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ECONOMIC AND LEGAL ASPECTS OF BIOFUEL PRODUCTION FOR OWN USE

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Abstract. The purpose of this paper has been to assess the costs and profitability of producing oilseed rape (OSR) methyl esters and using them on own farmstead. The breakdown of costs involved in converting OSR into esters included the following stages: feedstock (raw material production, pressing oil from seeds and converting oil into fuel (estrification). The production costs were calculated per annum and the revenue derived from selling by-products was added. A field study was carried out on a farm covering 1,200 ha situated Warmia-Mazury Voivodship. The cost of making 1 liter of esters was 3.28 PLN, but when the by-product (rapeseed meal – pulp) was utilized, the cost dropped to 1.76 PLN. Production of esters based on purchased feedstock (the current price is 180 PLN·dt^{-1}) is an unprofitable undertaking since the unit production cost is higher than the price of diesel oil. Ultimate values of the analyzed economic indices depended on the costs of growing feedstock (shaped by agritechnical treatments, type of seed material, fertilization rates and necessary plant protection treatments), the way the by-products are utilized (sale, valuable feed in animal nutrition, energy carrier). The biodiesel producer must take into account the alternative cost fuel production. The paper presents legal regulations pertaining to the production of biofuel for own use; additionally, costs of this alternative fuel versus conventional one were compared.

Key words: alternative fuels, methyl esters, biodiesel production plant, production costs

INTRODUCTION

In the current political and economic position of Poland, most of crude oil used for fuel production is imported, which generates many negative consequences, such as highly volatile prices of fuels and almost unpredictable price tendencies. The economic and social outcome of the above situation consists in cyclic economic problems in all branches of domestic economy, with the worst difficulties experienced in transport and in agriculture [Dzieniszewski 2009].

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Poland belongs to the biggest oilseed rape (OSR) producers in Europe [Europe in figures... 2010]. After Poland's access to the European Union, production of OSR has become a nearly strategic branch in plant production. The reason is the large content of oil in rape seeds, which can be used as feedstock for production of OSR oil esters – a fuel used to run diesel engines.

Each farmstead needs a supply of energy carriers, used for household needs or for agricultural production. Among such carriers, the leading role is played by diesel oil (DO), the fuel without which the contemporary, motorized agriculture could not thrive, since as much as 50% of the total fuel consumption per farm is made up of diesel oil (acc. to energy consumption per energy carriers) [Szeptycki and Wójcicki 2003]. Consequently, replacing diesel oil with some cheaper fuel could significantly diminish agricultural production costs. Biodiesel, fatty acid methyl esters (FAME) or pure plant oil (PPO), obtained from pressing oilseeds, could become such cheaper fuel [Bocheński 2003].

The most popular method used for processing OSR oil is transestrification. In this process, plant oil reacts with alcohol in the presence of an acid or alkaline catalyst. An ester (ethyl or methyl) of higher fatty acids is a product of this reaction. It is a renewable fuel having properties similar to those of diesel oil produced from crude oil [Żmuda 2003, Demirbas 2007a]. Apart from being eco-friendly [Demirbas 2007b, Koh and Ghazoul 2008], FAME has a considerable influence on many branches of economy [Jeżowski 2001, Frąckowiak 2002, Podkówka 2004].

It is not easy to make a complete breakdown of costs and benefits of producing biodiesel for own use. What needs to be done is to sum up the costs which are incurred at every stage of biodiesel production, including cultivation of the oil crop, pressing oil from seeds, transestrification and management of the production waste.

The objective of this paper has been to try and define the economic effects of replacing diesel oil with biofuel produced from OSR seeds and used on own, privately-owned farm[1]. In order to achieve this aim, it was necessary to determine production costs of oilseed rape seeds, OSR oil and esters.

