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TECHNOLOGICAL VALUE OF SELECTED POLISH VARIETIES OF RAPESEED*

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Key words: rapeseeds, varieties, technological value of seeds, oil quality.

Abstract

The objective of the study was to evaluate the technological value of double-improved Polish varieties of rape, i.e. two winter varieties: pollinated variety Kana and hybrid variety Pomorzanin, and one spring variety pollinated Bios. The technological values of seeds and the quality of oils were evaluated by determining their traits which are important in processing and nutrition, i.e.: 1000 seeds mass, geometric features of seeds, contents of oil, phosphorus, phenolic compounds and glucosinolates in seeds, pressing yield, lipid composition, degree of hydrolysis and oxidation of oil as well as contents of total phosphorus and non-hydratable phosphorus. Analyses demonstrated that seeds of the winter variety (Kana, Pomorzanin) were characterized by a higher technological value than those of the spring variety (Bios) due to a higher mass of 1000 seeds and oil content and a lower concentration of phosphorus compounds, including non-hydratable phospholipids. The highest nutritive value was demonstrated for oil processed from seeds of the winter hybrid variety Pomorzanin as it was characterized by the most optimal ratios of n-6 and n-3 acids. The least valuable raw material for the production of edible oil turned out to be seeds of the spring pollinated variety Bios which characterized by the lowest content of oil and, simultaneously, the highest content of non-hydratable phospholipids and unfavorable to health ratio of monounsaturated fatty acids.

WARTOŚĆ TECHNOLOGICZNA NASION WYBRANYCH KRAJOWYCH ODMIAN RZEPAKU

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Słowa kluczowe: rzepak, odmiany , wartość technologiczna nasion, jakość oleju.

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Abstrakt

Celem badań była ocena wartości technologicznej nasion podwójnie ulepszonych krajowych odmian rzepaku: dwóch ozimych – populacyjnej Kana i mieszańcowej Pomorzanin oraz jarej populacyjnej Bios. Wartość technologiczną nasion i jakość olejów oceniano, określając ważne w przetwórstwie i żywieniu cechy, takie jak: masa 1000 nasion i ich wymiary geometryczne, zawartość tłuszczu, fosforu, związków fenolowych i glukozynolanów, wydajność tłoczenia oraz skład lipidowy, stopień hydrolizy i utlenienia oleju oraz zawartość fosforu ogółem i niehydratowalnego. Stwierdzono, że nasiona odmian ozimych (Kana, Pomorzanin) cechowały się wyższą wartością technologiczną od nasion odmiany jarej (Bios), z uwagi na większą masę 1000 nasion i zawartość tłuszczu oraz mniejszą zawartość związków fosforu, w tym fosfolipidów niehydratowalnych. Najwyższą wartość żywieniową miał olej z nasion ozimej odmiany mieszańcowej Pomorzanin, ponieważ zawierał najbardziej optymalne proporcje kwasów n-6 i n-3. Najmniej cennym surowcem do produkcji oleju jadalnego okazały się nasiona populacyjnej odmiany rzepaku jarego Bios. Zawierały najmniej tłuszczu i miały równocześnie najwyższą zawartość fosfolipidów niehydratowalnych oraz niekorzystną dla zdrowia proporcję kwasów wielonienasyconych.

Introduction

Double-improved rape, i.e. erucic acid-free and low-glucosinolate rape, referred to as "canola" was created in Canada in 1974 (SHAHIDI 1990). In Poland, the first double-improved variety was created in the year 1978. Since 1992, only double-improved varieties of rape have been cultivated in Poland. Currently, the National Register of Varieties in Poland includes 66 winter varieties and 19 spring varieties of rape, both pollinated and hybrid ones (*Lista*... 2008).

