

THE UTILIZATION OF PHYTOMASS FOR ENERGY PRODUCTION IN AGRICULTURE

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The study is focusing on the energy utilization of cereal straw for grain drying. The aim of the study was to substitute the gas energy for the phytomass self-energy (wheat and barley straw) on post-harvest model line for grain drying, as well as unutilized waste from grain cleaning. The experimental measurements of cereal straw yield were carried out, its balance for animal husbandry needs and energetic purposes. The experimental measurements of straw boilers for combustion of straw were carried out on post-harvest model line. The post-harvest line has two dry kilns CHIEF CBS 14-6 type with a capacity of $2x$ for $15 \text{ t}\cdot\text{h}^{-1}$, which are connected to the straw broiler. The heat exchanger is integrated into the heating system of drying medium, so dry kilns meet the HACCP criteria for safety and quality of drying materials.

The experimental measurements on post-harvest model line confirm the efficiency of embedded investments to the construction of straw combustion broiler for grain drying purposes. In monitored year, the line worked under the verifying conditions for technical and technological capability. The financial costs savings on corn drying were $5,68 \text{ €}\cdot\text{t}^{-1}$. Total cost savings were $68\,529 \text{ €}$ in represented year. The total cost savings reach $142\,734 \text{ €}$ at whole season utilization of dry kiln and broiler for straw combustion, which represented return on investments for 4,2 years at total investments costs of $614\,087 \text{ €}$. The experimental measurements were carried out next year.

Introduction

The big expectations are put into the biomass designed for energy utilization, that will become an alternative renewable energy resource and will substitute a part of volatile non renewable energy resources (coal, petroleum products, natural gas), which partake by main share in problems connected to global warming.

The phytomass forms a considerable energy potential, which is equally spread over the whole Slovak republic. To most significant kinds of agricultural phytomass belong wheat, corn and rapeseed straw, dendromass from orchards, vineyards and self-seeding of permanent grasslands. Next to them, there are also excretions of livestock and some kinds of green plants suitable for gaseous biomass products production, such as biogas and biomass suitable for liquid biofuels production, such as biodiesel or bioalcohol.

Prognostic objective of EU countries assume, that the conditions for 12% share of biomass energy on total consumption will be established till 2012, which corresponds with conclusions of Kyoto protocol, which is also valid for Slovak republic.

In Slovak agriculture, potentially, it is possible to produce $46,5 \text{ PJ}$ of agricultural biomass energy, even without negative effect of energy utilization on animal husbandry (bedding, feeding) or soil nourishment (Pepich, 2005, Puchalski-Gorzalani, 2006). This value exceeds recent energy consumption in Slovak agriculture five times, which is about $9,4 \text{ PJ}$ (Pepich, 2005, Turan, 2007). The agricultural biomass of plant origin is called phytomass. The phytomass utilization for energy purposes in agricultural sector is possible in several ways (plant products drying, service water heating, farm buildings heating etc.). Phytomass has a big perspective at heat production for plant products drying.

Aim

The aim of the study was to substitute the gas energy on post-harvest model line at grain

drying – corn for the phytomass self-energy, as well as unutilized waste from grain cleaning.

Experimental measurements and construction design of straw combustion broiler were carried out on post-harvest model line. The post-harvest line has two dry kilns CHIEF CBS 14-6 type with a capacity of 15 t.h⁻¹.

Material and methods

For this purpose it was necessary to accomplish:

- The balance of self straw production and its utilization opportunities for combustion for grain drying purposes, farm buildings heating and service water heating.
- Construction and technological changes on post-harvest line related to the changing the way of drying medium (air) heating and warming.
- The design of the broiler with the capacity of 4,5 MW, combustion gases filter, regulating system of combustion and water heating.
- The design of safety system against fire at the broiler crash and at the attendance.
- The application of proposed design on existing post-harvest line with two dry kilns CHIEF CBS 14-6 type.
- Experimental monitoring of straw consumption and of the waste from the cleaning at corn grain drying.
- The monitoring of dry kiln performance and electric energy consumption.
- Economical evaluation of phytomass utilization at grain drying.
- The application of the dry kiln design for phytomass utilization for grain drying.

Results and discussion

The balance of self straw production and the waste after cleaning

The agricultural enterprise cultivates wheat and barley of all cereals. The straw yield, as well as the quantity of unutilized waste after cleaning is shown in table 1. Presented quantity of 3 672,98 t of phytomass is available for energy purposes.

Table 1

The straw yield and the quantity of unutilized waste after cleaning

Crop Yield	Acreage [ha]	Straw yield [t.h ⁻¹]	Total straw yield [t]	Comment
Wheat	779,76	3,05	2 378,27	
Barley	421,15	2,50	1 052,88	
Unutilized waste	–	–	241,83	Represents 1% of the total quantity of cleaned grain
Total phytomass quantity			3 672,98	

Gas consumption for grain and other seeds drying

During the monitored year, the post-harvest model line processed for enterprise itself or for services following quantity of individual kinds of grain and seeds of field crops, shown in table 2.

Table 2

The quantity of post-harvest modified grain.

