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CHARACTERIZATION OF SOME QUALITY PROPERTIES AND CHEMICAL COMPOSITION OF COLD-PRESSED OILS OBTAINED FROM DIFFERENT RAPESEED VARIETIES CULTIVATED IN POLAND

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Key words: rapeseed, *Brassica napus,* cold pressed oil, quality, fatty acids, tocopherols, sensory assessment, PCA.

Abstract

In this study comparison of quality parameters and chemical composition between cold-pressed oils obtained from 6 different rapeseed varieties, including double improved (RO), high-oleic (HORO) and yellow-seeded (YSRO), has been conducted. A clear correlation between fatty acid composition and oxidative stability of oils was observed. Variety-dependent variation in the content of individual tocopherols and slight differences in the content of total tocopherols was found. The results of oils sensory assessment based on PCA showed that the major sensory attributes assigned to ROs are seed-like and nutty, while sensory attributes like woody, strawy and astringent are strongly perceivable in HORO and YSRO.

Abbreviations: AV – acid value, CD – conjugated dienes, CT – conjugated trienes, IP – induction period, PV – peroxide value, *p*-AnV – *p*-anisidine value, RO – double improved „00" rapeseed oil, HORO – high-oleic rapeseed oil, YSRO – yellow-seeded rapeseed oil, α-T – alpha--tocopherol, γ-T – gamma-tocopherol, δ-T – delta-tocopherol, α-TE – α-tocopherol equivalent.

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CHARAKTERYSTYKA WYBRANYCH CECH JAKOŚCIOWYCH I SKŁADU CHEMICZNEGO OLEJÓW TŁOCZONYCH NA ZIMNO OTRZYMANYCH Z RÓŻNYCH ODMIAN RZEPAKU UPRAWIANEGO W POLSCE

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Słowa kluczowe: rzepak, *Brassica napus,* olej tłoczony na zimno, jakość, kwasy tłuszczowe, tokoferole, cechy sensoryczne, PCA.

Abstrakt

W pracy porównano parametry jakości i skład chemiczny olejów rzepakowych tłoczonych na zimno uzyskanych z 6 różnych odmian rzepaku, w tym: nasiona podwójnie ulepszone (RO), wysokooleinowe (HORO) i żółtonasienne (YSRO). Wyraźnie zaobserwowano korelację liniową między składem kwasów tłuszczowych a stabilnością oksydatywną uzyskanych olejów. W zależności od odmiany nasion użytych do tłoczenia stwierdzono różnice w zawartości poszczególnych form tokoferoli i niewielkie w ogólnej zawartości tokoferoli w otrzymanych olejach. Wyniki oceny sensorycznej olejów opartych na analizie PCA pokazały, że główne cechy sensoryczne olejów, takie jak: „typowy dla nasion" i „orzechowy" były przypisane odmianom podwójnie ulepszonym (RO), natomiast pozostałe cechy sensoryczne, takie jak: „typowy dla drewna, trawy, ściągający" były silnie odczuwalne w olejach z odmian HORO i YSRO.

Introduction

Production of rapeseed oil peaked in 2013/14 at 26.6 million tonnes, which placed it the third most important plant oil, after soy and palm oil (FAOSTAT 2015). Although the above figures do not distinguish the various types of rapeseed oil, there has been an increased interest by consumers for cold-pressed oils observed in recent years (MATTHÄUS and BRÜHL 2008). This trendis also noticeable in the Polish market, where an increased consumption of cold pressed oils, including rapeseed oil, is observed.

According to Codex Alimentarius Standard for Named Vegetable Oils (CODEX STAN 210–1999) oils „obtained, without altering the nature of oil, by mechanical procedures, e.g. expelling or pressing, without the application of heat" are defined as „cold-pressed oils". One of the most important parameter for the evaluation of the quality of cold-pressed oils is the sensory assessment, especially the intensity of sensory attributes. Typical cold-pressed rapeseed oil attributes are listed as follows: *seed-like*, *nutty*, *woody*, *astringent*, while off-flavours are described as *rancid*, *fusty*, *musty*, and *bitter* (BRÜHL and MATTHÄUS 2008).