The agricultural value of rape is determined in post-register variety experiments and is determined by such indicators as: resistance to diseases and lodging, number of seeds in silique, seed yield, mass of 1000 seeds as well as contents of oil, protein, dietary fibre and glucosinolates in the seeds (*Wyniki*... 2008). The agricultural value of varieties is consistent with the technological standard of seeds for processing (*Rośliny*... PN-90/R-66151) only in respect of glucosinolate contents. The technological standard of rape seeds for processing also includes the acid value of oil, content of impurities: useful, useless and mites as well as concentration of erucic acid. Scientific studies have confirmed the importance of all the above-mentioned indicators and have shown that the evaluation of the technological value of rape seeds should be completed with new indicators significant to storage, processing and nutrition, i.e. sizes of seeds, resistance to mechanical damage, lipid composition of oil with consideration given to ratios of polar and non-polar lipids, n-6 and n-3 fatty acids as well as hydratable and non-hydratable phosphorus compounds (SZWED et al. 1995, PŁATEK 1996, 1998, ROTKIEWICZ et al. 2002, ACHREMOWICZ, SZARY-SWORST 2005, TAŃSKA et al. 2008).

Studies conducted on various pollinated varieties indicate significant differences in their agricultural and technological values (MIŃKOWSKI, KRYGIER 1998, NOGALA-KAŁUCKA et al. 2002, ROTKIEWICZ et al. 2002, *Lista*... 2008, *Wyniki*... 2008).

Recently, hybrid varieties, whose high yield is determined by the effect of heterosis, have also been introduced into cultivation practice (BARTKOWIAK-BRODA 1998). Due to their higher yield (by ca. 6–10%) (*Wyniki*... 2008), they may be expected to predominate the pollinated varieties in the future. The agricultural value of hybrid varieties of rape has already been determined (*Lista*... 2008, *Wyniki*... 2008), yet research is lacking on their technological value. With this in mind, the objective of the reported study was to evaluate the technological value of a winter hybrid varieties of rape compared to that of two selected pollinated varieties, a winter and a spring one.

Material and Methods

The experimental material were seeds of three varieties of rape: winter hybrid variety Pomorzanin, winter pollinated variety Kana and spring pollinated variety Bios, originating from the harvest of 2007. The seeds were obtained from the Plant Breeding Station in Strzelce. Selection of varieties was incidental. In these study was important the evaluation of chemical composition of seeds of pollinated and hybrid rape varieties belonging to winter and spring forms.

The technological value of rape seeds was determined based on:

– the mass of 1000 seeds determined by weighing of 100 seeds separated from sample, geometric sizes of seeds assayed with the method of Digital Image Analysis (TAŃSKA et al. 2005),

– content of unripe seeds determined acc. to *Rośliny*... PN-90/R-66145,

– oil content determined acc. to *Nasiona*... PN-EN ISO 659:1999,

– phosphorus content determined with the method with ammonium vanadium acc. to *Rośliny*... PN-88/A-86930,

– content of phenolic compounds assayed with the spectrophotometric method as described by RIBEREAU-GAYON (1972),

– content of glucosinolates assayed with the glucose method as described by HEANEY et al. (1988), and

– contents of non-polar and polar lipids (glyco- and phospholipids) – by means of column chromatography as described by BEKES et al. (1983) with modifications by FENYVESI-SIMON et al. (1992).

Fraction composition was determined with the use of lipids extracted from the seeds according to the method of FOLCH (FOLCH et al. 1957). Pressing yield

was determined as the percentage of the mass of oil pressed from seeds to the mass of oil extracted with petroleum benzine in SOXHLET'S apparatus acc. to *Nasiona...* PN-EN ISO 659:1999. Whole seeds were cold-pressed using a screw oil expeller featuring a cylindrical perforated strainer basket (Komet laboratory CA 59 G). Mechanical impurities were removed from the pressed oil by centrifugation at 10,000 rpm.

The quality of oils, cold-pressed as specified above, was evaluated by assaying: acid value acc. to *Oleje...* PN-ISO 660:1998, peroxide value acc. to *Oleje i tłuszcze...* PN-ISO 3960:1996, anizidine value acc. to *Tłuszcze...* PN-93/A-86926, and fatty acid composition acc. to *Analiza...* PN-EN-ISO-5508:1996, in methyl esters prepared according to the method described by ZADERNOWSKI and SOSULSKI (1978). The contents of total and non-hydratable phosphorus were determined in oils extracted from roasted (1 hour, 100°C) seed pulp with the above-mentioned method.