METHODOLOGY

The farm, where the following profitability analysis of growing OSR for biodiesel production was conducted, lies in Warmia-Mazury Voivodship. The total area of the farm is 1,200 ha (all arable land), of which 330 ha is dedicated to growing winter oilseed rape. The farm has own machines for pressing oil as well as a drying room and a storehouse for keeping OSR seeds.

For our analysis of the biofuel production profitability, we assumed that:

– the feedstock (OSR) for production of esters will originate from own farm and has been valued at the level of costs of growing it on farm,

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- the above feedstock costs were increased by adding costs of pressing seeds and processing oil to biofuel (the oil pressing and fuel production plant running costs were included, as well as the costs of products used for estrification, equipment depreciation, repairs and services of the machinery; it was also assumed that one employee would operate the oil pressing machine and supervise production of biofuel),
- the due excise duty such as 0.01 $PLN \cdot l^{-1}$ was added to the production costs,
- the calculations did not include area support.

The volume of fuel production corresponds to the annual demand of the farm for fuel. The ester production costs include the revenue from selling the by-products of the estrification process (oilseed rape meal), which lowered the fuel production costs. It was assumed that no income was obtained from selling the glycerin phase. The investment profitability was calculated from the difference between the price of diesel oil and the cost of produced biodiesel, and the difference is the producer's income.

The winter oilseed rape production costs were calculated with the method worked out by the IBMER [Goć and Muzalewski 1997]. In this method, the costs of using tractors and other machinery include the total costs of their maintenance and exploitation. The unit cost of the exploitation of tractors and machines was computed according to their current price, standard use during the working life, working life, repairs index and exploitation efficiency of particular machines. All the above unit components of the production costs were expressed in $PLN \cdot h^{-1}$.

The maintenance costs include: depreciation, housing and maintenance as well as insurance. The exploitation costs comprise the costs of repairs, fuel, oils and fuel consumption. It was assumed that one hour of human labour cost 10 PLN. Prices of industrial means of production were determined according to the prices in April-June 2011.

LEGAL CONTEXT OF PRODUCTION OF BIOFUELS FOR OWN USE

The principal legal act governing development of the biofuel market in Europe is the Directive of the European Parliament 2003/30/EC of 8 May 2003 on the promotion of the use of biofuels and other renewable fuels for transport, which sets the minimum market share of biofuels. However, the legal act which governs the production of biofuels for own use in Poland is the Act of 25 August 2006 on biocomponents and liquid biofuels (Journal of Law 2006, No 169, Item 1199). This act regulates production, storage and turnover of biocomponents and liquid biofuels, including production of liquid biofuels by farmers for own use, marketing biocomponents and liquid biofuels, writing and submitting reports. According to Article 13, farmers are allowed to produce biofuels for own use having obtained an entry in the register of farmer biofuel producers [Bielski 2011].

In order to produce biofuels for own use, an agricultural producer should possess adequate technical appliances and facilities, which make it possible to produce fuels compliant with the firefighting, sanitary and environmental regulations. A permit to keep a tax warehouse for excise goods is also required. The liquid fuels made by farmers for own use should fulfill the quality requirements as indicated in the rules on the fuel quality monitoring and control.

The act sets an annual limit of 100 liters per 1 ha of arable land owned by the farmer for individual production of ester and pure plant oil, which in itself is fuel. After each calendar year, the farmer is obliged to submit, within 45 days, an annual report containing such data as the quantities and types of feedstock used for producing liquid biofuels for own use. The reports are submitted to the Agricultural Market Agency. Penalty fees are to be imposed on a farmer who produces liquid biofuels without an entry in the aforementioned register or who sells or otherwise disposes of it in another form. A farmer shall also be penalized if he exceeds the annual liquid biofuel production limit, impedes control actions undertaken by the register organ, fails to submit an annual report in due time or falsifies the information in the submitted report.

