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Economic evaluation of hemp (Cannabis sativa) grown for energy purposes (briquettes) in the Czech Republic

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Abstract. Depletion of fossil fuels and their environmental risks have brought to the foreground energy crops as a possible source of bioenergy. Industrial hemp (*Cannabis sativa* L.) has been suggested for production of solid biofuels (briquettes) due to good physic-mechanical properties as well as positive energy and combustion characteristics. This study determined economic potential of hemp briquettes production in the Czech Republic. A field trial was conducted in 2009–2014 in Prague in order to compare biomass yield (BY) of hemp varieties Bialobrzeskie (B) and Ferimon (F) harvested in autumn and spring period. Based on obtained results this study determined production costs of hemp briquettes (CZK t^{-1}), revenue (CZK t^{-1}) and rate of return (%) for four scenarios (B, F harvested in autumn and B, F harvested in spring). Briquettes production costs ranged from 4,015 CZK t^{-1} to 4,707 CZK t^{-1} for B in spring and B in autumn, respectively, due to 30% lower biomass yield in spring harvest. Results indicated that hemp briquettes production was not profitable if the selling price was the same as the price of wood briquettes and with BY obtained in experiment (7.18–10.7 t ha^{-1} of dry matter). Briquettes production in autumn made profit of 9% for B and 7% for F when subsidies for hemp cultivation were considered. In current conditions in the Czech Republic, utilization of hemp for briquettes production did not prove to be economically feasible.

Key words: hemp briquettes, economic analysis, production costs, revenue, rate of return.

INTRODUCTION

Energy is one of the most important commodities in today's world to ensure socio economic development of the country. Due to permanently decreasing reserves of conventional fossil fuels and their high environmental risks, countries have been looking for alternative sources of energy (Rehman et al., 2013). High potential lies in herbaceous biomass which has been on rise in recent years. To determine crops which are the most suitable for energy production, its energy characteristics, ecological impact and production economy must be investigated thoroughly.

Based on results of long term research and practical experience in the Czech Republic and foreign countries, industrial hemp (*Cannabis sativa* L.*)* has appeared to be promising energy crop in conditions of Central and Northern Europe (Honzík et al, 2012). Industrial hemp has been suggested by various researchers for production of biodiesel (Rehman et al., 2013), bioethanol (Tutt, 2011), biogas (Prade et al., 2011) and also briquettes (Mankowski & Kolodzej, 2008) for household heating. Uniqueness of hemp consists in its ability to yield about 10–15 t ha^{-1} in 100–120 days which is more than other energy crops (Kolarikova et al., 2014). Hemp has proved positive energy balance (Prade et al., 2011) and combustion properties which are comparable to woody materials (Mankowski & Kolodzej, 2013). Furthermore, it showed to be suitable for crop rotation due to its phytoremediation characteristics.

Since various energy crops with very similar or even better characteristics exist, production costs may play significant role in decision of producer which crop to cultivate. Until now many publications regarding hemp cultivation for various purposes have been published, however, any of them included detailed manual for evaluation of economy of hemp briquettes production.

The main objective of this contribution is to calculate production costs, revenues and profitability of hemp briquettes comparing two varieties of *Cannabis sativa* L. (Bialobrzeskie, Ferimon) harvested in autumn and spring seasons in conditions of the Czech Republic.

MATERIALS AND METHODS

Biomass yield (BY)

A variety of hemp of Polish origin Bialobrzeskie and French Ferimon were cultivated in Prague in 2009–2013 (5 independent seasons) in order to obtain biomass for the energy yield evaluation from its autumn and spring harvests. Hemp was grown on a trial plot of 100 m^2 (50 m^2 each) with seed rate of 60 kg ha^{-1} and the biomass yields of the small-scale plots (determined by collecting and weighing all plants) were extrapolated to a biomass yield per hectare (BY). The average values over the observation period were considered for the calculation of economic balance.