Results and Discussion

Values of the mass of 1000 seeds determined for the investigated varieties of rape were found to differ. The highest mass of 1000 seeds (6.76 g) was recorded for the hybrid variety Pomorzanin (Table 1). It was higher by 1.68 g than that assayed for the winter pollinated variety Kana and by 2.53 g than that assayed for the spring pollinated variety Bios. Results of post-register variety studies (*Wyniki...* 2008) indicate that the mean mass of 1000 seeds of rape variety Pomorzanin from the harvest of 2007 accounted for 6.2 g, whereas that of the other hybrid varieties – for 3.8–7.6 g.

Table 1

Discriminates of rapeseed technological value

Discriminate	Winter varieties		Spring variety
	Kana	Pomorzanin	Bios
Diameter of seeds (mm)	2.147 ± 0.09	2.359 ± 0.16	2.09 ± 0.11
Area of seeds (mm^2)	3.63 ± 0.31	4.39 ± 0.58	3.44 ± 0.36
Circularity (–)	0.98 ± 0.01	0.96 ± 0.02	0.96 ± 0.03
Mass of 1000 seeds (g)	5.08 ± 0.14	6.76 ± 0.21	4.23 ± 0.12
Oil content (% s.m.)	43.55 ± 0.39	42.10 ± 0.04	39.02 ± 0.08
Glucosinolates (μmol/g smb)	11.31 ± 0.015	11.58 ± 0.020	8.66 ± 0.017
Phenolic compounds (% s.m.)	6.35 ± 0.017	5.60 ± 0.019	4.96 ± 0.021
Yield of pressing (%)	75.4 ± 0.83	73.2 ± 0.76	72.8 ± 0.66
Phosphorus content (mg/kg)	5617 ± 66.5	6261 ± 60.4	6429 ± 58.7
Seed lipids composition (%):			
non-polar lipids	96.94 ± 2.3	97.08 ± 2.8	96.09 ± 2.8
glicolipids	1.15 ± 0.082	0.73 ± 0.043	1.26 ± 0.059
phospholipids	1.91 ± 0.106	2.19 ± 0.113	2.65 ± 0.141

In the case of seeds of the winter pollinated varieties harvested in the same year, the mass of 1000 seeds ranged from 3.7 to 5.6 g, whereas in those of the spring pollinated varieties it ranged from 2.6 to 5.4 g (*Wyniki*... 2008). These values indicate that the mass of 1000 seeds is mainly determined by the form of variety (pollinated, hybrid, winter, spring), and within the variety – by its type. Apart from the variety-specific factor, variability in the mass of 1000 seeds is a result of agroclimatic conditions of the crop (NIEWIADOMSKI 1983, JENSEN et al. 1995, MIŃKOWSKI 1998).

The values of the mass of 1000 seeds displayed a simple correlation with sizes of seeds, i.e. with their diameter and surface area, but were not correlated with the value of a circularity index (Table 1) which distinguished seeds of Kana variety whose plane projection most resembled a circle.

The analyzed samples of seeds did not contain any useless impurities, whereas out of the useful impurities – only unripe seeds that were specified in Table 1. A sample of the hybrid variety Pomorzanin was demonstrated not to contain any unripe seeds, whereas samples of rape of the pollinated varieties Bios (spring) and Kana (winter) were characterized by a high content of unripe seeds, accounting for 2.21 and 1.9%, respectively (Table 1). The technological standard (*Rośliny*... PN-90/R-66151) stipulates that seed bulk of rape designed for purchase and delivery for processing should not contain more than 2% of unripe and sprouted seeds in total.

