ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1213565

POSSIBILITY OF USE A SMALL FRACTION OF RAPE SEEDS FOR THE PRODUCTION OF BIOFUELS FOR COMPRESSION IGNITION ENGINES

Małgorzata Tańska

University of Warmia and Mazury
Department of Plant Raw Materials Processing and Chemistry
Cieszyński Square 1, 10-726 Olsztyn, Poland
tel.:+ 48 89 5234113, fax: +48 89 5233466
e-mail: m.tanska@uwm.edu.pl

Marta Ambrosewicz-Walacik, Szymon Nitkiewicz

University of Warmia and Mazury, Department of Mechatronics and ETI
Sloneczna Street 46A, 10-710 Olsztyn, Poland
tel.:+ 48 89 5245104, fax: +48 89 5245150
e-mail: marta.ambrosewicz@uwm.edu.pl

Abstract

The aim of the study was to determine the possibility of using small seeds of rape (diameter <1.6 mm,) perceived as a raw material of inferior nutritional quality, for the biofuels production. Research material was samples of industrial mass of rapeseeds originating from three Polish regions. The seed mass was cleaned in a sieve separator, removing mineral matter (stones), cereal grains, stems and dusts. Then, the sample was sifted through a set of sieves and two fractions were received: seeds with diameter >1.6 mm – sample F_1 and with diameter < 1.6 mm – sample F_2. Each fraction was characterized by its share in bulk mass, moisture content, 1000 seeds weight, yield of pressing, fat content and phosphorus content. Cold-pressed oils were determined in terms of total and unhydrated phosphorus content, acid value and fatty acids content. Fractionation by weight rapeseeds with using an industrial sieve separation may provide a simple method for improving the technological value of the raw material used for food purposes, and thus obtain fine seed that could be intended exclusively for the production of technical oil. Despite the stated inferior quality of small seeds, it was found that the increased values of some discriminants would not have impact on the technology of biofuel production and cost of production.

Keywords: *rape seeds, size, physical and chemical properties, biofuel production*

1. Introduction

The main raw material used in the UE for biodiesel production is double-improved rapeseed with reduced share of erucic acid (from 41-54% to <0.5%) and content of glucosinolates (from 170 to 15-25 µ /g DW) [12]. The factors determining its usefulness for the production of methyl esters of higher fatty acids include its cultivar, seed yield and the fat content in seeds [7, 9]. Seeds used in processing, both for food and for energy purposes, should originate from cultivars of double low rapeseed, characterised by a minimum oil content of 40%, a minimum percentage of oleic acid of 56%, acid value for fat ≤ 3.0 mg $KOH \times g^{-1}$ oil, erucic acid percentage < 1.0% and the content of alkenyl glucosinolates < 25 $\mu mol \times g^{-1}$ DW [12]. The superiority of this oil plant over other available oleaginous species (i.e. mustard, flax, camelina, sunflower) in terms of alternative fuels production results from the fact of the largest fat yield per unit area (average of 750-1200 kg per ha) and favourable energy efficiency indicators [4, 5, 8]. Seeds of winter oilseed rape are characterized by approx. 40 to 45% DW. On the other hand, for example, the fat content in the seeds of mustard is 31.7% DW, flax 39.2% DW and camelina 36.7% DW [16]. In addition, Jankowski and Budzyński showed that the profit of the energy accumulated in the oil, expeller and straw of oilseeds from 1 ha of winter rape is equivalent to the energy value of 3.4 tons of diesel fuel, 2.1-2.3 tons of diesel fuel per 1 ha of white mustard and spring rape, and 1.5 tons diesel from 1 ha of Indian and white mustard [8].

One of the main problems with using mentioned oil plants is involved with the competition between food and fuel industry. This contributes to the increase in raw material prices. One way to solve this problem is the cultivation of „energy rape" that can be plated on chemically contaminated and agricultural set-aside soils [6]. Immediate entering it on agriculturally degraded, acidic, set aside and marginal soils does not seem possible, because of its agronomic requirements, the level of yield and profitability. The real is, however, to provide such a production at the macro level on arable land. On the other hand, a good solution seems to be to use a small fraction of rapeseeds contained in the entire mass of seeds, which is characterized by worse quality discriminants due to food production than bigger seeds. Throughput of seeds mass of different seeds size makes it impossible to predict the final quality of product and costs of production.