Technological process of hemp briquette product

Economic analysis was calculated for large – scale utilization, therefore technological process included all necessary operations (fertilizing, tillage, hauling, soil preparation, sowing, mowing, compressing and transport and field treatment after harvest). For hemp processing into solid biofuel briquetting line comprised of separator RSM Turbo 180 and shredder STM 201 HL was considered. For pressing of the material briquetting device BrikStar 400 was used. Dry BY was recounted for moisture content (MC) 12% which was optimal for processing into solid biofuel. Loses during the separating and crushing were considered as 10%.

Economic inputs

Amount of material was taking into account as 60 kg of seeds per hectare for high biomass yield. For hemp grown for energy purposes it was considered 80 kg of pure nutrient of nitrogen, 45 kg of potassium chloride and 30 kg of phosphorus which was equal to 0.3 t of ammonium nitrate, 0.075 t of potassium salt and 0.17 t of superphosphate. Also 4.5 t of farmyard manure and 0.2t of limestone were considered. Hemp biomass was compressed into bales of 250 kg. For 1 bale 0.1 kg of string for fixing was considered. Briquettes were packed into 15 kg polyethylene (PE) bags. Prices of string and PE bags were assumed based on actual market prices.

Amount of labour and fuels was determined as a sum of labour requirements for component technological operations including hemp cultivation, harvesting and processing into briquettes. Work requirements and fuel consumption were based on average conditions of production. Average gross wage in agriculture accounted for 19,666 CZK per month of full time job. Average price per litre of diesel for final customer was 36.11 CZK l^{-1}. In compliance with regulation of Ministry of Agriculture 40% refund from consumer taxon diesel for farmers was in force for year 2013. Property insurance included natural disaster cover which was assumed to be 3% of total gross revenue.

To estimate depreciation of machines it was assumed that producer cultivated multiple crops not only hemp, thus machines were used in their full capacity. Machinery was bought in less than four years. It was supposed that producer cultivated hemp on rented land. Price represented average price for land in the Czech Republic in 2012. Costs for maintenance and reparation of machines and building as well as taxes and fees were assumed based on statistic of Czech Statistical Office. Producer owned all machines and performed all operations by himself, thus rent of machinery or services was not included. Overhead costs such as loan, leasing, etc. were not taken into consideration.

Total costs of briquettes production

Total costs (TC) of hemp briquettes production were calculated as a sum of fixed (FC) and variable costs (VC) (see formula 1, 2). Prices excluded value added tax (VAT 21%). Exchange rate of euro was taken into account as 25.97 CZK (average rate of Czech national bank for 2013).

$$TC = VC + FC \text{ (CZK ha}^{-1}\text{)} \quad (1)$$

where: TC – total costs; VC – variable costs; FC – fixed costs.

$$TC = (Cs + Cfe + Cst + Cbg + Cl + Cd + Ce + Cw + Ci) + (D + L + R + T) \text{ (CZK ha}^{-1}\text{)} \quad (2)$$

where: C – cost of: Cs – seeds; Cfe – fertilizers; Cst – string; Cbg – PE bags; Cl – human labour; Cd – diesel, Ce – electricity; Cw – water consumption; Ci – property insurance; D – depreciation of machines; L – land rent; R – reparation of machines and buildings; T – taxes and fees.

Price of labour per hour was determined from average month salary, increased by social insurance (25%) and health insurance (9%) divided by amount of working hours per month (160 hours). Price per litre of diesel was calculated from average price of fuel in 2013 decreased for refund of consumption tax (40% from 10.90 CZK).

Amount of string and PE bags was calculated based on formulas 3and 4:

$$Qs = \frac{\mathrm{BY}}{\mathrm{wtb}} \times \mathrm{qs} \text{ (kg ha}^{-1}\text{)} \quad (3)$$

where: BY – biomass yield with MC 12% (t ha^{-1}); wtb – weight of bale (t); qs –quantity of string for bale (kg).

$$Qbg = \frac{\mathrm{BYc}}{\mathrm{wtbg}} \text{ (PE bags ha}^{-1}\text{)} \quad (4)$$

where: BYc – biomass yield with moisture content (MC) 12% including 10% loses during crushing (t ha^{-1}); wt_{bg} – weight of PE bag with briquettes (t).