Rapeseed/canola oil has unique health benefits than many other plant oils, primarily due to favourable fatty acid composition and the high concentration of bioactive compounds. Rapeseed oil is very low in SFA (< 7%), rich in oleic acid (< 60%), and contains linoleic to α-linolenic essential fatty acids ratio of 2:1, making it nutritious (O'BRIEN 2009). Moreover, rapeseed oil is rich source of natural antioxidants, including tocopherols, polyphenols and phytosterols. Crude rapeseed oil contains valuable amounts of tocopherols (approx. 770 mg kg^{-1}), primarily γ-T (65%), followed by α-T (35%), while β- and δ-T are present at very low or undetectable concentrations (PRZYBYLSKI 2011). Rapeseed contains more phenolic compounds than most of the other oilseed plants. The most significant of these are sinapic acid and its derivatives (NACZK et al. 1998, KOZLOWSKA et al. 1990). However, during oil cold-pressing only a small proportion of phenolic compounds is transferred to the crude oil, while the rest is retained in the meal (KOSKI et al. 2002). Crude rapeseed oil is also a good source of sterols (4500–11300 mg kg^{-1}) but when oil is processed further, especially under high temperatures, sterol levels in oil can be reduced (MÖLLERS 2002). The reported sterol distribution in rapeseed/canola oil is as follows: β-sitosterol (52%), followed by campesterol (28%) and brassicasterol (14%) (VERLEYEN et al. 2002).

Pigments represent the natural components of oilseeds, they are considered important factors because they can impart undesirable green/brown colour to vegetable oils or facilitate oxidation in the presence of light. The composition and content of chlorophyll pigments present in the seeds of rapeseed depends on seed maturity. During ripening the chlorophyll pigments are gradually degraded – physiologically mature seeds (35 days before maturity) contain an average of 1239 mg kg^{-1} total chlorophylls, while 4 mg kg^{-1} of chlorophylls can be found in fully matured seeds (WARD et al. 1994, MÖLLERS 2002). The chlorophyll content in crude canola oil should be less than 30 mg kg^{-1}, with chlorophyll *a* and chlorophyll *b* in the ratio of 3:1, and approximately 95 mg kg^{-1} of carotenoids, with ~ 90% xanthophylls and ~ 10% of carotenes (ENDO et al. 1992).

The objectives of this research were: (1) to evaluate the variation of some quality parameters, minor components (tocopherols and pigments), fatty acid composition and oxidative stability of cold-pressed rapeseed oils acquired from different rape varieties (double improved „00", high-oleic and yellow-seeded) cultivated in Poland, (2) to distinguish oils based on their sensory assessment performed by applying principal component analysis.

Materials and Methods

Material. Samples of six rapeseed varieties, including double improved *B. napus* species: Bogart, Bojan, Monolit and Starter (Plant Breeding Strzelce Ltd. Co. – IHAR Group, Poland), yellow-seeded *B. napus* line PNz022 and high-oleic *B. napus* line PN 1170 (The Plant Breeding and Acclimatization Institute, Poznan, Poland). The selected rapeseed varieties were cleaned and stored in paper bags at 15 ± 2°C.

Oil extraction by cold-pressing. Samples of rapeseed (1.5 kg) were cold-pressed with the use of screw press (Farmet, Czech Republic), the temperature of the outflowing oil was in the range from 38 to 42°C. After pressing oils were filtered to remove particles, and afterwards kept in dark glass bottles under refrigeration temperature (4 ± 2°C) until analysed.

Chemicals and solvents. Analytical standards of δ-, γ- and α-tocopherols and 5α-cholestane were purchased from Sigma-Aldrich, (USA). HPLC grade methyl *tert*-butyl ether (MtBE), acetonitrile (ACN) were obtained from POCH (Poland). Chloroform, a high-purity grade (~99.5%) acetic acid, potassium hydroxide and potassium iodide were supplied by Chempur (Poland), solvents: isooctane and n-hexane were acquired from Merck (Germany).

Oil quality analysis. The cold-pressed rapeseed oils were analysed for acid value (*Animal and vegetable...* ISO 660:2005), peroxide value (*Animal and vegetable...* ISO 3960:1996), *p*-anisidine value (ISO 6885:2008). The conjugated dienes and trienes, expressed by absorption coefficient $E^{1\%}_{1cm}$ at λ_{max} 232 and 286 nm (*Animal and vegetable...* ISO 3656:2011), were determined using Thermo-Spectronic Helios β spectrophotometer.

