DE GRUYTER
OPEN
DOI: 10.1515/agriceng-2016-0005

ISNN 2083-1587; e-ISNN 2449-5999
2016, Vol. 20, No.1, pp.45-54
Agricultural Engineering
www.wir.ptir.org

POSSIBILITIES OF USING WASTE AFTER PRESSING OIL FROM OILSEEDS FOR ENERGY PURPOSES

Magdalena Kachel-Jakubowska[a*], Artur Kraszkiewicz[a], Marta Krajewska[b]

[a] Department of Machinery Exploitation and Management of Production Processes
[b] Sub-Department of Biological Bases of Food and Feed Technology
University of Life Sciences in Lublin

[*] *Corresponding author: e-mail: magdalena.kacheljakubowska@up.lublin.pl*

ARTICLE INFO

Article history:
Received: July 2015
Received in the revised form: September 2015
Accepted: October 2015

Key words:
oilcake,
heat of combustion,
calorific value,
oilseeds

ABSTRACT

Currently, many countries are establishing goals for substituting fossil fuels with biomass. This global trade in solid biofuels, which is to some extent already taking place, will have a major impact not only on other commodity markets like vegetable oils or animal fodder but also on the global land use change and on environmental impacts. It demonstrates the strong but complex link between biofuels production and the global food market, it unveils policy measures as the main drivers for production and use of biofuels and it analyzes various sustainability indicators and certification schemes for biofuels with respect to minimizing the adverse effects of biofuels. Biomass is seen as a very promising option for fulfilling the environmental goals defined by the European Commission as well as various national governments. We have measured selected physicochemical properties of several the most common oilseeds and the residue materials in the form of cakes, moisture, fat, heat of combustion, the calorific value and ash content. The results showed that the considered plants and waste derived therefrom can be a good energy source. Examples include sunflower oilcake, sesame, pumpkin and rapeseed cake, for which the calorific value amounted to respectively: 28.17; 27.77; 26.42 and 21.69 $MJ \cdot kg^{-1}$.

Introduction

A growing improvement of the living standard has caused a considerable growth of the human demand for electric and thermal energy. Global consumption of energy increased by 5.6% in the geometrical average since 1973 (BP, 2011). In majority of cases electric energy is generated from fossil fuels among which there are fossil oil, natural gas and coal, which is the most popular energy carrier (IEA, 2011). Such a popular use of these raw materials resulted in a considerable reduction of their resources (Kumar et al., 2010). However, one should remember that excavation and combustion of fossil fuel causes emission of greenhouse gases to atmosphere and in particular of methane and CO2, which consequently leads to climate changes (ICCP, 2013). Replacement of fossil fuels with energy produced from renewable sources such as agricultural biomass may considerably reduce the present level of greenhouse gases emission. Therefore, renewable energy was recognized as an important element for the future of our society (Blaschke et al., 2013). In case of Poland, since the base year (1998) to 2000 considerable changes of greenhouse gases emission related to the reduction of energy consumption in the domestic economy and changes in the use structure of these fuels were reported. It is necessary that the growing use of renewable energy sources reflected also the policy in many parts of the world including Poland. Common present energy strategies should concern, inter alia, the environmental issues including development of environment friendly technologies which aim at focusing on more efficient energy use, increase of energy supplies and reduction of air pollution and consequently the greenhouse effect. Poland as a party to the UN Convention on the climate changes is also obliged to develop and implement national strategies of greenhouse gases emission reduction, including economic and administrative mechanisms and periodical control of its implementation. In the realization strategy of the Poland's climatic policy guidelines draft, a 40% scale of greenhouse emission reduction was accepted as the upper limit of the scope of the analyses, which were carried, out and a 20-year time horizon (to 2020) (Ministry of Environment, 2003). Wood, energy plants, waste and agricultural waste are a common example of solid biofuels source (biomass), among which we distinguish straw or post-production residue from pressing oils for food or industry purposes (Kong et al., 2008; Demirbas, 2008b; Balat, 2008). Advantages over traditional fuels from biofuels production are mainly: greater energy safety, reduction of the negative impact on the environment and the social and economic issues related to the agricultural sector. Biofuels may be energy carriers for all countries (Balat, 2007; 2008; Demirbas, 2008a), because they are renewable and available in the whole world. Improvement of energy efficiency is considered as one of the most promising undertakings for the benefit of global reduction of CO2 emission and being independent from imported fossil fuels. Production of energy from renewable sources in the form of agricultural raw materials is recommended as a strategy of confrontation to the increase of the energy prices in order to support energy safety and solving the problem of Poland's fuel poverty. It is assumed that households consume at least 10% of their incomes for purchase of fuel to satisfy their energy needs (Baker, 2008). High prices of crude oil and gas emphasize a growing dependence of Europe from import of energy, motivating to searching for other sources aiming at the reduction of energy resources import and thus support of the biomass use. According to predictions of OECD/FAO (2014) oil plants production will increase by approximately 28% focusing on eight producers represented by Indonesia, Malesia, China, European Union, United States, Argentina, Brazil and India to 2023.

