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ENERGY AND ECONOMIC EFFECTIVENESS OF WINTER RAPE AND WINTER WHEAT CULTIVATION FOR LIQUID BIOFUEL PRODUCTION

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Abstract

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Aim of this study was an analysis and assessment of the economy and energy effectiveness of winter wheat and winter rape cultivation for liquid biofuel production. The cost of production and economical effect index is more profitable in case of winter rape. Also the final balance of energy effectiveness has shown better values if the biodiesel had been produced from winter rape as compared with bioethanol from winter wheat. Calculation of the obtained products and their comparison with an energy unit has shown that the netto energy from biodiesel was positive while that from bioethanol was negative, which means that in the latter case expenditure is greater than that gained in the produced biofuel.

biodiesel, bioethanol, production cost, energy input, labour input, energy effectiveness, fuel use

Study possibility of using agricultural row materials for energy needs has been taken for several years (Mokrzycki, 2005). Processing biomass to energy has got a lot of advantages such as reduction of chemical compound emission, greenhouse effect reduction, and biodegradation. An important advantage of this type of fuel is its possibility of continuity of its production (it is possible to renew this type of fuel). The cost of biofuel production is determinated by raw materials price. The price of raw materials depends on technologies and allocation system for agriculture. Costs of production of the most known liquid fuels such as bioethanol, rape's ester are about 2.4–2.6 times higher than costs of production of mineral fuels. However, decreasing of natural energy recourses (gas, oil, coal) causes that people are more interested in this type of energy. An important component of valuation of fuel's production, besides costs, is an energy effectiveness calculation. The energy effectiveness calculation shows how much energy must be used to get biofuel energy unit (Dobek, 2004). The advantage of energy effectiveness calculation is its independence of prices. Independence enables to compare the results.

An aim of a study was to evaluate a technology of winter wheat and winter rape production, to evaluate processing agricultural products into biofuels and to count energy and economical effectiveness coefficients of biodiesel production from winter rape and of bioethanol production from winter wheat.

MATERIALS AND METHODS

Studies were made in 2010–2012 on agricultural farms placed on the terrain of north- western Poland. In winter rape production traditional technology of cultivation was used (moldboard plough and disc harrows), in secondary tillage compactor was used. Fertilizer application was done three times by using trailed fertilizer distributor. Seeding was done by using multipurpose drill. During a vegetation season spraying was done four times by using single stage method, by using harvester adapted to winter rape harvest. Average yield of winter rape was 3.16 t·ha^{-1}.

In winter wheat production moldboard plough and cultivator was used. A secondary tillage was made by using seedbed preparation roller. Winter wheat was fertilized four times by using fertilizer spreader. Seeding was made by using multipurpose drill. During the vegetation season of winter wheat, spraying was done three times by using tractor sprayer. Winter wheat crop was done by using single–stage method by using combine harvester. Average crop of winter wheat was 5.24 t·ha^{-1} per a farm.

Costs of production were counted by using a method elaborated by IBMER Warszawa (Muzalewski, 2010). Costs of technologies were composed of cost of machines' exploatation, cost of tools and tractors, cost of materials and staples, cost of fuel and cost of labour. Costs of processing were counted by using a mathematical formula (1):

$$K_{pro} = \Sigma K_{mat} + \Sigma K_{agr} + \Sigma K_{pal} + \Sigma K_r + \Sigma K_{prz}, \text{ [zł·ha}^{-1}] \quad (1)$$

where:
K_{pro}......costs of biofuel production [zł·ha^{-1}],
ΣK_{mat}...costs of materials and staples [zł·ha^{-1}],
ΣK_{agr} ...costs of machines and tools [zł·ha^{-1}],
ΣK_{pal} ...costs of fuel [zł·ha^{-1}],
ΣK_r......costs of work [zł·ha^{-1}].
ΣK_{prz}...costs of processing winter rape into biofuel [zł·ha^{-1}].

Method elaborated by IBMER was used to analyze energy input connected to winter rape and winter wheat production (Anuszewski *et al.*, 1979; Wójcicki, 2002). Calculations include also energy costs and energy input which are necessary to produce biofuel from agriculture products. Cumulative energy–consumption was counted by using a mathematical formula (2):

$$E_{pro} = \Sigma E_{mat} + \Sigma E_{agr} + \Sigma E_{pal} + \Sigma E_r + \Sigma E_{prz}, \text{ [MJ·ha}^{-1}] \quad (2)$$

where:
E_{pro}......cumulative energy–consumption of biofuel production [MJ·ha^{-1}],
ΣE_{mat}...cumulative energy in materials and staples [MJ·ha^{-1}],
ΣE_{na} ....cumulative energy in machines and tools [MJ·ha^{-1}],
ΣE_{pal}....cumulative energy in fuel [MJ·ha^{-1}],
ΣE_r ......cumulative energy in work [MJ·ha^{-1}],
ΣE_{prz} ...energy which is necessary for processing crop into biofuel [MJ·ha^{-1}].