Another important legal act is the one of 11 May 2007 on amending the act on excise duty and amending some other acts (Journal of Law 2007, No 99, Item 666). This document introduces some considerable changes to the biofuel sector, for example rates of excise duties on biocomponents which in themselves are fuels were set at 10 PLN per 1,000 l regardless the CN code. Agricultural producers were also granted an additional financial incentive such as 45 euros per ha of energy crops, which include crops delivered for production of biocomponents.

ELEMENTS OF THE TECHNOLOGICAL PROCESS OF PRODUCING BIODIESEL

The technological process of making biofuel from oil plants consists of the following steps:
- production of OSR seeds – feedstock for biofuel production,
- securing sufficient amounts of OSR seeds for an annual production of biofuel,
- the so-called oil cold-pressing on a pressing technological line,
- converting oil into biodiesel on an estrification technological line,
- distribution of biofuel.

While making biofuel from OSR seeds, by-products are generated, which may either decrease or increase the total costs of making biodiesel, depending on how they are utilized. It is possible to lower the costs when the by-products have market value and find consumers or can be used by the fuel producer on his own farm. In contrast, when by-products must be recycled because they can be neither sold nor used, the production costs will rise. By-products are generated in considerably large amounts and how they will be dealt with should be determined as early as during the design of a biofuel production facility [Juliszewski 2007]. By-products can be divided into two groups: by-products of oil pressing, i.e. extraction meal and cake, and by-product of transestrification, i.e. the glycerin phase.

The former group of by-products can be used as a valuable feed component in farm animal nutrition to replace soyabean meal. Oilseed cake, in turn, is a product of cold-pressing of seeds that is not subjected to removal of fat. Cake can therefore be incinerated in furnaces (the calorific value is comparable to that of coal) [Juliszewski 2007].

The latter group of by-products consists of the glycerin phase. The fact that there is methanol in the glycerin layer makes it rather difficult to utilize in households. The glycerin layer contains around 5–20% of methanol. Such product cannot be utilized unless under special supervision. The glycerin phase utilization must be strictly controlled, although once it is purified and methanol-free, it can be used in several industries (e.g. cosmetics, tobacco, pharmaceutical, food processing, etc.) [Gaca 2006].

RESULTS OF THE ANALYSIS AND DISCUSSION

Costs of ester production. Costs of securing raw product for production of esters

The following economical calculations pertain to the actual yields per 1 ha of winter oilseed rape cropped farmland (with the technology applied on the analyzed farm, the average yield is 31 $dt \cdot ha^{-1}$). The data obtained from the farm served as a basis for calculating the costs of feedstock production in the present study.

The cost of producing seeds of winter oilseed rape with the technology used on the analyzed farm reached 2,733 $PLN \cdot ha^{-1}$. The cost of producing 1 dt of seeds was therefore 88.1 PLN. In a study reported by Dobek [2008], on the economic efficiency of biodiesel production, the costs of producing OSR seeds ranged from 67 to 78.1 $PLN \cdot dt^{-1}$ (depending on cultivation technologies). The highest variable costs were incurred by mineral fertilization (1,092 $PLN \cdot ha^{-1}$), which corresponded to 40% of all variable costs. The second most expensive element was the preparation of a oilseed rape plantation for harvest and the harvest itself (18.9%); these costs were followed by weed control and soil tillage (10.2 and 10.1%, respectively). Disease control and sowing generated similar costs (8.4 and 8.5%). The lowest share in the costs breakdown was attributed to pest control (just 3.9%).

OSR esters production costs

Crude OSR seeds can be pressed in small or moderate capacity cold-pressing mills. The farm analyzed in this paper will use two Farmet Duo oilseed presses, each worth 17,500 PLN. Esters will be produced in a Hydrapress W400 biorefinery of 420 liters daily capacity.

The investment outlay for the purchase of machines and other equipment for rapeseed oil production reached 80,500 PLN (Table 1). Other costs (which add to the costs of fuel production) cover repairs and servicing of the machinery as well as its depreciation (15 years).

