SUGAR BEETS USED FOR TRADITIONAL PURPOSES AND FOR ENERGY. AN ECONOMIC COMPARISON

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Abstract. The process of intensive transformation to which the sugar beet market in the European Union has been subject in recent years in order to meet the external obligations set by the WTO Panel, has had a severe impact on sugar beet production in Poland. Two major observations have been reported, namely a significant decrease of number of sugar beet farms and a reduction in those areas of tillage surfaces intended for sugar beet cultivation. It is worth mentioning that sugar beet is highly important to crop rotation and hardly any other plant in European agriculture can replace it. There is therefore both a strong need and a great opportunity for the further support and development of sugar beet production. As the international obligation to reduce greenhouse gas emission became effective, interest in biomass usage as a viable alternative to fossil fuels increased. This study thus set out to perform an economic comparison in respect of the use of sugar beets for traditional purposes and for energy, and to conduct an economic analysis of the income obtained from the sale of electrical energy sale by a biogas facility where sugar beets were used for biogas production. The comparative analysis was carried out taking both incomes from sugar beet production for sugar and root and leaf production for biogas into consideration. The results are very promising and allow the postulation that the use of sugar beet for biogas production provides an excellent opportunity for reviving defunct sugar plants and increasing the tillage surface for sugar beet in Poland.

Key words: sugar beet, biogas, income, sugar market in EU, renewable energy

Introduction

A new energy policy established recently within the European Union and, consequently, incumbent upon Poland, limits fossil fuels consumption and promotes the broader use of energy from renewable sources. The strategy set a target of 7.5% renewable energy sources in the national energy balance, to be achieved by 2010. Several possible sources of renewable energy are specified for current utilization, namely water, wind, solar radiation, geothermal power and biomass. Interestingly, biomass is currently perceived as feasible source of 70% of renewable energy in Europe. 30% of this energetic biomass is expected to come from post-cultivation waste materials obtained from agriculture and forestry and 70% from international energy plant tillage [Cebula 2009, Haque et al. 2009, Oniszk-Popławska 2009].

The final version of the renewable energy directive, itself part of the EU climate-energy package, was agreed upon in December 2008. As of that date, all the EU member countries are legally bound by the provisions of the directive as regards renewable energy sources.

The strong public interest pertaining to environmental protection and climate conditions, as well as the constantly increasing number of biogas plants in Europe makes reliable data regarding new substrates which could potentially be used for bio-methane production a requisite. For example, one of the potential candidates consists of by-products from the food industry. These already constitute a well-known and extensively utilized group of substrates; however, they are not yet used in biogas plants [Kryvoruchko et al. 2009; Mikola-jczak et al. 2009].

Over the past ten years, a dramatic decrease in the number of Polish sugar factories and a reduction of the country's sugar beet tillage areas has been observed. In the main, this is related to the fact that Poland's sugar market has been overtaken by companies from western part of the European Union. Small, less profitable, national sugar factories which were unable to compete with innovative, international, mass manufacturers underwent bankruptcy and were forced to close down production [Bzowska-Bakalarz et al. 2001, 2005]. This resulted in the progressive concentration of sugar production into the hands of the few competitive manufacturers which were able to meet the external criteria set by the WTO Panel and handle the demand of competitiveness within the European Union's sugar sector. As a result of these changes, of the seventy-sixactive sugar factories active in Poland in 2000, only eighteen were still working by 2009. The areas devoted to sugar beet cultivation decreased from 286000 ha in 2005 to 187000 ha in 2008, representing a decrease of 38% [Kasperska-Furman 2010].

Such a situation requires immediate attention as it may have a significant impact on the proper preservation of high soil culture. Sugar beet is classified as the most valuable root crop cultivated in Poland; it is extremely important to crop rotation and makes an excellent forecrop for many other plants. The reduction in the tendency toward sugar beet cultivation, provoked by economic causes, may therefore worsen the conditions of biological equilibrium across agriculture as a whole.

Under Polish climatic conditions, sugar beet, which is to say the root along with the leaves, numbers amongst the plants characterized by their yield of fresh mass. It is also characterized by high energy efficiency parameters and a short conversion time. These features allow sugar beets to take a leading position on the list of plants useful for energy purposes [Demirel et al. 2008; Haque et al. 2009; Kryvoruchko et al. 2009; von Felde A. 2008]. The efficiency of material intended for biogas production is defined by means of the following three parameters: mass obtained from the area, energy efficiency (Tabele 1), calculated on a per unit basis, and conversion time [Mann 2008; Wisniewski 2010].