Crop	Quantity [t]	Comment
Wheat	6 243,85	Presented quantities are valid for evaluated year.
Barley	3 178,12	
Sunflower	8,79	
Rapeseed	203,96	
Corn	12 057,59	
Total	24 183,49	

The average natural gas consumption for mentioned kinds of commodities drying during the last two years represented 358 646 m³. The enterprise is planning to expand the grain drying services to the capacity of 30 000 t, which represents a gas consumption enhancement up to 400 000 m³ per season.

Phytomass consumption for drying

We based our phytomass consumption calculation on average utilized straw and gas heat value (table 3).

Table 3

The performance of utilized energy sources

Energy source	Heat value [MJ.kg ⁻¹]	Comment
Wheat straw	15,04 – 16,78	The heat value depends on the straw quality, humidity etc.
Barley straw	14,77 – 15,86	
Average	14,91 – 16,32	The average heat value is shown.
Natural gas	34,30	1 m ³ of the gas = 0,8354 kg = 35,08 MJ

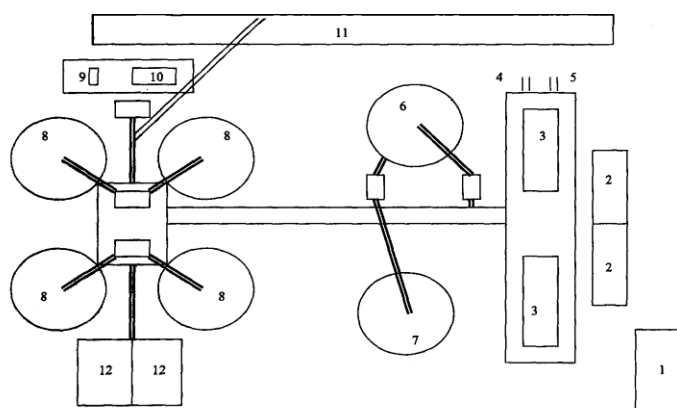
The weight of 1 m³ of the gas depends on the pressure in the system. In our case, the pressure on the burner regulating valve was 20 kPa. The average outdoor air temperature was 15 °C. Based on those values, we will specify the straw consumption. We used a gas consumption of 400 000 m³ per year during the calculation. Used straw heat value was the average low value i.e. 14,91 MJ.kg⁻¹. The total straw consumption for drying is 630,50 t.

The post-harvest line characteristics before reconstruction

The post-harvest line is composed of these main parts (picture 1):

- receiving scale,
- underline receiving bin,
- two grain cleaners PETKUS (K-527, K-547A),
- two dry kilns CHIEF CBS 14-6 burners and fans including,
- 4 steel silos Vítkovice type (4000 t),
- aero-technical devices with cyclones for dust collection,
- different types of conveyors (belt, bucket and screw).

Dry kilns were heated by natural gas.



Picture 1 The post-harvest line scheme:

1 – scale, 2 – skip loader, 3 – cleaners, 4 – gross waste, 5 – soft waste, 6,7 – dry kiln, 8 – silos, 9 – cleaner, 10 – trieur, 11 – floor warehouse, 12 – discharge conveyors with a buffer

Table 4

Technical parameters of dry kiln CHIEF CBS 14-6

a) The size of the buffer	
- buffer diameter	12,80 m
- the height at the edge	4,90 m
- the height at the top	8,91 m
- the height of dried material layer	2,5 m
b) Dry kiln performance, max.	15 t.h ⁻¹
c) Natural gas consumption	70-194 m ³ .h ⁻¹
d) Maximal quantity of evaporated water	2000 kg.h ⁻¹ o.v.
e) Installed electric input	120 kW

Dry kiln CHIEF CBS 14-6 a continuous buffer grain dry kiln. Technical parameters are shown in table 4. For 12 years of running 121 488,38 t of grain were dried. An annual average represents 10 124,03 tons.

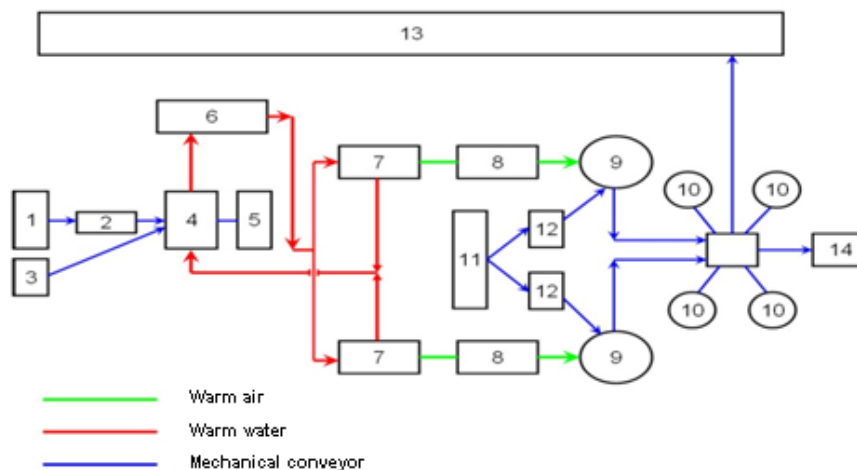
The heat consumption per 1 kg of evaporated water varied between 4,376 and 6,410 MJ. kg⁻¹ in different years. The heat consumption over 4 MJ.kg⁻¹ of evaporated water shows a uneconomic operation and at a high prices of the gas, there is an economically challenging drying.