It was assumed that the farm used 100 l diesel oil per 1 ha of arable lands annually for crop production. As Pągowski claims [2003], OSR oil esters have a lower calorific value (by 8 to 10%) than diesel oil, therefore a 10% higher fuel consumption by machines equipped with self-ignition engines was assumed. In order to produce 132,000 liters of biofuel annually (12,000 l used on the farm plus 10% higher use of esters), the amount of OSR seeds should be 3,828 dt (Table 2). The acreage needed to obtain such yield is 123.5 ha (which is 37.4% of the present-day farmland cropped with oilseed rape). The cost of producing 1 liter of esters was 3.28 PLN. This price does not include the income derived from selling cake or meal. The amount of oilseed rape meal obtained from processing the required volume of seeds is considerable and equals 2,507 dt. However, it will not be

Table 1. Investment expenses for biofuel production equipments (PLN)
Tabela 1. Nakłady inwestycyjne na urządzenia do produkcji biopaliwa (PLN)

Specification	Value
Biorafinery Hydrapress W400	25,500
Oilseed press Farmet Duo	35,000
Oil and tanks, division phase	10,000
Room adaptation (ventilation systems, pipes, poison warehouse, e.g.)	10,000
Total investment expenses	80,500
Other costs	
Depreciation expense (depretiation time 15 years)	5,367
Repair and maintenance cost	6,440
Total other costs	11,807

Source: Own research.
Źródło: Badania własne.

Table 2. Costs of the methyl esters production from own-planted rape seeds
Tabela 2. Kalkulacja kosztów produkcji estrów metylowych oleju rzepakowego z własnych nasion

Specification	Unit	Quantity	Price	Value
Costs of the rapeseed oil production				
Seeds	dt	3,828	88.10	337,426
Energy	kWh	4,022	0.56	24,652
Labour cost	h	1,914	8.00	15,312
Costs of the methyl esters production				
Methanol	l	20,114	1.60	32,183
Potassium hydroxide	kg	2,263	4.50	10,183
Energy cost	kWh	1,478	0.56	828
Depreciation (oil and esters production)				11,807
Total costs				432,391
By-products value (pulp)	dt	2,507	80.0	200,587
The cost of 1l esters production without by-products use				3.28
The cost of 1l esters production after by-products use				1.76

Source: Own calculation.
Źródło: Obliczenia własne.

difficult to deal with this quantity of meal on the farm as valuable feed for animal production. Having accounted for the income from selling the by-products, the annual cost of producing esters is now 231,807 PLN and the cost of 1 liter of esters produced on the analyzed farm falls to 1.76 PLN. The calculations performed by Bieniek et al. [2010] set the cost of production of 1 liter of OSR oil methyl esters, at the annual production output of 8,000 liters, at 4.90 PLN (this price did not include the income from selling oilseed rape cake or meal or the glycerin phase). Such a high unit price was certainly a consequence of a very high price of the feedstock used for production of these esters (112.1 PLN·dt^{-1}).

Evident savings can also be achieved when feeding engines with crude (unprocessed) plant oil [Pasyniuk 2009]. However, crude oil cannot be used to feed an unmodified diesel engine [Podkówka 2002, 2004; Pasyniuk 2009]. Using such fuel requires special systems to heat the fuel before it is fed into the injector of an engine [Dzieniszewski and Piekarski

2006] or else it can be used in Elsbett's engines, specially designed and constructed for this type of fuel [Frąckowiak 2002]. The disadvantage of the latter engines is that they are very costly to make.

The income from selling glycerin was not included in the present analysis. Initially, it was thought that glycerin could be an additional source of income or it could be used as fertilizer or animal feed supplement. However, it turns out that the glycerin used in the pharmaceutical, food processing of feed manufacturing industries is pure glycerol of a specific composition whereas the by-product obtained while making biodiesel in small-scale biorefineries, contains many undesirable substances apart from glycerol and is not sellable due to high contamination [Dzięgielewska 2006]. Gaca [2006] claims that this problem should be dealt with in the early stage of biodiesel production and the fate of the glycerin phase should be then determined.

