



## ECONOMIC EFFECTIVENESS OF STRAW PELLETS PRODUCTION<sup>1</sup>

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### ABSTRACT

The objective of the paper was to present straw pellets production technology and to determine their production costs. The paper presents also the cost structure and economic effectiveness of pellets production. Tests were carried out in EKO-BIOMASA company which produces pellets. It is located in Biechów in Świętokrzyskie Voivodeship. Unit costs of pellets production were: 310.20 PLN·t<sup>-1</sup> for option 1, 285.40 PLN·t<sup>-1</sup> for option 2 and 278.90 PLN·t<sup>-1</sup> for option 3. The most favourable was option 3 when the pellet production was carried out on the technology line in the 3-shift system day and night. In all three variants of pellet production, the highest costs were in case of electric energy. Its participation in the cost structure in relation to the option was within 42% (option 3) and 38% (option 1). The obtained indicator of economic effectiveness for all the investigated options was higher than one.

## Introduction

Compact biofuels, namely briquettes and pellets, are the most popular form of processed biomass in Poland. Raw materials for their production are obtained from: wood industry (any type of sawdust, wood shavings, chips, bark), from agricultural production (waste and post-production waste e.g. grain straw) and from fast growing plantations maintained for this purpose. In Poland, on energy plants plantations the most popular are: energy willow, poplar, black locust, Virginia mallow and miscanthus (Frączek et al., 2010).

Pellets are produced from the defragmented dry biomass in the agglomeration process under the influence of high pressure and temperature. As a result, its moisture is reduced, mass and energy concentration increase in the volumetric unit and the distribution and usage comfort of this biofuel increases (Mani et al. 2006; Denisiuk, 2006; Niedziółka et al., 2012).

Pellets have: low moisture content from 8 to 12%, low ash content, which depends on the type of raw material and often is higher than 0.5% and high calorific value. This features cause that this fuel is environmentally friendly and easy to transport, store and distribute (Szpryngiel et al., 2014).

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The process of pellet production from biomass is not complicated and originates in the production method of granulated fodder. However, on account of higher resistance during biomass pelletization, production line elements must have higher resistance (Jakubik and Kordylewski, 2008). During the pelletization process, defragmented plant material is compacted under the influence of internal and external forces and the final product in the form of pellet acquires a specific, constant geometrical form (Hejft, 2002; Frączek, 2010).

Pellet production consists in subjecting biomass to further processes: defragmentation, milling and pressing. Pellets production costs (Kwaśniewski, 2008; 2009) and their impact on economic effectiveness are significant elements in the assessment of the company's activity.

Participation of pellets production costs components may be as follows: raw material costs – 30-45%, costs of drying, milling, pelletization and storage – 30-50% and the costs of labour assessed as 1/6 of the production cost (Kwaśniewski, 2008; Witt and Kaitschmitt, 2007).

The production costs of compact fuels are presently a popular object of research in various companies which produce pellets and briquettes. The research which was carried out allows a precise characteristic of the compact fuel production processes and enables recommendation of the production costs reduction method.

The objective of the paper was to present pellet production technology from grain straw and reduction of the production costs. The paper presents also the cost structure and economic effectiveness of pellets production.

## Scope and methodology of research

Research was carried out in 2014 in EKO-BIOMASA Sp. z o.o. which produced pellets, located in Biechów, Pacanów municipality (Świętokrzyskie Voivodeship). This company was founded in 2006, it has 100 ha of AL and presently is one of the biggest producers of calorific pellets in the southern Poland. It also deals with cultivation of maize for grain and production and trade of calorific pellets produced of grain straw (wheat, barley and rye).

Collection of raw material for pellet production is carried out the entire year based on the contracts signed with agricultural farms (presently the company signed ca. a thousand of such contracts). Straw is bought from local farmers and from the area of: Kazimierza Wielka, Dąbrowa Tarnowska, Mielec, Sandomierz, Opatów, Włoszczowa and Miechów. Purchase price of 1 tonne of straw in the amount of PLN 100 was assumed as an average value for the purchased straw types. Transport costs were incurred by farm owners.

Based on the guided survey with company owners indispensable information concerning the applied production technology and technological line for pellet production was obtained. Documentation on finances kept by the company enabled full determination of production costs of the produced pellets.

Components of production costs of straw pellets were presented and they included:

- raw material purchase costs (straw),
- domestic transport costs,
- amortization of devices,
- costs of renovation and maintenance,
- costs of electric energy,
- costs of remuneration of employees.

The following were assumed in the calculations of the production costs:

- technological line with full equipment: PLN 1,500,000,
- amortization of the production technological line at the level of 20% in the year scale,
- electric power installed 760 kW,
- load of devices at the level of 80%.
- electric energy price of 0.45 PLN·kWh<sup>-1</sup>,
- employee's remuneration 15 PLN·h<sup>-1</sup>,
- for renovations and maintenance of machines and devices comprising a technological line monthly PLN 4200 for option 1 and PLN 9200 for option 2 and PLN 12500 for option 3 were designated.