Pigments. The carotenoid and chlorophyll pigments were assayed spectrophotometrically using the ThermoSpectronic Helios β spectrophotometer. Total chlorophylls were determined according to AOCS Method (1997), by measuring the absorbance of oil at 630, 670 and 710 nm in 10 mm spectrophotometer cell against air. The content of chlorophyll pigments was expressed in mg of pheophytin a in 1 kg of oil. Total carotenoid pigments were determined in accordance with BSI Method (1977) by measuring the absorbance of oil samples diluted in cyclohexane at 445 nm. The results were calculated for total carotenoid pigments amount, expressed as mg of β-carotene in 1 kg of oil.

Determination of fatty acid composition. A mass of 0.2 g of oil was weighed and dissolved in 2 ml of hexane. The mixture was submitted for saponification with 0.5 ml of sodium hydroxide solution in methanol (2 M) at room temperature for 2 h. Then 200 µl of the hexane layer was transferred into 1.5 ml autosampler vial and dissolved in 1 ml of hexane. The diluted FAME (1 µl of the sample) were separated on a GC-MS system (Agilent 6890N GC,

Agilent Technologies, USA) equipped with a BPX 70 capillary column (60 m length, 0.22 mm i.d., 0.25 μm film thickness) and flame-ionization detector (FID). Helium was used as a carrier gas at a flow rate of 1.5 ml/min. The column temperature was programmed at 2°C/min with initial temperature 130°C and final temperature 235°C. The injector was set at 230°C with split ratio of 100:1 and the detector was set at 250°C. Fatty acids were identified by comparing their retention times with authentic standards, and the results were reported as weight percentages following integration and calculation using ChemStation Software (Agilent Technologies).

Determination of tocopherols. A sample of 0.2 g of oil was dissolved in 5 ml of ACN/MtBE mixture (4:6 by vol.). The mixture was filtered through a micro syringe filter (titan PTFE 0.2 lm). Then, 5 μl of the sample was injected into a VP Shimadzu HPLC system coupled with DAD detector (SPD-M10AVP, Shimadzu, Japan) and fluorescence detector (RF-10AXL, Shimadzu, Japan), reversed phase octadecyl silica Gemini C 18 column (150 mm × 2 mm × 3 μm) (Phenomenex Torrance, CA, USA) and suitable guard column. The isocratic mobile phase was a mixture of ACN and MtBE (4:6 v/v) at a flow rate of 0.15 ml/min, and the column oven temperature was 35°C. Tocopherols were detected by standard UV spectrum analysis (190–370 nm). Quantification of tocopherols was conducted using data from the fluorescence detector (FLD) with excitation/emission wavelengths of 290/330 nm, respectively. All samples were analysed in triplicate and the tocopherol/oil ratio was expressed in mg/100 g.

The vitamin E content, expressed in *d*-α-tocopherol equivalents (α-TE) was calculated by multiplying milligrams of α-T by 1.0 and γ-T by 0.1 (EITENMILLER, LEE 2004).

Harris coefficient, expressed as the ratio of α-tocopherol equivalent [mg] to the mass [g] of polyunsaturated fatty acids in 100 g of the oil, was calculated (WITTING 1972).

Oxidative stability determined via accelerated stability test (Rancimat). Oxidative stability of the oil sampleswas determined with a Rancimat apparatus (Metrohm model 743; Metrohm KEBO Lab AB, Herisau, Switzerland). Briefly, oil samples were weighed (2.5 g) into the reaction vessel and heated to 120°C under air flow of 20 L/h. The induction period (IP) was expressed in hours (h).

Sensory analysis. Sensory evaluation was performed in triplicate with a selected and trained panel consisting of 10 persons in accordance with *Sensory analysis...* ISO 4121:2003 standard. The oil samples (15 ml) were served in vessels at room temperature. The sensory profile of oils was determined in accordance with the reference-sensory assessment of virgin rapeseed oils (BRÜHL, MATTHÄUS 2008). Eight flavour attributes – seed-like,

nutty, woody, strawy, astringent, rancid, fusty, musty (Table 1) – were chosen. A quantitative sensory description was conducted using a graded 10-point scale to measure the intensity of attributes, leading from zero („not detectable") to ten („intense"). The obtained data, after conversion from linear scale into numerical data, were presented as graphic projection of PCA.