The most common oil plants in the world are seeds of rape, sunflower and pumpkin. Flax, sesame, poppy, nigella or hemp seeds are less popular. Oil cake usually used as animal feed is a by-product at the production of food oil (Journal of Laws, No. 20, item 119, 2007). Their chemical composition differs in relation to the quality of used seeds or the method of oil extraction. They are formed during the physical process of pressing seed with cool method or with the use of solvents with the industrial method. The use of a pro-ecology technology of seeds processing without extraction of organic solvents does not cause emission of aliphatic hydrocarbons to atmosphere (Journal of Laws, No. 2, item 24, 2007). Oil cakes which are formed may have a wide scope of use. One should remember that the content of anti-nutrient compounds in oilcake may disqualify it as a food product for animals. At the same time a question arises concerning the possibility of its use as an organic fertilizer, enzymes, antibiotics, vitamins, biopesticides, additive to production of gas or solid fuels in the form of briquettes or pellets (Kalembasa and Adamiak, 2010; Ramachandran et al., 2007; Lingaiah and Rajasekaran, 1986; Mattucci et al., 1989; Özçimen and Karaosmanoğlu, 2004). It is confirmed by scientific news indicating physico-chemical values of oilcake on account of the content of such mineral components as Ca, Mg, P, Fe, Mn and biochemically active organic compounds (proteins 28-38%, fats 2.5-21%) (Muśnicski, 2003; Strzeliński. 2006; Wojciechowski, 2009; Kachel-Jakubowska et al., 2011). The presence of fat and protein in oilcake and their use as a raw material for solid fuels designed for combustion must include the possibility for formation of pitchy products during pyrolysis before ignition as well as formation of carbon black. It is estimated that the heat of combustion of rapeseed cake may be within 19.8 to 27 $MJ\cdot kg^{-1}$and the calorific value is approximately 26 $MJ\cdot kg^{-1}$ compared to an average calorific value of hard coal which is also approximately 26 $MJ\cdot kg^{-1}$ (Cieślikowski et al., 2006; Kachel-Jakubowska et al., 2013). In small refineries, a cold seed pressing method was popularized as a result of which, it is assumed that at the average from 1 tone of e.g. rape approximately 650 kilo of oil cake is obtained and in case of pressing and extraction 600 kilo of meal is obtained (Cieślikowski et al., 2006; Dzieniszewski, 2009). Subjecting oilcake to pelleting is related to 4-10 times increase in density, which also causes decrease of the transport and storing (Li et al., 2012 a, b; Liu et al., 2014).

The objective of the paper was to analyse the physical and chemical properties of seed of the selected plants for obtaining food oils therefrom and evaluation of the possibilities of using the residue after pressing for energy purposes.