The following were assumed in the calculations of domestic transport costs:

- costs of telescopic loader JCB 531-70: 235000 PLN,
- amortization of telescopic loader JCB 531-70 at the level of 18% in a year,
- fuel consumption by telescopic loader JCB 531-70: 6 l·man-hour<sup>-1</sup>,
- loading of a telescopic loader JCB 531-70 at the level of 70%.
- fuel price: 4.10 PLN·l<sup>-1</sup>.

Information describing raw material and produced pellets from straw:

- moisture of straw to 20%,
- final moisture of pellets 8-12%,
- calorific value 11-14.7 MJ·kg<sup>-1</sup>,

Pellets production costs were calculated per year. Analysis included three options:

- Option 1 – one-shift work, line performance 3000 kg·h<sup>-1</sup>, annual pellet production approx. 6700 tonnes,
- Option 2 – two-shift work, line performance 3000 kg·h<sup>-1</sup>, annual pellet production approx. 13400 tonnes,
- Option 3 – two-shift work, line performance 3000 kg·h<sup>-1</sup>, annual pellet production approx. 19200 tonnes,

The paper presents economic effectiveness of pellet production from grain straw as a relation of unit price of pellets sale (PLN·t<sup>-1</sup>) to the unit costs of pellet production (PLN·t<sup>-1</sup>).

## Research results

The following stages may be distinguished in the straw pellet production technology applied by EKO-BIOMASA company:

- transport of raw material from the storage to the technological line,
- preparation of raw material – tearing off and taking off nets from ballots,
- initial defragmentation of raw material, separation of stones, moisture stabilization, proper defragmentation (milling),
- transport of mixed raw material to the technological line of a granulator,

- evaporation and softening of raw material – giving proper plasticity and viscosity which facilitates pelleting,
- raw material agglomeration in the form of pellets,
- cooling produced pellets and reduction of their moisture level,
- loose shipping.

A technological line for pellet production, which consists of the following machines and devices, operates in the establishment:

- conveying table,
- straw cutter RSC-B24-90,
- cyclone
- hammer mill MBC 250
- screw conveyor PV-5025 (2 pcs.),
- moisture stabilizer Cormall MTX-H,
- filter-cyclone,
- chaff conveyor PS 100-14,
- buffer tank,
- screw conveyor PV-2250,
- conditioner 2400,
- Paladin 2400 granulator,
- tumble back feeder PKC 25 (2 szt.),
- cooler,
- storage.

The entire technological line is automatically controlled with the use of control cabinets with a central computer for operation of which 1 employee is needed.

Table 1 presents a characteristic of pellet production technology for the investigated options.

Table 1.

*Characteristics of pellet production technology for the investigated options*

Item	Specification	Unit	Option		
			1	2	3
1.	Production line performance	(kg·h <sup>-1</sup> )	3000	3000	3000
2.	Number of shifts	(-)	1	2	3
3.	Working hours per day	(h)	8	16	23
4.	Number of pelleting machines	(psc)	1	1	1
5.	Number of employees	(persons)	4	8	12
6.	Installed power	(kW)	760	760	760
		(t·days <sup>-1</sup> )	18.5	37	53
7.	Amount of pellet production (average)	(t·month <sup>-1</sup> )	558	1116	1600
		(t·year <sup>-1</sup> )	6700	13400	19200

Table 2 presents the component pellet production costs and general costs including the purchased raw material in the form of straw. On the other hand, figure 1 presents the cost structure for particular options. The total costs of production of one tonne of pellets for options 1, 2 and 3 were respectively: PLN 310.20, PLN 285.40 and PLN 278.90. For com-

parison the straw pellets production costs in another biomass processing establishment located in southern Poland were PLN 380 for a tonne of pellet and income from production of 1 tonne of pellets – PLN 62.80 (Szul, 2013).

Table 2.

*Pellet production costs for the investigated options (PLN·t<sup>-1</sup> of pellet)*

Item	Specification	Option		
		1	2	3
1.	Grain straw purchase costs	100.00	100.00	100.00
2.	Domestic transport costs	13.80	10.60	9.70
3.	Amortization of devices,	44.80	22.40	15.60
4.	Renovations and maintenance	7.50	8.20	7.80
5.	Electric energy	118.30	118.30	118.60
6.	Remuneration for employees	25.90	25.90	27.20
7.	Pellet production costs	310.20	285.40	278.90

In the analysed pellet production costs (for all options) the highest costs concerned the amount of the consumed electric energy. They were from 118.30 PLN·t<sup>-1</sup> pellets for options 1 and 2 to 118.60 PLN·t<sup>-1</sup> for option 3 (during the third shift a night tariff and electric energy price were not included because during the research the night tariff was not functioning). In the production costs structure it is respectively: 38%; 41% and 42%. Option 3 was the most favourable option of pellet production in the assessed company. (the lowest production costs). In the production costs structure in this case (except for electric energy consumption costs) raw material purchase costs were considerable (36%). Amortization of the used production line takes the following position in the pellet production cost structure.

