantly less sour ($p = 0.017$) than the other. For the samples of the two camelina oils, the one with the higher peroxide value was significantly more piquant ($p = 0.017$) and significantly less fusty ($p = 0.017$) than the other. Among the three argan oil samples, the herbal odour and aroma were significantly more perceived ($p = 0.025$) in the two samples with higher peroxide values. The three samples of hemp seed oil significantly differed in their tart odour and aroma ($p = 0.012$), which was least expressed in the sample with the highest peroxide values.

CONCLUSIONS

Unconventional oils and fats are marketed as „healthy“ oils with favourable fatty acid composition and are believed to represent “healthier” alternatives to commonly used oils. However, prolonged storage under light and at room temperature in retail stores can promote their oxidative deterioration. The unconventional cold-pressed oils and fats examined in this study were purchased in stores as they would be purchased by ordinary consumers, and their fatty acid composition, peroxide values, nutritional value parameters as well as sensory properties were determined. The oils with the highest contents of linoleic acid were hemp seed, walnut, grape seed, black cumin, poppy seed and peanut oil, while the highest contents of α-linolenic acid were found in flaxseed, sacha inchi and camelina oils. Hemp seed, rapeseed, mustard seed and walnut oils showed the most favourable *n*-6/*n*-3 fatty acid ratios. However, the results showed that the fatty acid composition of certain oils and fats may be taken as unfavourable together with their nutritional parameters, as shown by the ratios of *n*-6/*n*-3 fatty acids in grape seed, black cumin, peanut and poppy seed oils. Special attention should be paid to erucic acid, which is generally not present in plant oils and can only be found in certain oils. The results of our study show that erucic acid was detected in rapeseed, mustard seed and camelina oils. The recommended level of erucic acid was exceeded in one sample of mustard seed and one sample of rapeseed oil. Another attribute that determines the quality of oils and fats is the peroxide value, and the majority of samples had values above the permitted maximum value. Further, sensory analysis allowed us to identify oils and fats that may be considered unsuitable regarding sensory quality. One of the indicators is fusty odour and aroma, which was identified in grape seed, rapeseed and poppy seed oils. Based on the erucic acid and peroxide values, as well as the results of sensory analysis, we can conclude that some of the analysed oils on the Slovenian market were not suitable for human consumption. It is therefore important to implement a more rigorous official monitoring system to protect consumers.

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