Objective of the paper and methodology of research

Samples (1 kilo) of the selected seeds from 2014 yield constituted material for research. The research was carried out on seeds of the following oil plants: winter rapeseed Adriana cultivar, shell less pumpkin Olga cultivar, husked sunflower (country of origin -Bulgaria), fibre flax Luna cultivar, fibre hemp Beniko cultivar, blue poppy Major cultivar, black caraway, hulled sesame (country of origin – India). Research material in the form of rapeseeds, shelless pumpkin came from regular field cultivations carried out on the territory of Lubuskie Voivodeship. The remaining flax seeds and black caraway, sunflower, poppy came from F.H. AWIKO enterprise in Elizówka.

The research on the content of moisture in seeds was carried out with the use of a moisture analyser in the temperature of 120ºC, by Radwag max 50/1/WH company. The content of fat in seeds and oilcakes was determined according to Soxhlet method. This method consists in multiple constant extraction of fat substance from the ground and previously dried product with the use of organic solvent, solvent stripping and determination of fat substance with the gravimetric method.

The research material in the form of seeds was subjected to the pressing process with the use of screw press with a variable nozzle with the diameter of 8 mm along with the set of microscopic sieves by Farmet Duo company with a continuous operation. Before starting, the press was heated to the temperature of 60ºC and after the pressing temperature was stabilized, the proper pressing process was started. Stabilization was reached after pressing oil from the mass of approximately of 1 kilo of seeds; then the temperature was 70ºC. The pressing temperature was measured with Ama-digit thermometer. In the obtained oilcakes, the moisture content was determined with the same method as in case of seeds, namely by means of a moisture analyser in the temperature of 120ºC, by Radwag max 50/1/WH company.

Heat of combustion was determined according to the standard PN-14918:2010 with the use of calorimeter Parr 6400. On the other hand, the ash content was determined according to the standard PN-14775:2010 in the laboratory oven in the temperature of 550ºC. All analyses were carried out in three iterations. Statistical analysis was carried out in order to determine a mean value, minimal and maximum value, standard deviation, matrix correlation for all variables. Analyses were based on ANOVA statistics with the use of post-hoc tests, HSD Tukey's test. Calculations were made with the use of Statistica 10 by Statsoft.

Research results

Table 1 presents the results of physical and chemical parameters of the considered seeds and oilcakes after cold pressing of oil. The results presenting the moisture content in seed before pressing process were within 2.11% to 8.80% where the lowest moisture occurred in case of sunflower seeds and the highest in case of pumpkin seeds. After pressing, the water content in oil cakes was considerably low and was within 0.87 in pumpkin oilcake to 3.97% in rapeseed cake. Analyses concerning the fat content in seeds proved its highest content in sesame seeds (54.28%) and sunflower seeds (50.33%) and the lowest in black caraway seeds (16.09%). The fat content in the obtained cake was from 5.10% for hemp to 44.32% for sunflower. Sunflower and sesame seeds proved to have the worst properties with regard to obtaining oil in case of cold pressing of seeds. Thus, one may presume that too low temperature inside the press affects this situation.

Based on the obtained results of the statistical analysis on the evaluation of the relations of the fat content in the used oil seeds, no significant differences between the rape, sesame, flax and hemp seeds were determined. However, these differences were discovered between the rape and poppy seeds as well as pumpkin and sunflower seeds. In case of the statistical analysis concerning the fat content in oilcake, differences were reported in the sesame and sunflower oilcake in comparison to remaining raw materials.

Table 2 presents the results of the research on determination of the heat of combustion, calorific value and the ash content in the analytical state. At the average, the heat of combustion of the considered oilcakes was from 19 $MJ\cdot kg^{-1}$ (oilcake from pressing poppy and hemp) to almost 30 $MJ\cdot kg^{-1}$ (oilcake from pressing sesame and sunflower seeds). Since, the analysed samples had a low water content their calorific value was only slightly lower than the heat of combustion and was within 18.82 $MJ\cdot kg^{-1}$ for hemp and poppy to 28.17 $MJ\cdot kg^{-1}$ for sunflower. Whereas the ash content as a rule was within 3 to 7%. Only for poppy oilcake, the ash content was decisively higher and it was over 12%. The ash content in the waste biomass after oil pressing, except for poppy oilcake was comparable with the values of this parameter for other energy plants (Demirbas, 2004).