The energy effectiveness coefficients of technological processes connected with processing agriculture products into biofuel were taken from foreign and national literature. Values of energy effectiveness coefficients were counted by using the mathematical formula (Mokrzycki, 2005; Richards 2000) (3):

$$W_{ee} = \frac{\Sigma W_{prz}}{\Sigma W_{pro}}, \quad (3)$$

where:
W_{ee}......energy effectiveness coefficient,
ΣW_{pro}..energy–consumption of production biofuel and processing obtained crop [MJ·ha^{-1}],
ΣW_{prz}..energy of received fuel and biomass [MJ·ha^{-1}].

RESULTS AND DISCUSSION

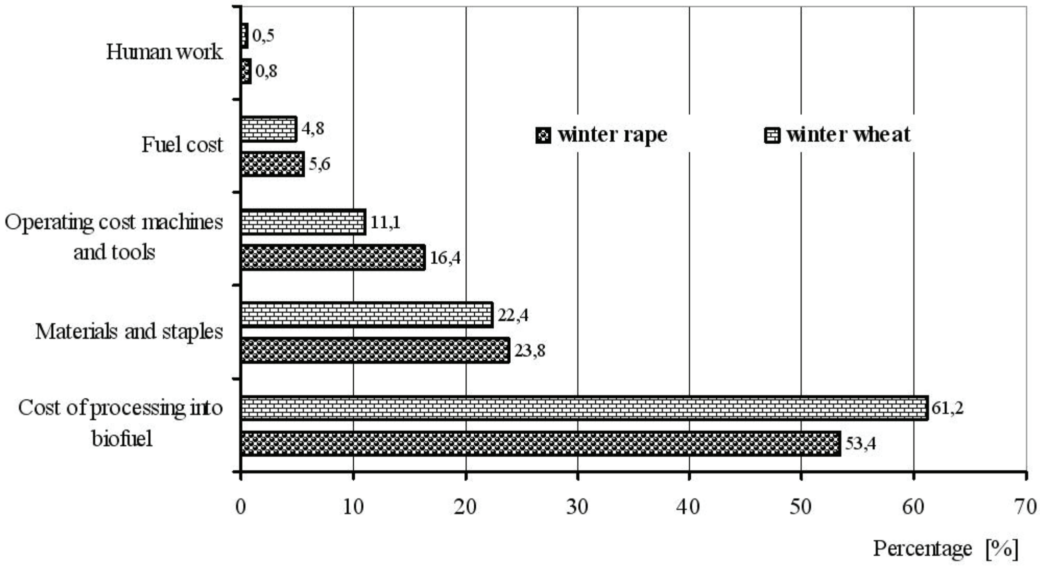
An analysis of total costs of winter rape and winter wheat production leads to a conclusion that costs of winter rape production are lower than costs of winter wheat production. Cost of winter rape production was 2727 zł·ha^{-1}, costs of winter wheat production – 2890 zł·ha^{-1}. In a structure of total costs the highest costs are materials' and staples' costs, machines and tools exploitation's costs, fuel costs and cost of labour. Costs of materials and staples in winter rape production were 1397 zł·ha^{-1} it is 51.23 %. Costs of materials and staples in winter wheat production were 1665 zł·ha^{-1} – it is 57.61 % of total production's costs. Very high there was also the cost of machines' and tools' exploitation. It was 958 zł·ha^{-1} (35.13 %) – in winter rape production and 829 zł·ha^{-1} (28.69 %) in winter wheat production.

The analysis of machines' and tools' exploitation costs, which were used in particular parts of production leads to the conclusion that the highest costs in winter rape production were agriculture cost – 389 zł·ha^{-1} (40.61 %) and costs of crop – 284 zł·ha^{-1} (29.65 %). Very similar there was in winter wheat production. The highest costs were agriculture costs – 326 zł·ha^{-1} (39.32 %) and costs of crop – 258 zł·ha^{-1} (31.12 %). The economical effectiveness coefficient in tested technologies was 1,43 in winter wheat production and 1.9 in winter rape production (Tab. I and Fig. 1).