On account of the maximum use of the line (operation for almost the whole day and night) amortization costs were 15.60 PLN·t<sup>-1</sup> and their participation in the cost structure was 6% (Fig.1).

On the other hand, the costs related to amortization of machines and devices for option 1 were almost three times higher than for option 3 and were 44.80 PLN·t<sup>-1</sup>. The main reason for such high difference is the fact that the production line (PLN 1500000) in option 1 was used to a small extent (one-shift work).

The other expenses comprising the production costs are remuneration for employees. In option 1 and 2 these were 25.90 PLN·t<sup>-1</sup> of pellets, although in the first case the production was carried out in one shift and in the second one – in a two-shift system. For the third option they were the highest (27.20 PLN·t<sup>-1</sup> of pellets) which resulted from a three-shift work.

In the analysed production costs, the lowest costs of production of one tonne of pellets (for all analysed options) were incurred for renovations and maintenance of machines and devices which comprise the technological line (their participation in the structure was from 2% for option 1 to 3% for option 2 and 3). Costs incurred for internal transport were included to the small expenses and the participation in the cost structure was within 3% (option 3) to 5% (option 1).

A power plant in Połaniec was the collector of pellets produced by the investigated company. During the research the price of pellets was at the average of 390 PLN·t<sup>-1</sup>. Including the production costs which were: 310.20 PLN·t<sup>-1</sup> for option 1, 285.40 PLN·t<sup>-1</sup> for option 2 and 278.90 PLN·t<sup>-1</sup> for option 3 and the income tax (19%), income from the production of one tonne of pellets was respectively:

- PLN 64.60 for option 1,
- PLN 84.70 for option 2,
- PLN 90.00 for option 3.

Figure 1 presents the pellet production costs structure for particular production options.

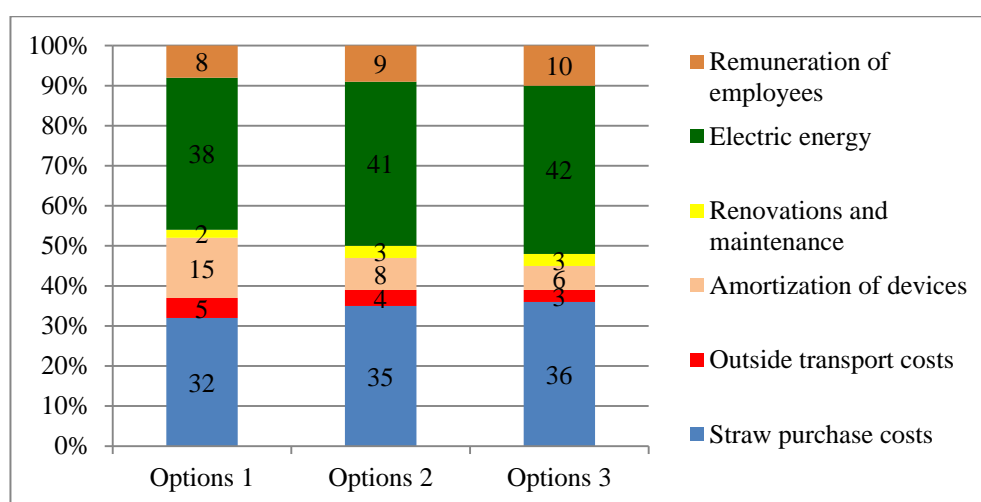


Figure 1. Pellet production costs structure for the investigated production options (%)

To sum up, the assessed straw pellet production technology applied by EKO-BIOMASA company allows production of considerable amount of pellets in the most favourable option 3 which reaches more than 19 thousands of tonnes per year. This production may be increased due to the possibility of technological line modification by installation of the second granulator. Due to the use of such a solution, except for the increase of the amount of the produced pellets, the production costs would be reduced which would allow the increase of income.

Economic effectiveness indicators of straw pellet production for the investigated options were presented in figure 2.