Table 1.
List of physicochemical parameters of selected seeds and oilcake obtained after pressing of oil

Specification		Moisture (%)		Fat (%)	
Raw material	Parameter	Seeds	Oilcake	Seeds	Oilcake
Rapeseed	min	4.25	3.55	41.12	7.48
	max	4.51	4.22	41.35	7.57
	average	4.41	3.97	41.24	7.52
	standard deviation	±0.14	±1.22	±0.12	±0.04
Pumpkin	min	8.00	0.90	47.00	8.48
	max	9.50	2.27	47.50	8.55
	average	8.80	0.87	47.23	8.51
	standard deviation	±0.76	±1.22	±0.20	±0.03
Flax	min	6.10	2.37	26.93	8.88
	max	7.40	3.03	27.19	8.91
	average	6.94	2.75	27.06	8.90
	standard deviation	±0.73	±0.34	±0.13	±0.01
Hemp	min	5.22	2.19	29.58	5.06
	max	6.37	2.31	29.96	5.14
	average	5.93	2.24	29.77	5.10
	standard deviation	±0.62	±0.34	±0.19	±0.04
Poppy seed	min	3.80	2.27	38.35	10.71
	max	4.60	2.50	41.08	11.08
	average	4.27	2.41	39.71	10.90
	standard deviation	±0.42	±0.12	±1.37	±0.18
Black cumin	min	5.31	2.03	15.06	9.82
	max	5.35	2.50	17.13	9.89
	average	5.33	2.41	16.09	9.86
	standard deviation	±0.02	±0.12	±1.03	±0.04
Sesame	min	2.31	2.44	54.26	42.56
	max	2.65	2.73	54.30	42.80
	average	2.43	2.60	54.28	42.68
	standard deviation	±0.19	±0.15	±0.02	±0.12
Sunflower	min	2.05	3.69	50.23	44.12
	max	2.16	3.99	50.44	44.52
	average	2.11	3.86	50.33	44.32
	standard deviation	±0.06	±0.15	±0.11	±0.20

Analysing the obtained results of the heat of combustion and the calorific value of the considered raw materials in the aspect of their energy use, it is reported that they are comparable as well as better in comparison to the values of analogical parameters for wood or straw. It depends on the fat content in the waste. Thus, the results were also considered on account of the fat content in particular oilcakes in relation to the heat of combustion (fig. 1).

Table 2.
The heat of combustion, the calorific value and ash content in the analyzed oil cake

Specification		Heat of combustion	Calorific value	Ash
Raw material	Parameter	(MJ·kg^{-1})	(MJ·kg^{-1})	(% d.m.)
Rapeseed	min	21.87	21.47	2.83
	max	22.40	21.92	3.24
	average	22.13	21.69	3.03
	standard deviation	±0.26	±0.23	±0.21
Pumpkin	min	26.42	26.47	6.03
	max	26.54	26.29	6.14
	average	26.51	26.42	6.09
	standard deviation	±0.03	±0.02	±0.05
Flax	min	19.06	18.79	6.00
	max	19.23	18.89	7.35
	average	19.14	18.83	6.67
	standard deviation	±0.09	±0.08	±0.67
Hemp	min	18.97	18.72	7.38
	max	19.17	18.91	7.53
	average	19.07	18.82	7.46
	standard deviation	±0.10	±0.10	±0.07
Poppy seed	min	18.97	18.52	11.78
	max	19.17	18.56	13.07
	average	19.07	18.54	12.43
	standard deviation	±0.02	±0.01	±0.65
Black cumin	min	19.75	19.52	6.52
	max	20.29	19.97	6.60
	average	20.02	19.75	6.56
	standard deviation	±0.27	±0.31	±0.04
Sesame	min	27.67	27.40	3.86
	max	28.45	28.15	4.12
	average	28.06	27.77	3.99
	standard deviation	±0.39	±0.38	±0.13
Sunflower	min	27.88	27.47	3.67
	max	29.33	28.88	3.72
	average	28.60	28.17	3.69
	standard deviation	±0.73	±0.71	±0.03