The oil content of the seeds of the varieties analyzed was relatively diversified, reaching from 39.02% in seeds of the spring pollinated variety Bios to 43.55% in seeds of the winter pollinated variety Kana. In seeds of Pomorzanin variety, the content of oil was average and reached 42.10% (Table 1). In turn, the mean content of oil determined in nation-wide variety investigations for rapeseeds of Pomorzanin and Bios variety harvested in 2007 accounted for 44.0 and 42.3%, respectively (*Wyniki*... 2008), i.e. was higher by ca. 2%. Seeds of winter pollinated and hybrid varieties of rape originating from harvests of 2004–2007 and cultivated under conditions of variety-specific experiments, contained 44–46% of oil on average, whereas in seeds of the spring varieties the oil content was lower by ca. 2–3% (*Wyniki*... 2006, *Wyniki*... 2008). The above-cited results, as well as research conducted on seeds of Polish varieties of winter rape cultivated in the years 1998–2008, point to a little-diversified range of oil content not exceeding 2% (MIŃKOWSKI 1998, MIŃKOWSKI, KRYGIER 1998, BANASZKIEWICZ et al. 2006, *Wyniki*... 2006, *Wyniki*... 2008).

Seeds of the winter rape varieties Pomorzanin and Kana were shown to be characterized by a similar content of glucosinolates, i.e. 11.5 μmol g^{-1} defatted d.m. on average. In turn, in seeds of the spring rape variety Bios the content of glucosinolates was lower by 25% (Table 1). These values confirm data

obtained in the post-register studies, indicating that the seeds of spring varieties exhibit a lower content of glucosinolates (*Wyniki...* 2008). The total content of glucosinolates demonstrated in seeds of the analyzed rape varieties is very low, as it constitutes barely 50% of the admissible level of alkenyl glucosinolates stipulated in the standard (*Rośliny...* PN-90/R-66151), reaching 25 μmol g^{-1} defatted d.m. Alkenyl glucosinolates constitute on average half the total glucosinolates and products of their hydrolysis are detrimental constituents of meal/pomace and oil (SØRENSEN 1990). Isothiocyanates occurring in oils give them an unpleasant aroma and are toxic to hydrogenation catalysts (NIEWIADOMSKI 1993).

In seeds of the investigated rape varieties, the total content of phenolic compounds ranged from 4.96% d.m. (Bios) to 6.35% d.m. (Kana) – Table 1. Phenolic compounds of rapeseeds are perceived as anti-nutrients. Their predominating compound is sinapin (an ester of choline and sinapic acid) that constitutes ca. 90% of all phenolic compounds occurring in rapeseeds (ROTKIEWICZ et al. 1976, ZADERNOWSKI 1987). Sinapin is a bitter compound that diminished palatability of rape fodder and the biological value of protein (ZADERNOWSKI 1987, KOZŁOWSKA et al. 1990).

The oil pressing yield of the seeds of the investigated rape varieties ranged from 72.8% (Bios) to 75.4% (Kana) – Table 1. Pressing yield, especially that of cold-pressing, is an important indicator of the technological value of rape seeds. A higher pressing yield is typical of greater seeds that are characterized by a higher contribution of endosperm (cotyledons + radicle), containing more oil than the seed coat (ZADERNOWSKI et al. 1993, ROTKIEWICZ et al. 2002). Cotyledons of seeds of greater sizes are more susceptible to disintegration as they require less work input necessary to damage their cellular structure (TAŃSKA et al. 2008).

In seeds of the analyzed rape varieties, the total content of phosphorus followed the order: Bios > Pomorzanin > Kana (Table 1). In ripe rape seeds, the predominating form of phosphorus compounds were phytins, constituting 60–90% of total phosphorus acknowledged as anti-nutritional constituents of the non-lipid fraction of seeds (THOMPSON 1990, ROTKIEWICZ et al. 1999, TROSZYŃSKA 2004).