I: *Cost of winter wheat and winter rape production in the tested technologies*

Specification	Winter rape	Winter wheat
	zł·ha^{-1}	zł·ha^{-1}
Machines exploitation's costs without fuel costs and labour costs	958	829
Fuel costs	326	359
Labour costs	46	37
Materials and staples	1 397	1 665
Total costs	2 727	2 890
Economical effectiveness of production seeds	1.90	1.43

Turning crops into biodiesel and bioethanol we have to bear some additional costs which cause that costs biofuel's production are higher. For example cost of conversion rape into esters was (3120 zł·ha^{-1}) and it was higher by 14.41 % than costs of rape's seeds production (2727 zł·ha^{-1}). In bioethanol production also cost of processing was higher – it was 4560



1: *The cost structure of the percentage biodiesel production and bioethanol*

zł·ha^{-1} and it was higher by 57.78% than cost of winter wheat production (2890 zł·ha^{-1}). Economical effectiveness of production biodiesel was 1.1. It's a proof that biodiesel production is profitable. In bioethanol production economical effectiveness was 0.64. It leads to the conclusion that cost of production and of processing was higher than value of received energy included in bioethanol and straw (Tab. II).

The analysis of cumulative energy–consumption in the tested technologies of production leads to the conclusion, that cultivation of winter wheat (34508 MJ·ha^{-1}) was characterized by higher cumulative energy–consumption. It was higher by 20,46% than energy–consumption of winter rape production – 28648 MJ·ha^{-1} (Tab. III and Fig. 2).

In winter wheat production the cumulative energy–consumption of materials and staples was 23150 MJ·ha^{-1}, which was 67.08% of total energy–consumption, in rape production it was 18520 MJ·ha^{-1}, which was 64.65% of total energy–consumption. The analysis of cumulative energy–consumption of machines and tools, which were used in tested technologies, leads to the conclusion, that agriculture was characterized by the highest energy–consumption. In winter wheat production it was 1974 MJ·ha^{-1}, which was 29.01% of energy–consumption of machines and tools. In winter rape production it was 2521 MJ·ha^{-1}, which was 40.49% of energy–consumption machines of tools.

Also much energy is using in a process of crop. In the process of crop of winter wheat it is 1586 MJ·ha^{-1} (23.71 %), in the process of crop of winter rape it is 1758 MJ·ha^{-1} (28.24 %). The energy effectiveness coefficient in technology of winter wheat production was 1.81, in technology of winter rape production was 1.12. The effectiveness processing coefficient (processing agricultural products into biofuel) was 2.49 – biodiesel and 2.02 – bioethanol.

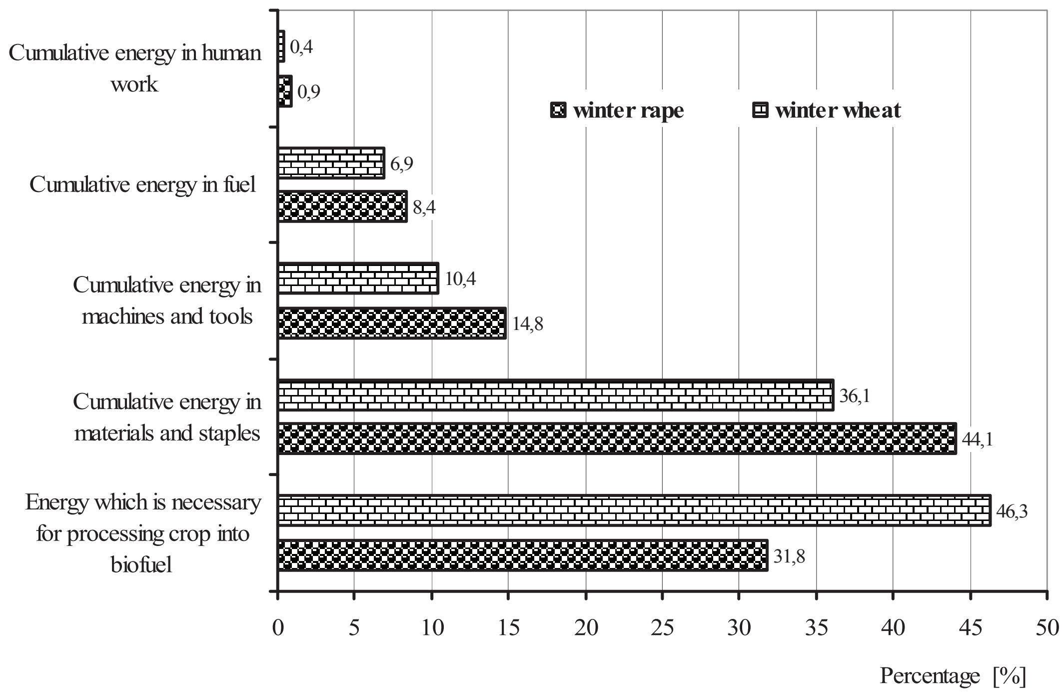
In conclusion it is possible to make a statement that the higher energy effectiveness coefficient was obtained in biodiesel production from rape (2.49), than in bioethanol production from wheat (2.02). In tested technology of winter rape cultivation and