Making a profit is one of the main targets for any production sector, including agriculture. A simple statement of income arrived at by deducting the costs incurred during the production and sales of goods or services from the obtained revenue, permits a rapid assessment of a business's profits or losses over a given period of time to be made. The same also is also true for sugar beets producers.

Table 1. Use of plant substrates of different origin in biogas production [Mann 2008; Wisniewski 2010]

Substrate	Yield $t \cdot ha^{-1}$	Methane $m^3 \cdot t^{-1}$ o.d.m.	Methane $m^3 \cdot ha^{-1}$	$kWh \cdot ha^{-1}$ grass	$kWh \cdot ha^{-1}$ net	Proportion
Cereal	8	426	2749	26669	9601	50%
Maize	60	325	5496	53307	19191	100%
Sugar beet	70	442	6757	65539	23594	123%
Sugar beet leaves	42	324	1306	12672	4562	24%
Sugar beet roots + leaves	112	417	8063	78210	28156	147%

Several factors have major influence on the high costs of sugar beets tillage and its current structure and, in consequence, have a crucial impact on the profitability of sugar beet production in Poland. Within the last few years, new mechanized cultivation technologies have been successfully introduced in this part of Europe; however, in parallel with that came a significant increase in the prices for the machinery for sugar beet cultivation, as well as for materials and services. Nowadays, farmers who wish to compete in this demanding market are also expected to purchase seeds of a required quality. Therefore, although the expenditure on human labour is decreasing, other costs are constantly rising. In conditions such as these, there is an thus an urgent need to provide opportunities which will lead to increase in the profitability of sugar beet tillage. One such opportunity is the possibility of allocating plants to energy purposes [Gorzelany et al. 2000, Gorzelany et al. 2010].

The available literature contains insufficient information concerning the possibilities of using sugar beet as a substrate for biogas production. This study thus set out to performan economic comparison in respect of the use of sugar beets for traditional purposes and for energy, and to conduct an analysis of the income obtained from the sale of electrical energy by a biogas facility where sugar beets were used for the purposes of energy. In relation to this, the paper also puts forward an analysis of the possibilities inherent in an alternative direction in sugar beet management, namely as a material for agricultural biogas plants.

Materials and methods

In order to discuss the cost-related problems of sugar beet tillage, the study makes use of a cost calculation based on the current prices of production means and services. The calculations were made in line with the presumptions of the basic rules for sugar beet tillage, with herbicides being used to fight weeds and the harvest and transportation service executed. They were carried out in euros, at an exchange rate of 1 euro to 4 Polish zloty.

The calculation method elaborated at the IBMER in Warsaw (Institution for the Building, Mechanisation and Electrification of Agriculture) [Muzalewski 2010] was used for estimation of tractor, machinery and equipment exploitation costs, as well as for the comparison of mechanization costs and mechanism service costs. The exploitation costs include maintenance costs as a constant cost and running costs, as variable costs. Maintenance costs cover amortization, storage, insurance and, where applicable, bank loans and the interest they incur.

During the exploitation period, amortization costs reflect the current purchase price of the machine in question. The costs of storage and conservation equal 0.5-1% of the price of machine purchase per year. The running costs are composed of unitary repair costs, unitary fuel and grease costs, the cost of unitary support materials and unitary labour costs.

Depending on the machine, unitary repair costs across the entire exploitation period amount to 40-70% of its actual purchase price. The sum of the maintenance and utilization costs gives the costs of machine exploitation per working hour. The costs of tractor aerator labour, calculated per unit of executed work (ton, ha), was obtained through dividing the exploitation costs by their efficiency. The data for these calculations were collected from the author's own research, the IBMER calculation cost methodology and information from a farm located in Wielkopolska, a region of central western Poland.

Two technologies were given consideration in calculating the costs of sugar beet tillage. The first is a standard technology for the cultivation of sugar beet for their current primary use, which is sucrose production. The second one is used to cultivate whole plants intended for biogas purposes and which also entails the harvest and storage of the leaves.

For the harvest and transportation of the leaves, two trailers are deemed indispensable, while the use of long foil sleeves (AgBag Systems) was factored in for storage. The exploitation costs per trailer labour unit equals 62.1 euro/ha and the loading costs, along with the foil sleeve, 5.75 euro$\cdot$t^{-1}, which in the case under analysis, gives a total cost of 349.38 euro$\cdot$ha^{-1}. An additional factor increasing the costs of sugar beet tillage for biogas production is the higher level of nitrogen fertilization, which considerable raises the yield of fresh mass per hectare. In the calculations here, additional nitrogen fertilization of 30 kg$\cdot$ha^{-1} is assessed as generating a cost of 6.75 euro$\cdot$ha^{-1} [Dobek 2005a; Dobek et al. 2005b; Kasperska-Furman 2010].