It is believed that it would be appropriate to separate, using sieve separation, seeds with < 1.6 mm size, what could provide a valuable raw material for the fuel industry, and the remaining larger fraction of seeds would be used to produce food products. Therefore, the aim of the study was to determine the quality characteristics of the seed fractions with various sizes, due to the extracted oil for the biofuels production.

2. Material and methods

The research material was industrial mass of rapeseeds originating from three Polish regions (north, central and south). The seed mass was cleaned in a sieve separator, removing mineral matter (stones), cereal grains, stems and dusts. Then, the sample was sifted through a set of sieves and two fractions were received:
Fraction F_1 – seeds with > 1.6 mm size (Fig. 1a),
Fraction F_2 – seeds with < 1.6 mm size, (Fig. 1b).

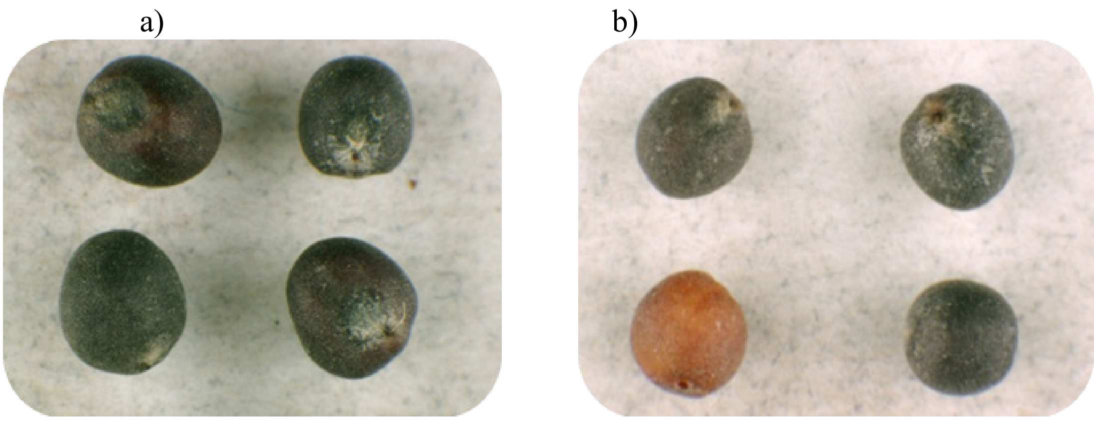

Fig. 1. Rape seeds with different dimension: a) > 1.6 mm, b) <1.6 mm

Each fraction was characterized by its share in bulk mass, moisture content (PN-EN ISO 662:2001P), 1000 seeds weight, yield of pressing, fat content (PN-EN ISO 659:2010P) and phosphorus content (PN-ISO 10540-1:2005).

The cold-pressed oils were extracted by using a screw oil expeller featuring a cylindrical perforated strainer basket Komet laboratory CA 59 G (IBG Monforts & Reiners, Germany), with temperatures ≤ 40 °C. Mechanical impurities were removed from the pressed oil by centrifugation in a centrifuge type C 5810 R (12 000 rpm, 10 min) (Eppendorf, Germany). The sample of industrial hot-pressed rapeseed oil was extracted from crushed seeds conditioned at 110°C for 30 minutes and then pressed at 110-120 °C.

Cold-pressed oils were determined in terms of total and unhydrated phosphorus content (PN-ISO 10540-1:2005), acid value (PN-EN14104:2004P), and fatty acids content (PN-EN ISO 12966-4:2015-07E). The composition of fatty acids in oils was determined according to the Polish Standard (ISO 5508:1990) using methyl esters that had been previously prepared as described by Zadernowski and Sosulski [18]. The quality analysis of fatty acids was performed on a GC 8000 FISONS series gas chromatograph with a flame-ion detector and a DB-225 type column (30 m × 0.25 mm × 0.15 µm) and helium as a carrier gas. Fatty acids were identified based on the retention times determined for fatty acid models.