Table 1
Attributes used for sensory assessment of cold-pressed rapeseed oils and descriptors for perceived sensations

Attributes	Descriptors
Seed-like	green, cabbage, asparagus, fresh vegetable, sometimes with a sulphuric note
Nutty	hazelnut, nutty
Woody	wet wood, pencil, stem, pod but also sometimes resembling to chipboard possibly together with rancid
Strawy	straw, barn, throat feels rough
Astringent	rough mouth feeling, furred teeth, like tannins in red wine
Rancid	oxidised oil
Fusty	sour, fermented flavour, silage
Musty	musty smell, mouldy taste, french salami, especially white coated

Source: BRÜHL, MATTHÄUS (2008)

Statistical analysis. All experiments were carried out in triplicate. Statistical analysis was performed using Statistica 10 software. Data were expressed as Mean ± SD or as percentage. Variables were compared by T-test, one-way Anova; post hoc Tukey Test and the significance of differences among means were determined at $p<0.05$. The results obtained from the sensory assessment of oil samples were subjected to Principal Component Analysis (PCA) applying XLSTAT software (Addinsoft, France, Version 2014.6.04).

Results

The quality of the analysed cold-pressed rapeseed oils, assessed in terms of degree of hydrolysis and oxidation, was high, which testified to the appropriate technological value of the seeds used in the research. All oils fulfilled requirements pertaining to the AV (< 4 mg KOH g^{-1}) and PV (< 15 meq O_2 kg^{-1}) specified in the standard for cold-pressed and virgin oils (CODEX STAN 210–1999). The content of secondary oxidation products, resulting from the decomposition of hydro-peroxides, *p*-AnV of all oils did not exceed the value of 1.0, which testified to the insignificant influence of the cold-pressing process on the secondary degree of oxidation of the oil. These results are in agreement with previous studies (TAŃSKA et al. 2009, KRALJIC et al. 2013). The CD content ranged from 1.32 (% E) in HORO, up to 1.75 (% E) in YSRO (Table 2).

The lowest average CD concentration in HORO is related to its specific fatty acid composition – the amount of oxidisable PUFAs decreased to ~15%, and the amount of oxidation-resistant oleic acid increased up to ~76% (Table 3). Scarce concentration of CT detected in all oils (0.07–0.20% E) indicates negligible impact of cold-pressing on the formation of oxidation by-products, such as unsaturated α- and β-diketones and β-ketones.

Table 2

Tocopherols content α-tocopherol equivalent (mg/100 g) in ROs, HORO and YSRO produced by cold-pressing

Rapeseed oil variety	α-T	γ-T	δ-T	Total tocopherols	α-TE
RO Bogart	21.8 ± 1.41^{bc}	33.4 ± 1.95^{bc}	1.2 ± 0.04^{a}	56.4 ± 1.05^{c}	25.18 ± 1.61^{b}
RO Bojan	26.8 ± 2.56^{abc}	35.2 ± 0.21^{bc}	0.7 ± 0.17^{b}	62.7 ± 2.49^{ab}	30.34 ± 2.59^{ab}
HORO	21.3 ± 2.37^{c}	42.4 ± 0.72^{a}	0.1 ± 0.01^{c}	63.8 ± 2.70^{ab}	25.54 ± 2.44^{b}
RO Monolit	25.6 ± 1.85^{ab}	31.0 ± 2.48^{c}	0.6 ± 0.04^{b}	57.2 ± 2.78^{bc}	28.72 ± 2.10^{ab}
RO Starter	28.4 ± 1.34^{a}	37.4 ± 0.35^{ab}	1.3 ± 0.09^{a}	67.1 ± 1.10^{a}	32.18 ± 1.38^{a}
YSRO	22.7 ± 3.29^{abc}	41.8 ± 3.63^{a}	0.6 ± 0.05^{b}	65.1 ± 2.42^{ab}	29.60 ± 3.65^{ab}

Different superscript letters within each column indicate significant differences ($p<0.05$) between each rapeseed variety