Amount of electricity was calculated as electric input power of briquetting line multiplied by number of hours used for processing of 1t of material and amount of hemp biomass produced from 1ha of land (see formula 5).

$$Qe= qe*h*BY \text{ (kWh ha}^{-1}\text{)} \quad (5)$$

where: qe – input power(kW h^{-1}); h – working hours (h t^{-1}); BY – biomass yield with MC 12% (t ha^{-1}).

Cs–Ce were determined by multiplication of quantity of spent material and human labour (kg, ton, kg, PE bags, hour, l, kW) and price per single unit (CZK) (see formula 6). Prices of inputs are summarized in Table 1.

Table 1. Prices of inputs (CZK $unit^{-1}$)

Item	Unit	Price per unit (CZK)	Source
Seeds			
Bialobrzeskie	kg	110	Agritec Sumperk (2013)
Ferimon	kg	155	
Fertilizers			
Limestone (50% CaO)	t	757	
Superphosphate (18% P_2O_2)	t	9,473	
Potassium chloride (60% K_2O)	t	10,360	Czech Statistical Office (2013)
Ammonium Nitrate (27,5% N)	t	6,604	
Farmyard manure	t	230	Own calculations
Fuel			
Diesel	1	24.6	
Electricity	kWh	2.62	Czech Statistical Office (2013)
Human labour	h	165	Own calculations (2013)
Land	ha	1,430	Ministry of Agriculture (2012)
Other material			
String	kg	60	Average market prices (2013)
PE bags	bag	1.5	

$$Cx= Qx* Px \text{ (CZK ha}^{-1}\text{)} \quad (6)$$

where: Qx – quantity of spent material or labour (kg, ton, hour, l, kW); Px – price per unit (CZK $unit^{-1}$).

Depreciation of machinery was calculated as a purchase price of machine divided by depreciation period of particular machine (6 years for agricultural machinery, 4 years for machines for chemical protection and fertilizing, 4 years for briquetting line) and by recommended annual use and multiplied by hours used for production process (see formula 7).

$$D = \frac{pm \times h}{(n \times R)} \quad (CZK\ ha^{-1}) \qquad (7)$$

where: Pm – purchase price of machine (CZK); n – depreciation period (years); R – recommended annual use (years); h – hours of use (h ha^{-1}).

Total revenue from briquettes production

Total revenue (TR) was determined by the quantity of hemp briquettes produced from 1 ha of land (t ha^{-1}) multiplied by respective price per ton of hemp briquettes (CZK t^{-1}) and decreased by VAT valid for 2013 – 21% (see formula 8).

$$TR = Qb * Pb * VAT \quad (CZK\ ha^{-1}) \qquad (8)$$

where: Qb – quantity of briquettes (t ha^{-1}); Pb – price per unit (CZK t^{-1}); VAT – value added tax (21%).

Profit from briquettes production

Profit from production was calculated as total revenue minus total costs (see formula 9).

$$Pr = (TR - TC) \quad (CZK\ ha^{-1}) \qquad (9)$$

where: TC – total costs (CZK ha^{-1}); TR – total revenue (CZK ha^{-1}).

Grants and Subsidies

Subsidies SAPS (Single area payment scheme) and TOP -UP were considered in the calculation. Others were not taking into account since they were not stable and change over time. In 2013 SAPS accounted for 6,069 CZK ha^{-1}. The most updated data stated complementary payment TOP-UP to be 491 CZK ha^{-1} in 2012.

RESULTS AND DISCUSSION

Hemp yield

In autumn harvests average of 22.1 t ha^{-1} of Bialobrzeskie was harvested with MC around 57%. Variety Ferimon yielded around 25.6 t ha^{-1} of green biomass with average moisture content 59.8% (see Table 1).

When harvested in spring, yield was significantly lower due to loses of leaves–with overage five years value reached 8.36 t ha^{-1} of Bialobrzeskie and 9.79 t ha^{-1} of Ferimon which accounts for loses about one quarter of yield for both varieties and corresponds to dry matter yield 7.2 and 8.2 t ha^{-1} for Bialobrzeskie and Ferimon, respectively (see Table 2).