In the case of sugar beet tillage destined for sucrose production, the leaves stay in the field. However, as they are known to contain 80% of the whole plant mass and considering use of whole plants for biogas production, the calculation in the case being analysed has proved that it is possible to obtain up to 136.71t/ones of fresh mass per hectare.

The root and leaf biogas efficiency was obtained under a previous experiment conducted at the PULS Institute of Agricultural Engineering. Biogas efficiency from 1 ton of dry root mass reached 750 m^3 of biogas (57.8% of methane) and, in case of the leaves, 540 m^3 of biogas (59% of methane). The content of dry root mass amounts to 24%, whereas and that of the leaves, 13.6%. The energy efficiency of the indispensable co-substrate, which is to say, slurry, the biogas efficiency of which equals 301 m^3 of biogas (58% of methane) was also taken into account in calculations presented here.

The basic data as regards electric energy prices and certificates values were accepted in line with the directives of the Energy Regulatory Office and Ministry of Economy currently in force. The principles for the calculations of income from biogas production were as follow:

– Average prices of electric energy sale – 49.30 euro$\cdot$MWh^{-1},
– Green certificate value – 67.20 euro$\cdot$MWh^{-1},
– Yellow certificate value – 47.46 euro$\cdot$MWh^{-1}.

In the case of sugar beet production for sucrose, the income was obtained from the sale of the roots to sugar factories whereas, in the case of sugar beet used for energy, the income was generated through the sale of electric energy, heating and the local utilization of digestates.

Results and discussion

The calculations were performed on the basis of the results obtained by a working, non-experimental farm located in Wielkopolska, a region of central western Poland. The results of the calculations of the costs and profits for sugar beet production are presented in Table 2.

Table 2. Cost calculation of sugar beet production [author's analysis]

Technology		Costs and profitability of sugar beet production [euro·ha^{-1}]
Beet yield [dt]		189,875
Sowing material	Cost [euro·kg^{-1}]	Sowing material
Basic material 'B'	116.25	133.69
Charlock	1.00	20.00
Phacelia	2.50	-
Total		153.69
Fertilizer	Cost [euro·dt^{-1}]	Fertilizer
Fosforan amonu	25.00	25.00
Korn – Kali	25.00	75.00
Saltamonia	19.25	-
Cow manure	0.75	187.50
Lime	0,75	22.50
Kizeryt	35.00	70.00
Salman with boron	18.00	-
Adob SB 2	32.50	107,25
Total		487.25
Plant protection	Cost [euro·kg^{-1}·l^{-1}]	Plant protection
Roundap energy 450 SL	11.75	35.25
Metanal Elite 274 EC	30.23	84.63
Goltix 700 S.C.	18.75	18.75
Venezar 80 WP	36.90	11.07
Lontrel 300 SL	91.78	9.18
Basfoliar 36 Extra	1.50	15.00
Duet	33.25	33.25
Total		207.13
DIRECT COST		848.07
Type of treatment	Cost [euro·ha^{-1}]	Type of treatment
Spraying	4.81	28.85
Mineral fertilizer application	2.62	7.86
Stubble crop	25.65	25.65
Organic fertilizer application	54.13	54.14
Ploughing	56.30	56.30
Slicking and harrowing	13.82	27.64
Pre-planting cultivation I	15,48	15.48
Pre-planting cultivation II	29.52	-
Seeding	36.58	36.58
Total		252.49

Type of treatment	Cost [euro·ha^{-1}]	Type of treatment
Lime application	37.50	37.50
Yield	210.00	210.00
Clearing, loading, transport	0.28	208.86
Total		456.36
Additional costs	Cost [euro·ha^{-1}]	Additional costs
Farming tax	36.43	36.43
INDIRECT COST		745.28
Total costs		1593.35
PRODUCTION COST per UNIT [euro·dt^{-1}]		2.10
Main product (net)		1782.93
DIRECT SURPLUS		934.86
INCOME FROM PRODUCTION		189.57
Single Area Payment Scheme □ SAPS	84.83	84.83
Sugar: additional payment	9.86	749.06
Agro-environmental subvention	105.00	105.00
Agricultural profit (financial issue)		1128.46

The direct costs of plant production, with a yield at the level of 75.95 t·ha^{-1}, reached 848.07 euro·ha^{-1}, while the indirect costs as arrived at were 745.29 euro·ha^{-1} (Table 2). The resultant agricultural profit thus totalled 1128.46 euro·ha^{-1}.