Table 3

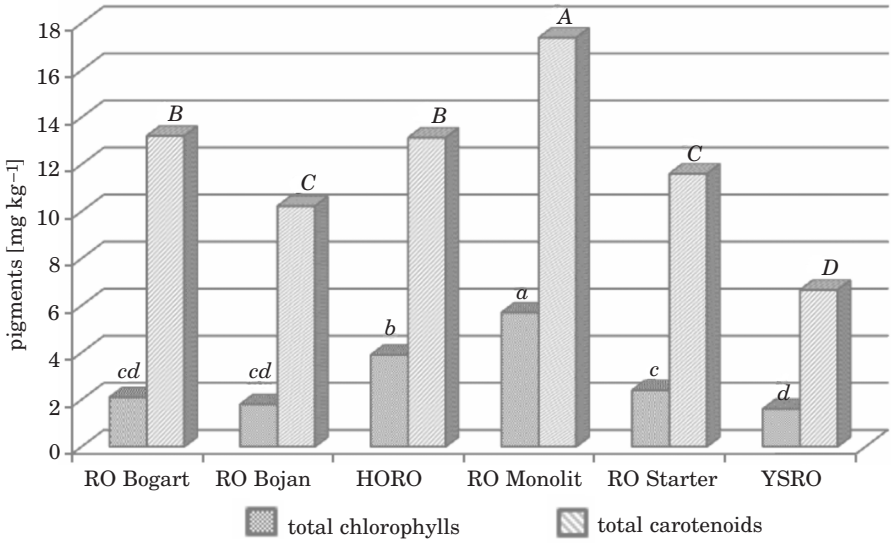
Quality characteristics of ROs, HORO and YSRO produced by cold-pressing

Specification	Rapeseed oil variety					
	RO Bogart	RO Bojan	HORO	RO Monolit	RO Starter	YSRO
AV [mg KOH g^{-1}]	1.08 ± 0.06^{b}	0.50 ± 0.04^{c}	0.42 ± 0.02^{d}	1.47 ± 0.03^{a}	0.55 ± 0.03^{c}	1.46 ± 0.00^{a}
PV [mEq O_2 kg^{-1}]	0.46 ± 0.07^{bc}	0.54 ± 0.08^{b}	0.84 ± 0.06^{a}	0.49 ± 0.01^{b}	0.38 ± 0.04^{cd}	0.56 ± 0.06^{a}
p-AnV	0.35 ± 0.12^{b}	0.26 ± 0.06^{b}	0.14 ± 0.03^{b}	0.37 ± 0.10^{b}	0.9 ± 0.17^{a}	0.4 ± 0.09^{b}
K_{232}	1.48 ± 0.03^{b}	1.47 ± 0.04^{bc}	1.32 ± 0.03^{d}	1.49 ± 0.03^{b}	1.42 ± 0.02^{c}	1.75 ± 0.03^{a}
K_{268}	0.11 ± 0.00^{b}	0.09 ± 0.00^{b}	0.07 ± 0.00^{c}	0.11 ± 0.00^{b}	0.07 ± 0.00^{c}	0.20 ± 0.01^{a}
Induction period [h]	3.75 ± 0.04^{bc}	3.80 ± 0.09^{b}	6.54 ± 0.10^{a}	3.60 ± 0.08^{cd}	3.91 ± 0.05^{b}	3.51 ± 0.07^{d}

Different superscript letters within each row indicate significant differences ($p<0.05$) between each rapeseed variety

Pigments are considered important factors as they exhibit antioxidant properties, but when oil is exposed to light and heat, they can act as pro-oxidants (YANG et al., 2013). In crude canola oil less than 30 mg kg^{-1} of chlorophyll pigments and approximately 95 mg kg^{-1} of carotenoids can be found (ENDO et al. 1992). The concentration of carotenoid pigments in analysed oils ranged from 6.66 to 17.39 mg kg^{-1} (YSRO and RO pressed from the seeds of Monolit variety,

respectively), while the average chlorophyll pigments content was 2.92 mg kg^{-1} (Figure 1), which is in agreement with previously published data (KRALJIC et al. 2013, YANG et al. 2013, GHAZANI et al. 2014).