Based on the analysis of the obtained results it was observed that in two cases (concerning sesame and sunflower), where the fat content was the highest, the heat of combustion has also quite high values and was respectively 28.06 and 28.60 MJ·kg^{-1}. However, it is not confirmed by the rule because also rapeseed cake had a quite high heat of combustion and it was 22.13 MJ·kg^{-1}and pumpkin 26.51 MJ·kg^{-1} at the fat content of 7.52% and 8.5% (fig. 1).

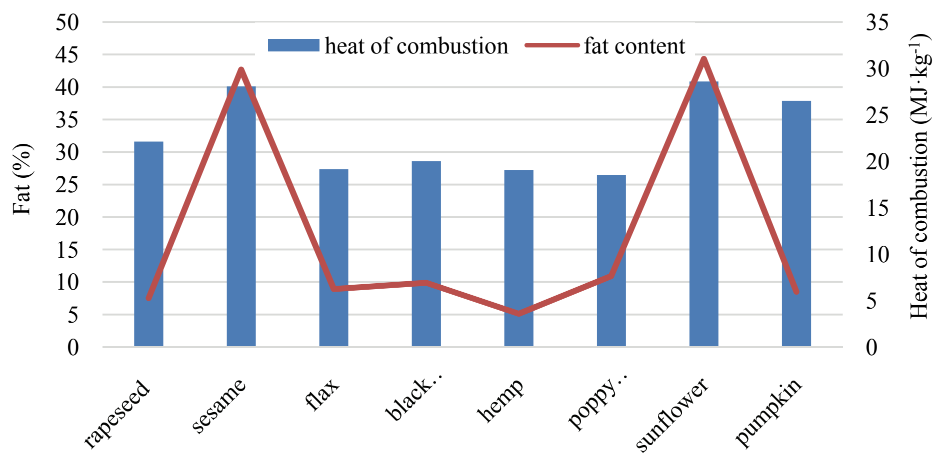

Figure 1. Effect of fat content heat of combustion cake

What is more, the statistical analysis which was carried out (fig. 2) of the heat of combustion of particular oilcakes confirmed previous assumptions concerning the existence of the statistical difference between the value of heat of combustion between the rape seeds and sesame and sunflower and pumpkin seeds.