3. Results and discussion

The share of fine fraction in the industrial mass of rapeseeds, from various Polish regions was different. Most seeds with <1.6 mm diameter was found in a sample from the central part of Poland, and the least from south region. It was also shown that small seeds were characterized by a higher moisture content, lower mass of 1000 seeds, and yield of pressing and fat content (Tab. 1). Observed in the analysed samples fat content was similar to content of this compound in seeds of spring varieties of rape, that are also commonly used and seeds of other species (linseed and camelina) [15, 16].

Tab. 1. Characteristics of rapeseeds fraction

Region	Seeds fraction	
	F_1	F_2
	share of fractions [%]	
north	94.97	5.03
central	86.82	13.18
south	96.62	3.38
	moisture [%]	
north	6.74	6.97
central	5.61	6.28
south	6.13	6.40
	mass of 1000 seeds [g]	
north	4.75	2.25
central	4.97	2.59
south	5.07	2.54
	yield of pressing [%]	
north	69.07	52.52
central	68.52	55.33
south	69.15	55.43
	fat content [%DW]	
north	45.92	38.82
central	45.49	38.57
south	46.22	38.57

Analysing the quality of the cold-pressed oils, one was found that the samples obtained from the seeds of smaller dimensions were characterized by increased value of the acid number, however permissible due to the requirement for oils intended to the production of biodiesel (Tab. 2). The literature reports that the acid value of oils subjected to the transestrification should characterized by from 1 mg KOH/g of oil [17] to a 6 mg KOH/g of oil [3, 10, 13, 14].

It was also shown that the oils obtained from smaller seeds were characterized by higher total and non-hydratable phosphorus content. Total phosphorus content in oil pressed from fine seeds was in the range of 519-634 ppm, while in sample obtained from bigger seeds 315-478 ppm (Tab. 2). It should however be noted, that both samples would have to be subjected to hydration process due to the fact that according to Walisiewicz-Niedbalska [11], the phosphorus content in oils intended for transestrification should have be less than 50 ppm, while the American Society for Testing and Materials (ASTM D6751) [1] and British Standard (BS EN 14214) [2] have stipulated the maximum total phosphorus content in biodiesel products to be 10 ppm. However, the usage of oil obtained from smaller seeds characterized by higher content of phosphorus does not contribute to the need for an additional process, generating costs production.

Tab. 2. Characteristics of rapeseed oils pressed from different seeds fraction

Region	Seeds fraction	
	F_1	F_2
	Acid value [mg KOH/g]	
North	0.68	1.52
Central	1.03	2.85
South	0.40	1.35
	Total phosphorus content [ppm]	
North	313	519
Central	478	634
South	315	522
	Non-hydratable phosphorus content [ppm]	
North	125	169
Central	140	199
South	122	160

Oils extracted from the two analysed samples of seeds were characterized by almost the same profile of fatty acids. According to PN-EN 14214 [11] one of the main discriminant of eligible oil for biodiesel production is share of linolenic acid, which should not exceed 12%, due to the fact that it is especially susceptible to oxidation. All analysed samples fulfilled this requirement (Tab. 3).

Conclusion

Fractionation of rapeseeds mass with using an industrial sieve separation may provide a simple method for improving the technological value of the raw material used for food purposes, and thus obtain fine seed, that could be intended exclusively for the biofuel production. Despite the stated worse quality of fine seeds, it was found that the increased values of some discriminates would not affect the need for change the technology of biofuel production, and thus increase the cost of production. Moreover, it has been shown that fatty acid composition of oils pressed from the seeds with different dimensions was practically identical. Application of the proposed method of sourcing raw material for the biofuels production would reduce the competition between the food and fuel sector, and thus may affect the stabilization of rapeseed price.

Tab. 3. Composition of fatty acids in oils pressed from different seeds fraction

Fatty acids	Region		
	north	central	south
palmitic acid			
F_1	3.94	4.10	4.13
F_2	4.54	4.37	4.53
palmitoleic acid			
F_1	0.23	0.16	0.21
F_2	0.33	0.29	0.29
stearic acid			
F_1	0.67	0.90	0.85
F_2	0.96	0.89	0.94
oleic acid			
F_1	67.77	63.67	66.64
F_2	63.28	62.50	64.87
linoleic acid			
F_1	17.41	19.95	17.50
F_2	20.25	21.06	18.94
linolenic acid			
F_1	8.93	9.72	9.40
F_2	9.25	9.42	8.62
arachidonic acid			
F_1	1.05	1.47	1.26
F_2	1.37	1.44	1.79
erucic acid			
F_1	0.00	0.01	0.00
F_2	0.00	0.01	0.00
others			
F_1	0.01	0.02	0.01
F_2	0.02	0.02	0.02

References

[1] *American Society for Testing and Materials* (ASTM) *D6751* Standard specification for biodiesel fuel blend stock (B100) for middle distillate fuels.