Table 2. Biomass yield and dry matter yield for five years average

	Autumn		Spring	
	Bialobrzeskie	Ferimon	Bialobrzeskie	Ferimon
BY (t ha^{-1})	22.1	25.6	8.4	9.8
DM (t ha^{-1})	9.6	10.7	7.2	8.2

Total costs of briquettes production

Production of briquettes in autumn harvest cost 39,426 CZK ha^{-1} for B and 44,120 CZK ha^{-1} for F. Other direct costs took the highest share of TC for both scenarios including costs of fuels (21%, 20.2%), reparation of machines and buildings (7%, 6.2%), insurance against natural disasters (3.5% for both varieties), land rent (3.6%, 3.2%) and water (0.3% for both varieties), for B and F, respectively. Costs of material inputs (seeds, fertilizers and other material) accounted for 35% of TC.

TC for spring harvest were 34,566 CZK ha^{-1} and 39,116 CZK ha^{-1} for grown varieties B and F which lowered the sum by 12.3% and 11.3%, respectively in comparison with autumn harvest. Division of costs was very similar as in autumn harvest. Higher costs of briquettes production from varieties B and F in autumn harvest were caused by larger BY and thus higher labour demand, electricity consumption, etc. Although TC per hectare were higher in autumn in comparison with spring, when recalculated per tonne, they were14.7% and 13.6% lower, respectively (see Fig. 1).

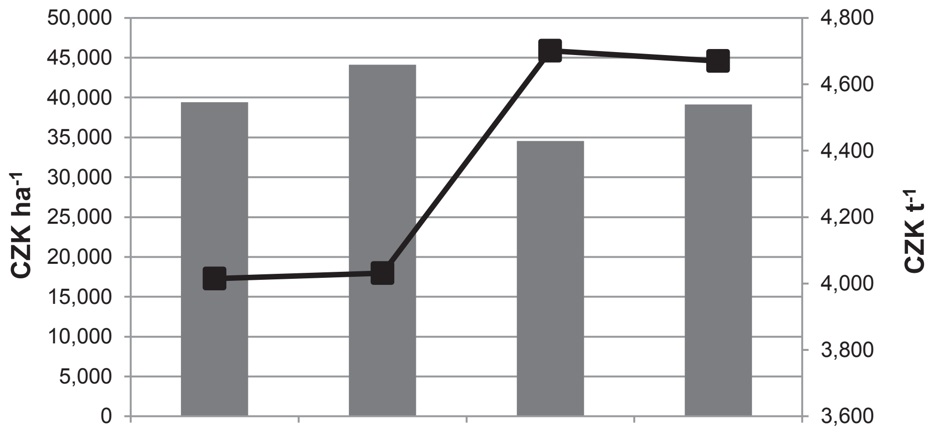

Figure 1. Total costs of briquettes production (comparison) (A – autumn harvest, S – spring harvest).

Although TC per hectare were higher in autumn harvest, when recalculated per tonne they were 15% lower for B and 14% lower for F than in spring (4,015 CZK t^{-1}, 4,031 CZK t^{-1}, respectively).

Structure of costs was very similar in all scenarios. FC made approximately one quarter of TC. Material inputs accounted for almost 40% of TC in all scenarios. Fuels made approximately one fifth of total costs; 70% of costs were made by consumption of electricity. Labour costs represented on average 16% of TC. Share of depreciation costs was quite high; varying between 11–13%. Costs of water consumption and taxes and fees were insignificant, representing less than 1%.

Profit from briquettes production

Since production costs of hemp briquettes were higher than revenues in all scenarios, none of them made any profit. Loses varied significantly between harvesting periods, being much higher in spring. Surprisingly, in both harvests F showed to be more loss making, even though its BY was higher and thus, higher profit was expected. When subsidies SAPS and TOP –UP were taken into account, economy of production slightly improved and moderate profit was gained in autumn harvest (see Table 3).