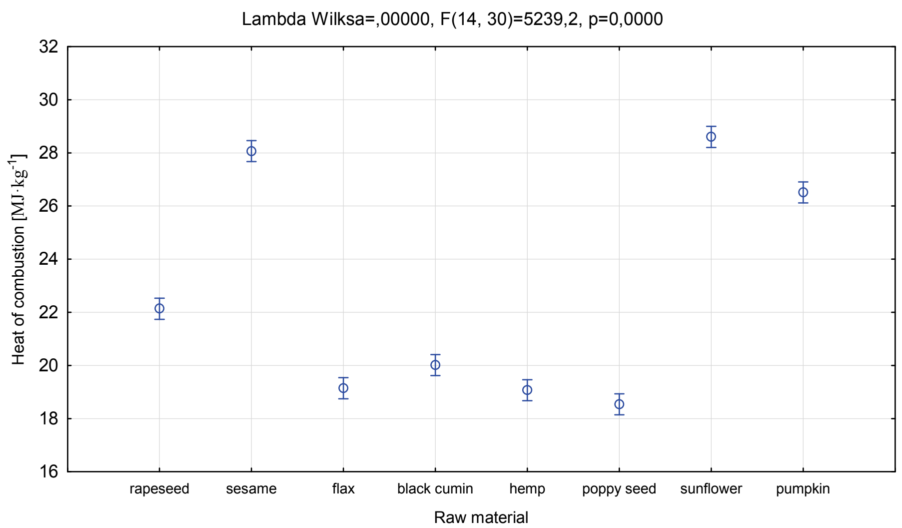

Figure 2. Statistical analysis of the heat of combustion used oilseeds

Conclusion

Agricultural biomass in the form of oilcake, which is formed as a result of oil seeds processing, has perfect fodder properties (considerable content of fat) but also based on the obtained results may be used as a valuable energy carrier. The phenomenon of the growing social awareness and even bigger access to devices which enable an independent process of processing the cultivated food products is caused by the growing number of waste, which must be managed. Based on the obtained results, one may state that the considered plants and the post-production waste obtained therefrom may constitute a good energy source. Sunflower, sesame, pumpkin and rapeseed cake, for which the calorific value was respectively: 28.17; 27.77; 26.42 and 21.69 $MJ \cdot kg^{-1}$. However, there are still many issues to be analysed and tested with regard to pellet or briquette production with an addition of these oilcakes, the impact on the heating system, the course of the heat of combustion or the composition and the quality of fumes particularly in heating installations of low power.

References

Baker, W. (2008). Off-gas consumers. Technical Annex. Information on households without mains gas heating. London: Consumer Focus,. Obtained from: http://www. consumerfocus.org.uk/ publications/off-gas-consumers-information-onhouseholds-without-mains-gas-heating.

Balat, M. (2007). An overview of biofuels and policies in the European Union. *Energy Sources Part B, 2*, 167-181.

Balat, M. (2008). Hydrogen-rich gas production from biomass via pyrolysis and gasification processes and effects of catalyst on hydrogen yield. *Energy Sources Part A, 30*, 552-564

Blaschke, T., Biberacher, M., Gadocha, S., Schardinger, I. (2013). Energy landscapes: meeting energy demands and human aspirations. *Biomass Bioenergy, 55*, 3-16.

B.P. (2011). Statistical review of world energy. British Petroleum, [Online]. Obtained from: http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf.

Cieślikowski, B., Juliszewski, T., Łapczyńska-Kordon, B. (2006). Utylizacja na cele energetyczne produktów ubocznych technologii biopaliw. *Agricultural Engyneering, 12,* 51-57.

Demirbas, A. (2008). Economic and environmental impacts of the liquid biofuels. *Energy Education Science Technology, 22,* 37-58.

Demirbas, A. (2008a). Recent progress in biorenewable feedstocks. *Energy Education Science Technology, 22,* 69-95.

Demirbas, A. (2008b). Biohydrogen generation from organic wastes. *Energy Sources, Part A, 30,* 475-482.

Dz. U. nr 2, poz. 24. (2007). *Rozporządzenie Ministra Rolnictwa I Rozwoju Wsi z dnia 8 stycznia 2007 roku w sprawie materiałów paszowych wprowadzanych do obrotu.*

Dz. U. nr 20, poz. 119. (2007). *Rozporządzenie Ministra Rolnictwa i Rozwoju Wsi z dnia 23 stycznia 2007 roku w sprawie dopuszczalnych zawartości substancji niepożądanych w paszach*.

Dzieniszewski, G. (2009). Wybrane aspekty ekologiczne i ekonomiczne zasilania silników diesla paliwami roślinnymi. *Agricultural Engyneering, 6*(115), 45-52.

IEA. (2011). *World energy outlook*. Paris: International Energy Agency.

IPCC. (2013). Summary for policymakers. In: Stocker TF., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung J., Nauels A., Xia Y., Bex, V., Midgley, P.M. editors. Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Kachel-Jakubowska, M., Kraszkiewicz, A., Szpryngiel, M., Niedziółka, I. (2011). Możliwości wykorzystania odpadów poprodukcyjnych z rzepaku ozimego na cele energetyczne. *Agricultural Engyneering, 6(*131), 61-68.

Kachel-Jakubowska, M., Kraszkiewicz, A., Szpryngiel, M., Niedziółka, I. (2013). Analysis of the characteristics of raw materials used in production of solid biofuels. *Agricultural Engyneering, 2*(143), 103-111.

Kong, L., Li, G., Zhang, B., He, W., Wang, H. (2008). Hydrogen production from biomass wastes by hydrothermal gasification. *Energy Sources Part A, 30*, 1166-1178.