It is important to mention that part of the income was arose from the subventions paid to farmers in line with European and national regulations. This must, of necessity, be taken into account. However, it may well undergo significant change, probably in the form of reductions, when European Union's new budget takes effect post-2013.

The production and storage costs for sugar beet roots and leaves for energy purposes were calculated as being 2503.64 euro·ha^{-1} and arose from the such components as the common costs of plant production (Table 1), transport involving two trailers, and storage in plastic bags (AgBag Systems) (Table 3). However, the calculated income for this scenario totalled 4682 euro·ha^{-1}.

Table 3. Costs biogas efficiency and energy production calculated for 1 ha of sugar beet production for energy purposes [author's analysis]

Production of sugar beet for energy purposes		
Root yield	t·ha^{-1}	75.95
Leaf yield	t·ha^{-1}	60.76
Total root and leaf yield	t·ha^{-1}	136.71
Transport and storage costs		
Leaf transport cost	euro·ha^{-1}	124 20
Leaf silage cost[1)]	euro·ha^{-1}	349.38
Root storage cost[1)]	euro·t^{-1}	5.75
Root storage cost[1)]	euro·ha^{-1}	436.71

Biogas production efficiencyr[2)]		
Roots	$m^3 \cdot ha^{-1}$	175.00
Leaves	$m^3 \cdot ha^{-1}$	70.00
Methane production efficiency[2)]		
Roots	m^3 $CH_4 \cdot t^{-1}$ f.m. [3)]	13291.00
Leaves	m^3 $CH_4 \cdot t^{-1}$ f.m. [3)]	4253.00
Energy production	$kWh \cdot ha^{-1}$	45681.00
Price of electric energy sale (*Polish pricing*)	$euro \cdot kWh^{-1}$	0.1025
Income from sugar beet for energy purposes	$euro \cdot ha^{-1}$	4682.30

[1)] Storage costs - market cost of filling the polythene bag (AgBag Systems)
[2)] The efficiency of biogas (and methane) production were established by means of experiments carried out by the author using a 21-chamber biofermentor
[3)] f.m. = fresh matter

Table 4. The efficiency of sugar beets use in the two types of production

Total economic balance	Unit	Sugar production	Energy production
Sugar beet production cost	$euro \cdot ha^{-1}$	1593.35	1593.35
Sugar beet root storage cost	$euro \cdot ha^{-1}$	0	436.71
Leaf transport cost	$euro \cdot ha^{-1}$	0	124.2
Leaf silage cost (AgBag System)	$euro \cdot ha^{-1}$	0	349.38
Total costs	$euro \cdot ha^{-1}$	1593.35	2503.64
Profit from root / energy sale	$euro \cdot ha^{-1}$	2721.81	4682.30
Economic balance	$euro \cdot ha^{-1}$	1128.46	2178.66

Table 4 clearly shows that the use of sugar beets as a substrate for the production of electric energy in a biogas facilitydelivered double the profit when compared to their traditional use as a substrate in a sugar factory. The costs incurred in cultivating sugar beet for energy purposes is much higher than for traditional use, since certain supplementary procedures, such as the transport and storage of both roots and leaves must be taken into account. This difference is presented in Figure 1.

It is, however, important to emphasize that the higher costs involved in the transport and storage of both roots and leaves in the energy-production scenario can be completely ignored, given the high income thus generated. This income could be even higher per ha if the producer were to use more intensive nitrogen fertilization during the vegetation period and, in consequence, receive a increase of approximately 15-30% in total yield. An increase of this nature is impossible in case of sugar beet for traditional purposes because of the resultant, unacceptable high nitrate concentration in the crop. In contrast to the sugar factory, the higher nitrate content is of no significance to a biogas facility [Sarec et al. 2009].

Furthermore, the sale of heat energy produced from biogas burning can be very profitable, given the fact that, after biogas combustion, only about 40% of the total energy is represented in the form of electricity, while the remaining 60% is converted to heat.