Table 3. Costs, revenues, subsidies and profit

		Autumn harvest		Spring harvest	
		Bialobrezskie	Ferimon	Bialobrezskie	Ferimon
Total costs	CZK ha^{-1}	39,426	44,120	34,566	39,116
Total revenue	CZK ha^{-1}	36,466	40,644	27,274	31,151
Subsidies	CZK ha^{-1}	6,560	6,560	6,560	6,560
Profit	CZK ha^{-1}	3,599	3,084	-732	-1,405

All scenarios showed negative profitability without any external financial support, even if included the profitability raised up to maximum 9% in the best case (B in autumn). Assumed briquettes price 4,701 CZK t^{-1} (includingVAT) was too low. The minimum selling price of briquettes to cover total production costs would have ranged between 5,151 CZK t^{-1} to 6,070 CZK t^{-1} depending on variety and harvesting period. To reach medium profitability of 30%, the selling price of hemp briquettes would have been 30% and 40% higher for autumn and spring production, respectively than considered price. If the selling price of hemp briquettes stayed the same as it was assumed, BY in DM had to increase by 1.6–4.1 t ha^{-1} (11.2–12.3 t ha^{-1}) for investigated scenarios to become profitable.

Production of briquettes from whole hemp plant showed to be unprofitable without grants and subsidies with current market prices of competitive solid biofuels. Hemp economy slightly enhanced with subsidies in autumn scenarios, however the profitability remained still above average in comparison with other crops.

From economic point of view autumn harvest was recommended because BY was significantly higher which subsequently increased revenue from 1 ha of cultivated land by 23–25%. However, majority of authors argued that spring harvest was preferable for energy purposes due to lower MC and improved chemical properties (Honzík et al., 2012; Prade et al., 2012; Weger et al., 2012). Thus, the optimal harvesting time must be found to ensure both high BY and suitable chemical features of hemp.

Study revealed that cultivation of hemp solely for briquettes production without any subsidies was not profitable for producers in current market conditions of the Czech Republic. Panoutsou (2012) made economic analysis of hemp cultivation for stalks in Poland and Netherlands and ascertained that in both countries the cultivation was not profitable without receiving any financial help (-38% and -46%, respectively).

CONCLUSIONS

Biomass harvested in autumn produced 9.6 t ha^{-1} of variety B and 10.7 t ha^{-1} of F resulting in TC 39,426 CZK ha^{-1} (1,518 € ha^{-1}) and 44,120 CZK ha^{-1} (1,698.9 € ha^{-1}), respectively. When harvested in spring, yield was 30% lower accounting for 7.18 t ha^{-1} of B and 8.2 t ha^{-1} of F with TC 34,566 CZK ha^{-1} (1,334 € ha^{-1}) and 39,116 CZK ha^{-1} (1,506.2 € ha^{-1}). Higher TC in autumn were caused by higher BY which subsequently required more human labour and fuel for processing and higher depreciation costs due to higher use rate of briquetting line.

Although hemp did not show to be economically viable solely for briquettes production, combine production for both stem and seeds could be suggested.

Utilization of whole hemp plant for briquettes production did not show to be economically feasible due to relatively high production costs and low prices of competitive wood briquettes. The future development depends mainly on final price of product and situation on the market with other solid biofuels.

Hemp outstanding features such as high biomass yield in relatively short time, good energy characteristics, low input requirements, versatile use, etc. should be taken into consideration. Furthermore, unlike perennial crops hemp does not require any long term commitment for its cultivation.

Since higher BY positively affected hemp production economy, further research regarding improvement of hemp yield would be suggested to decrease TC and enhance hemp competitiveness on the market with solid fuels.

Based on available resources and own results hemp would be recommended rather as a break crop in fields planted with food crops than for targeted annual cultivation. Due to unfavourable situation on wholesale market with solid biofuels, hemp is not feasible as a main cash – crop for producer, but rather like complementary plant which brings additional income from sales and provides ecological biofuel for own heat consumption.

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