II: *Cost of the production and processing of winter wheat and winter rape crop for bioethanol and biodiesel*

No.	Specification	Biodiesel	Bioethanol
		zł·ha^{-1}	zł·ha^{-1}
1	Costs of plant cultivation	2 727	2 890
2	Costs of processing into biofuel	3 120	4 560
3	Total costs (poz.3 + poz.2)	5 847	7 450
4	Value of biofuel	4 762	4 190
5	Value of straw	452	574
6	Value of oil meal	1 240	–
7	Total profit (poz.4 + poz.5 + poz.6)	6 454	4 764
8	Economical effectiveness of production (poz.7/poz.3)	1.1	0.64

III: *Cumulative energy expenditures of winter wheat and winter rape production in the compared technologies*

Cumulative energy	Winter rape	Winter wheat
	MJ·ha^{-1}	MJ·ha^{-1}
Machines and tools	6 226	6 690
Fuel	3 520	4 420
Labour work	382	248
Materials and staples	18 520	23 150
Total cumulative energy–consumption	28 648	34 508
Energy effectiveness of production	1.12	1.81



2: *Percentage share cumulated energy of production biodiesel and bioethanol*

its crop processing into biodiesel the cumulative energy–consumption was 42008 MJ·ha^{-1} and 31.8% of it – 13360 MJ·ha^{-1} was used for processing crop into biofuel. In tested technology of bioethanol production from winter wheat the cumulative energy–consumption was higher by 52.87% than energy–consumption of biodiesel production – it was 64219 MJ·ha^{-1} and 34508 MJ·ha^{-1} (53.73%) of it was used to cultivate winter wheat, another 29711 MJ·ha^{-1} (46.27%) was used to process the winter wheat to bioethanol.

After conversion obtained products to energy unit it's possible to make a statement that yield netto energy in biodiesel production was 62711 MJ·ha^{-1} and in bioethanol production was 65658 MJ·ha^{-1}. It means than expenditures (of labour, energy) beared to produce bioethanol were lower than expenditures beared to get back bioethanol as biofuel (Tab. IV).

IV: *Energy balans of the production and processing of winter wheat and winter rape crop for bioethanol and biodiesel*

Specification	Winter rape	Winter wheat
	MJ·ha^{-1}	MJ·ha^{-1}
Energy value used on production	42 008	64 219
Energy value of biofuel	42 091	43 387
Energy value of straw	61 620	86 460
Energy value of oil meal	1 008	–
Energy value received after processing	104 719	129 847
Energy effectiveness coefficient	2.49	2.02
Yield netto energy	+62 711	+65 628

SUMMARY

Production costs of winter rape were 2727 zł·ha^{-1} and were lower than production costs of winter wheat by 163 zł·ha^{-1}.

Economical effectiveness of production of winter wheat was 1.43 of winter rape was 1.9. Economical effectiveness of processing into biofuel was 1.1 (biodiesel) and 0.64 (bioethanol).

Cumulative energy–consumption, which is necessary to produce winter wheat was 34508 MJ·ha^{-1} and was higher than energy–consumption, which is necessary to produce winter rape by 5860 MJ·ha^{-1}.

After conversion obtained products to energy unit it's possible to make a statement that yield netto energy in biodiesel production was 62711 MJ·ha^{-1} in bioethanol production was 65628 MJ·ha^{-1}.

REFERENCES

ANUSZEWSKI, R., PAWLAK, J., WÓJCICKI, Z., 1979: Energochłonność produkcji rolniczej. Metodyka badań energochłonności produkcji surowców żywnościowych. Warszawa: Wydawnictwo IBMER, 23–28.

DOBEK, T., 2004: Efektywność ekonomiczna i energetyczna uprawy pszenicy i rzepaku ozimego z przeznaczeniem na produkcję biopaliw płynnych. *Inżynieria Rolnicza,* 11, 3: 109–116. ISSN 1429–7264.

MOKRZYCKI, E., 2005: *Podstawy gospodarki surowcami energetycznymi*. Kraków: Wydawnictwo Naukowo-Dydaktyczne AGH, 422. ISBN 83-8938-823-5.

MUZALEWSKI, A., 2010: *Koszty eksploatacji maszyn*. Warszawa:Wydawnictwo IBMER, 40–46. (ISBN N).

RICHARDS, I. R., 2000: *Energy balances in the growth of oilseed rape for biodiesel and of wheat for bioethanol*. Levington Agriculture Report, BABFO. [Available online: http://ecosse.org/jack/research/sustainable/levington/levington.pdf].

WÓJCICKI, Z., 2002: *Wyposażenie i nakłady materiałowo-energetyczne w rozwojowych gospodarstwach rolniczych*. Warszawa: Wydawnictwo IBMER, 139. ISBN 83-8626-462-4.

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