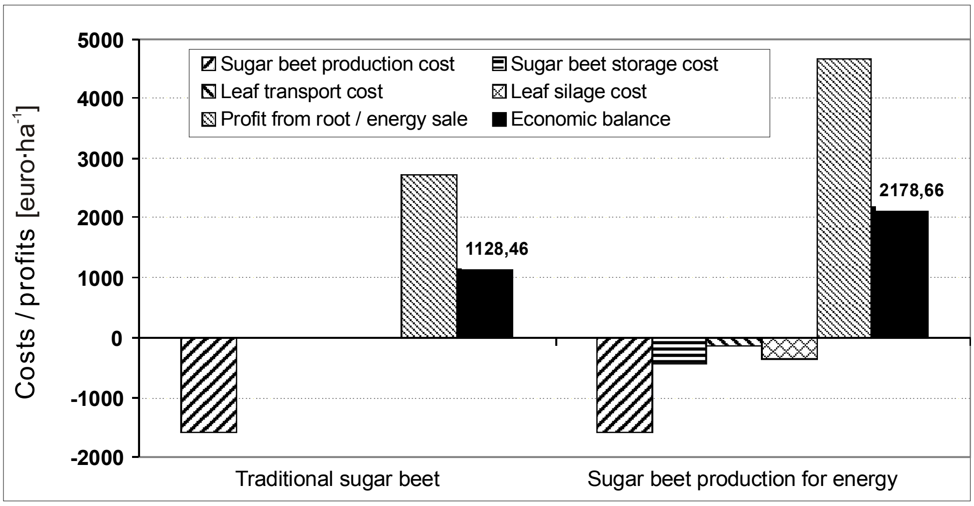

Fig. 1. Total economic balance for the sugar beet production scenarios analyzed

Additional profit can be obtained from the use of the digestates in agriculture as a fertilizers. However, its real NPK rating is greatly dependant on the other co-substrates used in the fermentation process.

Finally, it is worth mentioning the fact that certain biogas facility amortization and exploitation costs should be included in deliberations such as these. However, these costs are highly dependant on the size of facility in question and should thus be calculated individually in every case.

Conclusions

1. The comparison of the two technologies demonstrates that the highest costs are incurred for production of the material. For this reason, the optimization and reduction of sugar beet production costs would seem to be the main factors to be addressed with a view to increasing profitability.
2. The profit from producing sugar beets for energy purposes can be much higher than its traditional use as a substrate for the manufacture of sugar. Higher profits can also be obtained from the additional sale of the heat energy generated by biogas combustion and the post-fermentation digestates for use as a fertilizer.
3. Some supplementary costs, namely those relating to the biogas facility's amortization and exploitation, should also be considered. These costs are highly dependant on the size of facility in question and should thus be calculated individually in every case.

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TRADYCYJNE I ENERGETYCZNE WYKORZYSTANIE BURAKA CUKROWEGO. ANALIZA EKONOMICZNA

Streszczenie. Proces intensywnej transformacji rynku produkcji cukru, której została poddana Unia Europejska w ostatnich latach, w celu spełnienia zobowiązań zewnętrznych wyznaczonych przez panel WTO, miał poważny wpływ na produkcję buraków cukrowych w Polsce. Nastąpił znaczny spadek liczby gospodarstw uprawiających buraki cukrowe i zmniejszenie powierzchni przeznaczonej na uprawę tej rośliny. Jednakże burak cukrowy jest bardzo ważną rośliną w produkcji rolniczej, zarówno z punktu widzenia miejsca w płodozmianie, jak i opłacalności uprawy. Badania wskazują także na szerokie możliwości alternatywnego wykorzystania buraków. Istnieje zatem potrzeba wspierania rozwoju produkcji buraka cukrowego. Dzięki międzynarodowym zobowiązaniom do redukcji emisji gazów cieplarnianych, wzrosło zainteresowanie wykorzystaniem biomasy, w tym buraka cukrowego, jako alternatywy dla paliw kopalnych. Artykuł obejmuje ekonomiczne porównanie wykorzystania buraków cukrowych do produkcji cukru i alternatywnego, do produkcji energii. W pracy przeprowadzono analizę ekonomiczną dochodów uzyskanych ze sprzedaży energii elektrycznej przez biogazownię, w której buraki cukrowe były wykorzystywane do produkcji biometanu. Analiza porównawcza została przeprowadzona dla dochodów z produkcji buraków cukrowych przeznaczonych na cukier oraz z przeznaczeniem do produkcji biogazu, wykorzystując korzenie i liście. Wyniki pozwalają na stwierdzenie, że wykorzystanie buraków cukrowych do produkcji biogazu może być podstawą do zwiększenia powierzchni uprawy buraków cukrowych w Polsce, a także do zaadaptowania zamkniętych cukrowni na biogazownie.

Słowa kluczowe: burak cukrowy, biogaz, koszty, rynek cukru, odnawialne źródła energii

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