[2] *British Standard 14214:2010*, Liquid petroleum products. Fatty acid methyl esters (FAME) for use in diesel engines and heating applications, Requirements and test methods.

[3] Buczek, B., Czepirski, L., *Applicability of used rapeseed oil for production of biodiesel,* Inform, Vol. 15, No. 3, pp. 186-188, 2004.

[4] Budzyński, W., Bielski, S., *Surowce energetyczne pochodzenia rolniczego*, Cz. 1, Biokomponenty paliw płynnych, Acta Scientiarum Polonorum, Agricultura, Vol. 3, No. 2, pp. 5-14, 2004.

[5] Budzyński, W., Ojczyk, T., *Rzepak – produkcja surowca olejarskiego*, ART Olsztyn 1996.

[6] Frąckowiak, P., *Paliwo z rzepaku szansą aktywizacji obszarów wiejskich*, Cz. I, Pozyskiwanie paliwa silnikowego z olejów roślinnych, Prz. Techn. Roln. Leś., Vol. 1, pp. 6-9, 2002.

[7] Heimann, S., *Aktualne problemy dotyczące badania odmian rzepaku na cele konsumpcyjne oraz biopaliw i makuchy*, Forum producentów roślin zbożowych, kukurydzy i rzepaku, pp. 47-52, Polagra – Forum, 2002.

[8] Jankowski, K., Budzyński, W., *Potencjał energetyczny roślin oleistych*, Problemy Ekologii, Vol. 2, pp. 31-38, 2004.
[9] Kachel-Jakubowska, M., Szpryngiel, M., *Analiza perspektyw wytwarzania biopaliw płynnych w Polsce*, Inżynieria Rolnicza, Vol. 8, No. 117, pp. 47-53, 2009.
[10] Kotowski, W., *Z przepracowanych tłuszczów*, Agroenergetyka, Vol. 3, No. 9, 2004.
[11] PN-EN 14214+A1:2014-04/AC:2014-11E, Paliwa do pojazdów samochodowych, Estry metylowe kwasów tłuszczowych (FAME) do silników o zapłonie samoczynnym (Diesla), Wymagania i metody badań.
[12] PN-R-6615:1990, *Rośliny przemysłowe oleiste, Ziarno rzepaku i rzepiku podwójnie ulepszonego*.
[13] Radziemska, E., Lewandowski, W., Szukalska, E., Tynek, M., Pustelnik, A., Ciunel, K., *Biopaliwa z rzepaku, Przygotowanie surowca do otrzymania biodiesla w warunkach gospodarstwa rolnego oraz pilotowe metanolizy*, Chemia, Dydaktyka, Ekologia, Metrologia, Vol. 14, No. 1-2, pp. 79-84, 2009.
[14] Ramadhas, A. S, Jayaraj, S., Muraleedharan, C., *Biodiesel production from high FFA rubber seed oil,* Fuel, Vol. 84, pp. 335-340, 2005.
[15] Tańska, M., Rotkiewicz, D., Ambrosewicz, M., *Technological value of selected Polish varieties of rapeseed,* Polish Journal of Natural Sciences, Vol. 24 No. 2, pp. 122–132, 2009.
[16] Tańska, M., Rotkiewicz, D., Ambrosewicz-Walacik, M., *Effect of industrial conditions of heat treatment of rape, mustard, flax and camelina seeds on the quality of oils intended for biodiesel production,* Polish Journal of Natural Sciences, Vol. 28, No. 4, pp. 449-462, 2013.
[17] Walisiewicz-Niedbalska, W., *Metanoliza*, In: Biodiesel, gliceryna, pasza z rzepaku, pod red. Podkówki W., pp. 44-71, Bydgoszcz 2004.
[18] Zadernowski, R., Sosulski, F., *Composition of total lipids in rapeseed*, Journal of the American Oil Chemists‘ Society, Vol. 55, pp. 870-872, 1978.