The composition of the lipid fraction of rape seeds was predominated by non-polar lipids which in seeds of the winter rape varieties, i.e. Pomorzanin and Kana, constituted ca. 97% of total lipids, whereas in seeds of the spring variety Bios – 96% (Table 1). In seeds of the later varieties, the highest percentage was noted for polar lipids, glyco and phospho-lipids, which together constituted 3.91% of total lipids. The lowest percentage of polar lipids (2.82%) was determined in seeds of the hybrid variety Pomorzanin. This was mainly due to the lowest content of glycolipids in respect of all varieties examined.

The ratios of non-polar to polar lipids are an important indicator, but have not yet been applied in the evaluation of the technological value of seeds. A higher technological value is attributed to seeds with the highest possible content of the non-polar fraction constituted by triacylglycerols. In turn, the non-triacylglycerol constituents of oil, predominated by polar phospholipids, have to be removed in refining processes as they deteriorate the quality and shelf life of oil (NIEWIADOMSKI 1993, PŁATEK 1996, 1998, ROTKIEWICZ et al. 1998).

The degree of hydrolysis and oxidation of oils pressed from seeds of the investigated varieties of rape was low. The acid value of oils pressed from rape seeds of Pomorzanin and Bios varieties did not exceed 0.50 mg KOH/g oil, and that of oils prepared from Kana variety was 0.70 mg KOH/g oil (Table 2). Such a low of degree of oil hydrolysis in the analyzed seeds results from both the high quality of the seeds (fresh, ripe, pure) and cold-pressing of oil. Industrial seed bulk of rape is usually characterized by a higher degree of oil hydrolysis. According to the Polish quality standard (*Rośliny*... PN--90/R-66145), the acid value of rape seeds designed for processing should not exceed 3 mg KOH/g oil. In edible cold-pressed oil, the admissible level of the acid value is higher and accounts for 4 mg KOH/g oil (*Tłuszcze*... ZN-94/SGO-01), whereas in refined edible oils it accounts for 0.3 mg KOH/g oil (*Oleje*... PN-86908:2000).

The peroxide value of oils pressed from seeds of the investigated varieties of rape ranged from 0.80 to 0.92 mEq O_2/kg oils, thus indicating a very low degree of oil oxidation (Table 2). In cold-pressed oils, the admissible level of the peroxide value reaches 10 mEq O_2/kg oil (*Tłuszcze*... ZN-94/SGO-01), whereas in refined oils it reaches 5 mEq O_2/kg oil (*Rośliny*... PN-90/R-66145).

Table 2

The chemical characteristic of rapeseeds oil

Discriminate	Winter varieties		Spring variety
	Kana	Pomorzanin	Bios
Acid value (mg KOH/g oil)	0.67 ± 0.00	0.50 ±0.08	0.45 ± 0.00
Peroxide value (mEq O_2/kg oil)	0.92 ± 0.01	0.80 ± 0.09	0.88 ± 0.01
Anisidine value	0.1 ± 0.0	0.1 ± 0.0	0.7 ± 0.0
Total phosphour content (mg/kg oil)	434 ± 31.1	441 ± 29.1	476 ± 26.8
non-hydratable (mg/kg oil)	183 ± 16.1	218 ± 20.3	214 ± 10.6
The share of fatty acid (%)			
palmitic acid	4.88	5.06	4.65
stearic acid	1.89	1.91	1.92
oleic acid	62.32	65.05	59.94
linoleic acid	19.17	18.47	19.87
linolenic acid	9.40	7.10	10.83
eicosanoic acid	1.26	1.17	1.46
erucic acid	ślady	ślady	ślady
Relation between acids n-6 : n-3	2.04:1	2.60:1	1.83:1

In turn, the anisidine value – determining the content of secondary products of oxidation (JEŻEWSKA 1991) – of the analyzed oils fluctuated between 0.1 (Pomorzanin and Kana) and 0.7 (Bios), which points to barely initiation of the oxidation processes (Table 2). The significance of that indicator in the evaluation of an oxidation degree of lipids has recently been appreciated, thereby it has been introduced into the qualitative standard of refined oils. The highest admissible value of this indicator has been stipulated at a level of 8 (*Rośliny...* PN-90/R-66145).