Mean values denoted by the same letter by the columns do not constitute statistically significant differences at $p<0.05$

Fig. 1. Pigments [mg kg^{-1}] in ROs, HORO and YSRO produced by cold-pressing

According to the sources, regular rapeseed varieties contain approximately 60% of C18:1 fatty acid, while C18:1 fatty acid content in HORO range from 69 to 77% (BARTH 2009), which is consistent with the results obtained in this study (Table 4). HORO clearly differ from oils pressed from regular rapeseed varieties (Bogart, Bojan, Monolit and Starter), and from YSRO in terms of PUFAs concentration (15.1% vs. 29.0–30.9%). Modifying fatty acid composition by decreasing the amount of oxidisable fatty acids such as C18:2 and C18:3 fatty acids, and increasing the amount of oxidation-resistant fatty acids, such as C18:1 fatty acid, disrupted nutritionally favourable C18:2 to C18:3 essential fatty acids ratio of 2:1 in HORO. As it could be seen from Table 4, HORO contain nearly the same level of C18:2 and C18:3 fatty acids (7.7 and 7.4%, respectively), in contrast to ROs and YSRO, exhibiting desirable 2:1 ratio of ω-6 and ω-3 fatty acids. Samples of YSRO and HORO had the lowest SFAs concentration (5.5 and 5.8%, respectively), while ROs showed typical SFAs content of ~7%.

Typically, tocopherol ratio of 65% γ-T and 35% α-T is commonly found in rapeseed oil (MÖLLERS 2002). However, the amounts of total and individual tocopherols in extracted oil may fluctuate within one rapeseed variety, since

Table 4

Fatty acid composition [%] of ROs, HORO and YSRO produced by cold-pressing

Fatty acid	Composition [%]					
	RO Bogart	RO Bojan	HORO	RO Monolit	RO Starter	YSRO
C16:0	3.89 ± 0.05^{b}	4.11 ± 0.01^{b}	3.62 ± 0.06^{a}	4.42 ± 0.03^{c}	4.62 ± 0.02^{c}	3.53 ± 0.05^{a}
C18:0	1.59 ± 0.04^{a}	1.88 ± 0.03^{b}	1.71 ± 0.05^{b}	2.02 ± 0.04^{c}	1.52 ± 0.05^{a}	1.52 ± 0.02^{a}
C18:1	61.07 ± 0.05^{a}	61.03 ± 0.05^{a}	76.64 ± 0.01^{b}	61.04 ± 0.06^{a}	61.14 ± 0.06^{a}	61.02 ± 0.03^{a}
C18:2	19.18 ± 0.04^{d}	18.82 ± 0.07^{c}	7.74 ± 0.03^{a}	18.91 ± 0.04^{c}	18.11 ± 0.05^{b}	21.04 ± 0.01^{e}
C18:3	10.57 ± 0.01^{c}	10.63 ± 0.04^{c}	7.42 ± 0.06^{a}	10.14 ± 0.06^{b}	11.45 ± 0.04^{d}	9.92 ± 0.08^{b}
C20:0	0.48 ± 0.07^{a}	0.64 ± 0.03^{c}	0.52 ± 0.04^{b}	0.62 ± 0.05^{c}	0.61 ± 0.03^{c}	0.54 ± 0.05^{b}
C20:1	1.17 ± 0.04^{a}	1.32 ± 0.02^{c}	1.32 ± 0.05^{c}	1.23 ± 0.05^{b}	1.23 ± 0.05^{b}	1.21 ± 0.04^{b}
C22:1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Others	1.18 ± 0.03^{b}	1.93 ± 0.05^{e}	1.23 ± 0.05^{b}	1.71 ± 0.06^{d}	1.54 ± 0.06^{c}	0.94 ± 0.03^{a}
SFA	6.00 ± 0.04^{c}	6.62 ± 0.06^{d}	5.82 ± 0.03^{b}	7.03 ± 0.01	6.73 ± 0.05^{d}	5.54 ± 0.06^{a}
MUFA	62.27 ± 0.03^{a}	62.31 ± 0.03^{a}	77.95 ± 0.04^{b}	62.41 ± 0.06^{a}	62.33 ± 0.03^{a}	62.21 ± 0.04^{a}
PUFA	29.78 ± 0.02^{b}	29.44 ± 0.02^{b}	15.12 ± 0.06^{a}	29.04 ± 0.04	29.53 ± 0.04^{b}	30.91 ± 0.04^{c}
n-6/n-3	1.78 ± 0.04^{c}	1.81 ± 0.07^{c}	1.03 ± 0.03^{a}	1.93 ± 0.03^{c}	1.62 ± 0.05^{b}	2.14 ± 0.05^{d}
Harris coefficient	0.84 ± 0.03^{a}	1.03 ± 0.05^{b}	1.69 ± 0.05^{c}	1.06 ± 0.05^{b}	1.09 ± 0.06^{b}	0.87 ± 0.04^{a}

SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, n.d. – not detected

Values (means ± SD) bearing different superscripts are statistically significantly different ($p<0.05$)

their presence in oil is influenced by many factors, such as climate conditions, genotype, content of PUFAs in oil, and processing/storage conditions (GHAZANI et al. 2014). There are also noticeable variety-dependent differences in the ratio between individual tocopherols, as well as slight variation in the total tocopherols content. Regular canola oil contain on average 695 mg kg^{-1} of total tocopherols, while 901 mg kg^{-1} of tocopherols can be found in high-oleic low-linolenic canola oil (PRZYBYLSKI 2011). The largest amounts of γ-T were detected, followed by α-T, trace amounts of δ-T, and no β-T, but the amount of individual tocopherols varied significantly ($p<0.05$), depending primarily on the rapeseed variety (Table 2). In HORO and YSRO γ-T was present in the largest concentration (42.4 and 41.8 mg/100 g, respectively), while the highest amount of α-T was detected in RO produced from seeds of Starter variety (28.4 mg/100 g). Despite the differences in the amounts of individual tocopherols, there was no significant difference in the total tocopherol content between HORO, YSRO and RO pressed from seeds of Bojan variety. The lowest amount of tocopherols were found in RO acquired from seeds of Bogart variety (56.4 mg/100 g), and the highest in RO obtained from seeds of Starter variety (67.1 mg/100 g). KRALJIC et al. (2013) found similar concentration of total tocopherols in cold-pressed oils, in contrary to GHAZANI et al. (2014), who found nearly 2-fold lower total tocopherol content (~36 mg/100 g) in the studied cold-pressed oils. The amount of vitamin E (α-tocopherol equivalents) in the

analysed oil samples varied from 25.18 to 32.18 mg/100 g, which is typical for low erucic acid rapeseed (LEAR) oils (GUGAŁA et al. 2014).

In order to determine nutritional value of examined oils, Harris coefficient was calculated. HORO was marked by the highest Harris coefficient (1.69), which is a result of decreased PUFAs content, while Harris coefficient calculated for ROs and YSRO ranged from 0.84 to 1.09. However, all oils exhibited proper physiological value (α-TE to PUFA ratio (mg g^{-1}) of 0.6:1, as a minimum to protect against PUFA peroxidation) (VALK, HORNSTRA 2000).

The oxidative stability of vegetable oils is determined by their fatty acid composition and antioxidants, mainly tocopherols but also other non-saponifiable constituents. The effect of fatty acids on stability depends mainly on their degree of unsaturation and, to a lesser degree, on the position of the unsaturated functions within the triacylglycerol molecule (KAMAL-ELDIN 2006). The fatty acid composition of vegetable oils is affected by botanical source, as well as by genetical variations. Traditional plant breeding and genetic manipulations of conventional oilseed crops have resulted in high-oleic oil varieties. Modifying fatty acid composition by decreasing the amount of oxidisable fatty acids such as α-linolenic and linoleic acids and increasing the amount of oxidation-resistant fatty acids such as oleic acid improved the oil's oxidative stability (MERRILL et al. 2008). From the results shown in Table 3 it can be concluded that the IP length differences of the examined oils arise mainly from to differences in the fatty acid composition, with superior oxidative stability of HORO (6.54 h) compared to YSRO (3.51 h), and ROs and (3.60–3.91 h). The oxidative stability of cold-pressed ROs in studies conducted by KOSKI et al. (2002) ranged from 2.1 to 4.5 h, while the IP of HORO examined by MATTHÄUS (2006) was 7.3 h.

PCA was performed for the mean ratings of each rapeseed oil across the 8 chosen attributes (Table 1). As presented in Figure 2 the first two PCs accounted for 85.20% of variability (51.70% and 33.50%, respectively). PC1 was highly contributed by the following sensory attributes: astringent (0.815), strawy (0.808), seed-like (-0.796) and nutty (-0.795) while PC2 was highly contributed by woody sensory attribute (0.817) – Table 5. The score plot of PCA shows a clear differentiation of oils obtained from different rapeseed varieties. As shown in Figure 2, YSRO and HORO are placed in the right portion of the score plot, in contrast to oils obtained from regular rapeseed varieties, which are in the left portion. Figure 2 also showed the positioning of the oil samples with respect to the intensity of the sensory attributes. ROs were similarly characterized by nutty and seed-like sensory attributes, the most noticeable sensory attributes in YSRO were woody and strawy, while astringent sensory attribute was strongly perceivable in HORO.