The economic effect of using esters

This analysis relies on the assumption that all the diesel oil consumed at the farm has been replaced by biofuel produced by the farmer. According to Bieranowski [2006], biodiesel produced from OSR oil (OSR oil methyl ester) can be used in all types of compression-ignition engines without making any changes in their construction. Such oil can be burnt in its pure form or in mixtures with traditional diesel fuel made from petroleum.

The price of diesel oil in our calculations was that of 24 August 2011, i.e. 5.03 $PLN \cdot l^{-1}$. The data in Table 3 clearly indicate that by using biofuel made from the feedstock grown on own farm, the farm can actually lower the costs of agricultural production. The savings can reach as much as 280,000 PLN annually. The production profitability is most heavily affected by two factors: the market price of diesel oil and the costs of oilseed rape seed production. Costs of producing biofuel would be evidently much higher if the feedstock was supplied externally. The current prices for OSR seeds[2] are on average 180 $PLN \cdot dt^{-1}$, which makes production of esters unprofitable, even when oilseed rape meal is sold (the price per 1 l of esters is then around 4.42 PLN, which makes it 0.12 PLN higher than the price of diesel oil sold for agricultural purposes).

Table 3. Effect of replacing fossil diesel oil with methyl esters from own-planted seeds
Tabela 3. Efekt zastąpienia oleju napędowego estrami wyprodukowanymi z własnych nasion

Specification	Unit	Quantity	Price (PLN)	Value (PLN)
Fossil diesel consumption	l	120,000	4.30[a]	515,880
Biofuel consumption	l	132,000	3.28[b]	432,394
Biofuel consumption	l	132,000	1.76[c]	231,807
Alternative cost of biodiesel production				173,160

[a]Subsidy for agricultural fuel included, [b]biofuel cost without by-products sale, [c]biofuel cost with by-products sale.
Source: Own calculation.
Źródło: Obliczenia własne.

[2]http://www.farmer.pl/agroskop/ceny_rzepaku (Accessed on 26.08.2011).

According to Stiglitz [2004], when a private company is to make an investment decision, it considers possible variant solutions, estimates projected outlays and revenues, calculates the profitability of investment projects and selects one of these projects. At this stage, it is also recommendable to analyse alternative costs (costs of lost opportunities), which in the relevant literature [Begg 2003, Milewski 2003, Klimczak 2011] are defined as an equivalent of the output that a given factor of production could generate, should it be used in another, possibly optimal way. Analysis of alternative costs of biodiesel production for own use is justifiable because rapeseed is a mobile resource, i.e. they can be transferred to different, alternative uses. In this case, the financial losses of a producer incurred by not using the best opportunities are considerably high. By selling raw material to make biofuel – according to the current prices on rapeseed – the producer can get 689,040 PLN. When buying conventional fuel in the amounts needed on the farm, the producer will spend 515,880 PLN. Economically speaking, when the above values are compared, it becomes clear that the alternative monetary cost of the producer who decides to produce biofuel from rapeseed will reach about 173,000 PLN. Moreover, it is possible to invest the capital allocated to constructing the biofuel production facilities. An alternative cost is not always associated with a monetary value. It is also borne if the production of biodiesel is abandoned. The alternative cost of undertaking biodiesel production is for example increased emission of pollutants to the atmosphere (especially greenhouse gasses) due to combustion of fossil fuels rather than biodiesel (ecological aspect) or – from a broader perspective – lack of diversification in the fuel sector, poorer development of the agricultural product market or not employing a person needed to run the biodiesel installation (social aspect).

It should be noted that a complete evaluation of marketing biofuels on an industrial scale is influenced by several other factors [Tys et al. 2003]. Wójcicki [2007] believes that the major factor restraining production of biocomponents and biofuels in Poland is their high production costs versus the retail prices of conventional fuels. Thus, their economic effectiveness is low or sometimes negative at a simultaneous negative energy effectiveness.