The total content of phosphorus compounds in oils, extracted from rapeseed comminuted and roasted under laboratory conditions, ranged from 434 to 476 mg/kg oil. Literature data indicate that industrial pressed oils contain 125–277 mg/kg, whereas the extracted oils contain from 300 to 1190 mg of phosphorus/kg oil (NIEWIADOMSKI 1993, PŁATEK 1998, ROTKIEWICZ et al. 1998).

In oils, the major phosphorus compounds are phospholipids, being structural lipids. They are the main constituents of biological membranes in a seed cell, in which they constitute the membranes of all cellular organelles, including spherosomes (ROTKIEWICZ et al. 2000a). During seed processing, as a result of mechanical and/or thermal degradation of membranes, phospholipids released from them are dissolved in oil (NIEWIADOMSKI 1993, ROTKIEWICZ et al. 2002). They are the cause of turbidity and sediments appearing in oil which impair the course of some refining and modifying processes, hydrogenation and esterification in particular (NIEWIADOMSKI 1993, SHAHIDI 1990).

From the technological point of view, phospholipids are divided into hydratable and non-hydratable ones (PRZYBYLSKI, ESKIN 1991). The first are easily-removable in the hydration process, whereas the latter require the application of acids, thus forming sparingly-utilizable sewage (NIEWIADOMSKI 1993). The non-hydratable phospholipids are likely to constitute 30–40% of total phospholipids, depending on the quality of raw material, technology of production and storage of crude oil (ROTKIEWICZ et al. 1999). In oils pressed from seeds of the analyzed varieties of rape, the percentage of non-hydratable phosphorus ranged from 30% in oil from rape seeds of Pomorzanin variety to 36% in oil from rape seeds of Bios variety, which corresponded to phosphorus contents of 132 and 171 mg/kg oil, respectively (Table 2).

In terms of the contribution of fatty acids, the pollinated varieties (Kana and Bios) were similar, whereas the variety Pomorzanin was found to be different. In oil pressed from seeds of this variety, the concentration of oleic acid was the highest (65.05%), whereas concentrations of linoleic and linolenic acids were the lowest (18.47% and 7.10%, respectively), (Table 2). Oils produced from the pollinated varieties, i.e. winter Kana and spring Bios, were characterized by a similar concentration of linoleic oil, and by various

concentrations of oleic and linolenic acids. Oil from seeds of the spring variety was characterized by the highest concentration of linolenic acid (higher by 3.73% than oil from seeds of variety Pomorzanin) and the lowest concentration of oleic acid (lower by 5.11% than oil from variety Pomorzanin). All the analyzed oils were found to contain trace amounts of erucic acid (Table 2).

The nutritive value of lipids is determined by the linoleic:linolenic acid ratio. According to literature data, the ratio should range from 3:1 to 5:1 (ACHREMOWICZ, SZARY-SWORST 2005). All the oils of the varieties examined, the most similar value to the optimal ratio of those acids reaching 2.6:1 was found for oil from rape seeds of variety Pomorzanin (Table 2).

Conclusions

1. The three analyzed varieties of rape, higher technological values were reported for the winter varieties: pollinated Kana and hybrid Pomorzanin. Their seeds were riper than the seeds of spring variety Bios, contained fewer phosphorus compounds and were more oil-susceptible to pressing than a lower concentration of non-hydratable phospholipids.

2. The lowest technological value was found for seeds of the pollinated spring variety Bios. They were the smallest, contained the highest concentration of phosphorus compounds and had the lowest concentration of oil with the highest contribution of non-hydratable phospholipids.

3. Owing to the optimal ratio of n-6 to n-3 acids, the highest nutritive value was ascribed to oil pressed from rape seeds of hybrid variety Pomorzanin.

4. In a breeding of new varieties of rape one should take into consideration such discriminates as: content and proportions of hydratable and nonhydratable phospholipids and proportions of n-6 and n-3 acids.

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