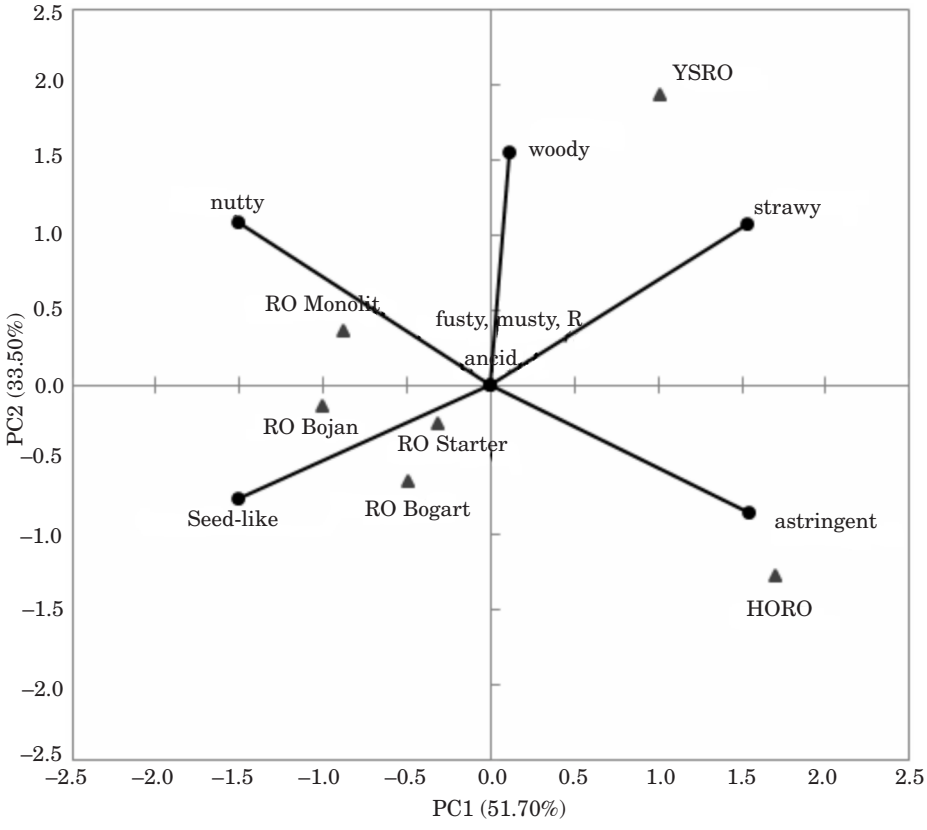


Fig. 2. Principal component analysis (PCA) based on sensory attributes profiling analysis of ROs, HORO and YSRO produced by cold-pressing

Table 5

Principal component analysis (PCA) factor loadings for the sensory attributes of ROs, HORO and YSRO produced by cold-pressing

Sensory attributes	PC1	PC2
Seed-like	**-0.796**	-0.398
Nutty	**-0.795**	0.571
Woody	0.056	**0.817**
Strawy	**0.808**	0.567
Astringent	**0.815**	-0.448
Rancid, fusty, musty	0.000	0.000

Values in bold are loadings with an absolute value greater than 0.70

Conclusions

The quality parameters of all cold-pressed rapeseed oils were within Codex Alimentarius limits which testifies to the high quality of the seeds used in the research. HORO was marked by the highest oxidative stability (IP = 6.54 h), most likely due to the lowest amount of PUFAs (15.1%), in contrast to YSRO, which has the lowest induction period (3.51 h) and the highest PUFAs concentration (30.9%). The highest pigments content was found in RO obtained from seeds of Monolit variety (23.09 mg kg^{-1}), while YSRO had nearly 3-fold lower pigments concentration (8.26 mg kg^{-1}). The highest total tocopherols content was found in conventional RO acquired from seeds of Starter variety (67.1 mg/100 g), which was also marked by the highest α-tocopherol concentration (28.4 mg/100 g), while γ-tocopherol was present in the largest concentration in HORO and YSRO (42.4 and 41.8 mg/100 g, respectively). Principal component analysis differentiated cold-pressed oils based on their sensory assessment.

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