Kumar, A., Kumar, K., Kaushik, N., Sharma, S., Mishra, S. (2010). Renewable energy in India: current status and future potentials. *Renewable Sustainable Energy Review, 14*(8), 2434-42.

Li, H., Liu, X.H., Legros, R., Bi, X.T., Lim, C.J., Sokhansanj S. (2012a). Pelletization of torrefied sawdust and properties of torrefied pellets. *Applied Energy, 93*, 680-685.

Li, J., Brzdekiewicz, A., Yang, W., Blasiak, W. (2012b). Co-firing based on biomass torrefaction in a pulverized coal boiler with aim of 100% fuel switching. *Applied Energy, 99*, 344-354.

Lingaiah, V., Rajasekaran, P. (1986). Biodigestion of cow dung and organic wastes mixed with oil cake in relation to energy. *Agricultural Wastes, 17*, 161-173.

Liu, Z., Quek, A., Balasubramanian, R. (2014). Preparation and characterization of fuel pellets from woody biomass materials, agro-residues and their corresponding hydrochars. *Applied Energy, 113***,** 1315-1322.

Mattucci, E., Grassi, G., Palz, W. (1989). Pyrolysis as a basic technology for large agro-energy projects. *Commission of the European Communities*, CD-NA-11382-EN-C.

M.Ś. (2003). Strategie redukcji emisji gazów cieplarnianych w Polsce do roku 2020. Projekt

Muśnicki, Cz. (2003). *Szczegółowa uprawa roślin.* Praca zbiorowa. Tom II, Wydawnictwo Akademii Rolniczej we Wrocławiu. ISBN 83-89189-17-8.

OECD-FAO (2014). *Agricultural Outlook.* ISBN 978-92-64-211742.

Özçimen, D., Karaosmanoğlu, F. (2004). Production and characterization of bio-oil and biochar from rapeseed cake. *Renewable Energy, 29,* 779-787.

Ramachandran, S., Singh, S.K., Larroche, C., Soccol, C.R., Pandey, A. (2007). Oil cakes and their biotechnological applications: a review. *Bio-resour Technolology, 98*, 2000-2009.

Smulikowska, S. (2006). Wartość odżywcza wytłoków rzepakowych produkowanych w kraju dla drobiu. *Wiadomości Zootechniczne, 44*(3), 22-28.

Strzeliński, J. (2006). Możliwości wykorzystania w żywieniu bydła produktów ubocznych powstających przy głębokim tłoczeniu oleju z nasion roślin oleistych i produkcji bioetanolu. *Wiadomości Zootechniczne, 44*(3), 56-66.

Magdalena Kachel-Jakubowska, Artur Kraszkiewicz, Marta Krajewska

MOŻLIWOŚCI WYKORZYSTANIA ODPADÓW PO TŁOCZENIU OLEJU Z NASION ROŚLIN OLEISTYCH NA CELE ENERGETYCZNE

Streszczenie. Biomasa jest postrzegana jako bardzo obiecująca opcja do spełnienia celów środowiskowych określonych przez Komisję Europejską, jak również rządów w innych krajach. Dlatego też przeanalizowano wybrane właściwości fizykochemiczne kilku najpowszechniejszych roślin oleistych oraz ich pozostałości poprodukcyjnych w postaci makuch, pod kątem zawartości wilgoci, tłuszczu, ciepła spalania, wartości opałowej oraz zawartości popiołu. Na podstawie uzyskanych wyników można stwierdzić, iż rozpatrywane rośliny oraz pozyskane z nich odpady poprodukcyjne mogą być dobrym surowcem energetycznym. Przykładem mogą być makuchy słonecznika, sezamu, dyni i rzepaku, dla których wartość opałowa wynosiła kolejno: 28,17; 27,77; 26,42 oraz 21,69 $MJ \cdot kg^{-1}$.

Słowa kluczowe: makuchy, ciepło spalania, wartość opałowa, rośliny oleiste