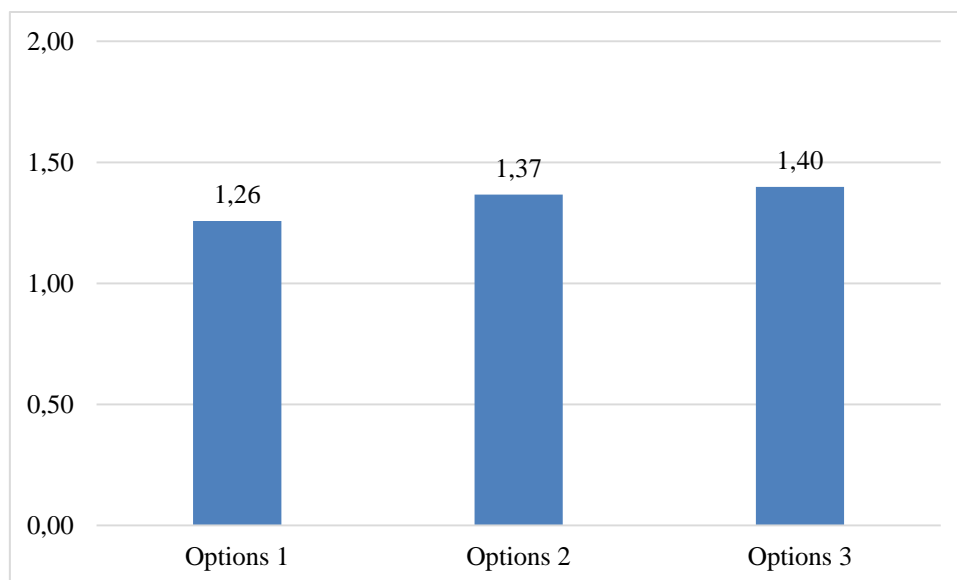


Figure 2. Economic effectiveness of pellet production for the investigated options (-)

Analysis of the obtained results should entice a statement that straw pellet production in the investigated company is profitable for all the applied options. Also, the economic effectiveness indicators are higher than unity. The highest value of the indicator was obtained for option 3 because the production cost of one tonne of pellets was the lowest (production carried out at three shifts).

#### Statements and conclusions

1. The investigated company carries out a whole-year straw collection from farms located to 100 km from the headquarters of the establishment. The final moisture of pellets is within 8 to 12% and the calorific value from 11 to 14.7 MJ·kg<sup>-1</sup>.
2. The most favourable production option was option 3 when the operation of the technological line was carried out for the entire day. In this case the costs of production of 1 tonne of pellets was the lowest and amounted to 278.90 PLN·t<sup>-1</sup>. While for option 1 and 2 these costs were higher (they were respectively: 310.20 PLN·t<sup>-1</sup> and 285.40 PLN·t<sup>-1</sup>).
3. In all three investigated pellet production options the highest costs were related to the electric energy consumption costs. They were 118.60 PLN·t<sup>-1</sup> for option 3 and 118.30 PLN·t<sup>-1</sup> for option 1 and 2. Its participation in the cost structure was within 42% (option 3) and 38% (option 1).
4. The lowest costs of production of one tonne of straw pellets were incurred for renovations and maintenance of machines and devices which comprise the technological line. They were 7.50 PLN·t<sup>-1</sup> for option 1 and 8.20 PLN·t<sup>-1</sup> for option 2.

5. In the period of research in the company, the total amount of the produced pellets was sold to the power plant in Połaniec for the average price of 390 PLN·t<sup>-1</sup>. Including the total costs incurred for production and income tax on each produced tone of pellets the yield in the amount from PLN 64.60 (option 1) to PLN 90.00 (option 3).
6. In EKO-BIOMASA company, where research was carried out pellet production is profitable for all the investigated options. The indicator of economic effectiveness for all investigated options was higher than one.

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## **EFEKTYWNOŚĆ EKONOMICZNA PRODUKCJI PELETÓW ZE SŁOMY ZBÓŻ**

**Streszczenie.** Celem pracy było przedstawienie technologii produkcji peletów ze słomy zbóż oraz określenie kosztów ich wytwarzania. W pracy przedstawiono także strukturę kosztów oraz efektywność ekonomiczną produkcji peletów. Badania przeprowadzono w firmie EKO-BIOMASA produkującej pelety, która znajduje się w Biechowie (woj. świętokrzyskie). Jednostkowe koszty produkcji peletów wyniosły: 310,20 PLN·t<sup>-1</sup> dla wariantu 1, 285,40 PLN·t<sup>-1</sup> dla wariantu 2 oraz 278,90 PLN·t<sup>-1</sup> dla wariantu 3. Najbardziej korzystnym był wariant 3, gdy produkcja peletów prowadzona była na linii technologicznej w systemie 3 zmianowym przez całą dobę. We wszystkich trzech wariantach produkcji peletów, największe koszty stanowiła energia elektryczna. Jej udział w strukturze kosztów w zależności od wariantu wahał się od 42% (wariant 3) do 38% (wariant 1). Uzyskany wskaźnik efektywności ekonomicznej dla wszystkich badanych wariantów był większy od jedności.

**Słowa kluczowe:** pelety, słoma, koszty produkcji, efektywność ekonomiczna