CONCLUSIONS

It can be concluded from the above analyses that using OSR oil esters produced on a given farm can generate measurable financial benefits and the return on investment rate can be very high, but the result is highly dependent on the fuel demand on that farm. The more fuel is consumed, the lower the unit cost of biofuel production. Another important element which can improve the profitability of biofuel production is the utilization of by-products. The cost of securing OSR seeds, however, remains the most significant cost-creating element. It is unprofitable to use purchased seeds (at their current price) to produce methyl esters (even when by-products are sold). The unit cost of producing biofuel is higher than the cost of buying diesel oil.

Resources of rapeseed on the farm is limited, however, can be used in many ways. One way is the biofuel production (in place of the sale at current market price). However, the producer must take into account, that the financial benefits lost due to the chosen way to use the resource. It should be emphasized, that the alternative cost is subjective by nature and is always sustain by the person taking a decision.

Although there are relatively simple and inexpensive machines and facilities for estrification of OSR oil available on the market today, this solution is not easy to implement in real-life practice. Apart from much burdensome paperwork, the technical aspects can be troublesome as well. Methyl ester, which is used for production of esters, is a dangerous poison, and its turnover and storage are strictly controlled. The same can be said about the catalyst – potassium hydroxide (KOH) – which is a highly caustic substance and therefore its use is regulated by the work safety rules. Batches of pressed OSR oil may differ from one another in the chemical composition and – when same amounts of alcohol and catalyst are used – the end product may be of different quality. Utilization of the glycerol waste could also raise problems as this substance is dangerous to the environment. In short, producing biofuel on a farm for own use can prove to be a very complicated undertaking. How difficult it can actually be is verified by the fact that it has been five years since the law was made to enable farmers to produce biofuels for own use and the biofuel producers register has just four entires[3]. One must therefore agree with Wójcicki [2007], who concluded that if the price relations were favorable for biocomponents and biofuels than, under conditions of the market economy, no other incentives for biofuel producers would be necessary for biofuels to be used on a wide scale.

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EKONOMICZNE I PRAWNE ASPEKTY PRODUKCJI BIOPALIWA NA WŁASNY UŻYTEK

Streszczenie. Celem pracy była ocena kosztów oraz opłacalności produkcji estrów metylowych oleju rzepakowego i wykorzystanie go we własnym gospodarstwie. Analiza kosztów produkcji estrów rzepakowych obejmowała następujące etapy produkcji: produkcję surowca, tłoczenie oleju z nasion i przetworzenie oleju na paliwo (estryfikacja). Koszty produkcji obliczono w skali roku i uwzględniono dochód ze sprzedaży produktów ubocznych. Badania przeprowadzono w gospodarstwie rolnym o powierzchni 1200 ha w woj. warmińsko--mazurskim. Wyprodukowanie 1 litra estrów wyniosło 3,28 zł, w przypadku zagospodarowania produktów ubocznych (wytłoków) cena spada do 1,76 zł. Ostateczne wskaźniki ekonomiczne zależą przede wszystkim od kosztów pozyskania surowca (na które wpływają między innymi zabiegi agrotechniczne, rodzaj materiału siewnego, intensywność nawożenia oraz niezbędne zabiegi ochrony roślin), wykorzystania produktów ubocznych procesu estryfikacji (sprzedaż, cenna pasza w żywieniu zwierząt lub jako nośnik energii). Producent biodiesla musi liczyć się również z kosztami alternatywnymi podjętej działalności. Przedstawiono uwarunkowania prawne produkcji biopaliw na własne potrzeby, a także dokonano porównania kosztów paliwa alternatywnego odniesione do paliwa konwencjonalnego.

Słowa kluczowe: paliwa alternatywne, estry metylowe, wytwórnia biodiesla, koszty produkcji

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