The post-harvest line characteristics after reconstruction

The reconstruction of the post-harvest model line involved only the dry kiln, especially heating and warming devices for drying medium. It involved a heating source exchange and related reconstruction work.

Based on presented energy calculations (table 2 and 3) we proceeded to proposed project object realization.

Technological scheme of reconstructed post-harvest line is shown in picture 2. The heat exchanger is integrated into the heating system of drying medium, so dry kiln meets the HACCP criteria for safety and quality of drying materials (grain).



Picture 2 Technological scheme of reconstructed post-harvest line:

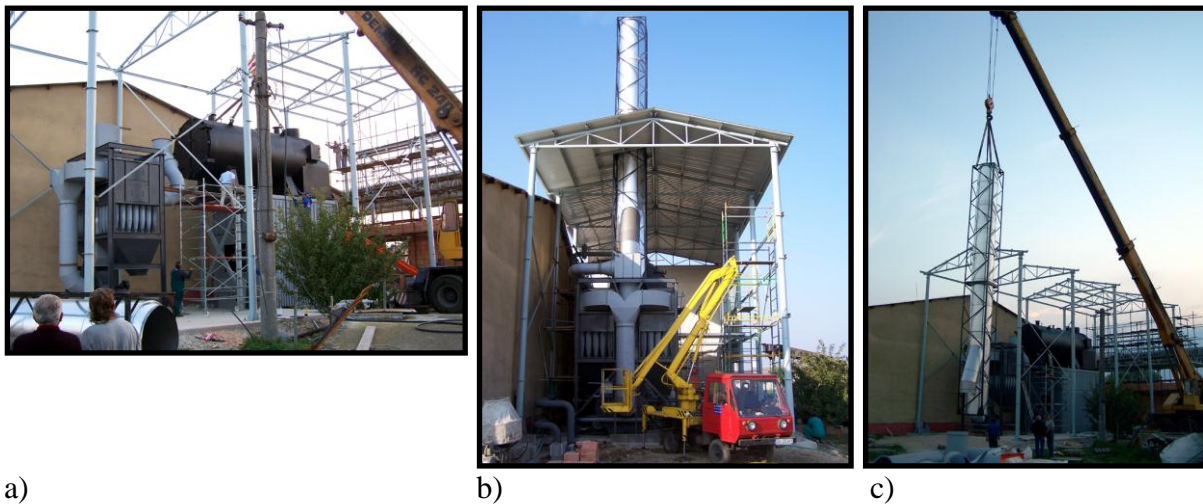
1 – bales storage with bales feed conveyor, 2 – dosing device, 3 – dosing system of waste after cleaning, 4 – fire chamber of the broiler, 5 – combustion gases separator (filter), 6 – tank for heated water (20 m³), 7 – heat exchanger, 8 – fan, 9 – CHIEF dry kiln, 10 – steel silos with active aerating, 11 – receiving bin, 12 – cleaners, 13 – floor warehouse, 14 – discharge buffer

Energy unit – broiler

Based on the design of the broiler (table 5, picture 3 and 4), it is possible to burn straw bales and waste after cleaning simultaneously (picture 5 and 6).

Straw combustion runs continuously according to set mode. Angled bale is split by special device and according to the demand, the straw is automatically transported into the fire chamber of the broiler in set amount.

Incurred combustion gases runs through the separator – filter (MULTICYKLÓN type of the filter with the capacity of $20\,000\text{ m}^3\cdot\text{h}^{-1}$), which separates (absorb) soft solid particles, which are drifted with combustion gases into the chimney. The broiler has a storage tank for hot water. There is a 20 m^3 of the water in the system. The water is heated to the temperature of $60\text{-}70\text{ }^\circ\text{C}$.



Picture 3a – 3c The assembly work of the broiler construction and broiler installation view



Picture 4 The broiler after reconstruction view



Picture 5 The waste after grain cleaning dosing on the post-harvest line



Picture 6 Straw bales transportation into the broiler



Table 5

Technical parameters of the energy unit (broiler)

Broiler type	BIOLANG TSZB-045
Broiler capacity	4,5 MW
Water temperature	60-74 °C
Water temperature behind the temperature about	50-55 °C
Maximal quantity of evaporated water	2000 kg.h ⁻¹
Maximal dry kiln capacity	15 t.h ⁻¹
Dry kiln electric input	120 kW
Broiler room electric input	105 kW
Storage tank for hot water	20 m ³
Phytomass consuption (straw)	0,34-0,66 t.h ⁻¹

At this temperature, water enters the exchanger for each dry kiln independently. The fans of 60 kW input absorb cold atmospheric air through the exchanger. As a result, the water is cooling to 50-55 °C. The heated air (55-60 °C) is transported to the dry kiln by the fan.

The broiler is a prototype and unique with its capacity and construction design. The design of the self broiler with the capacity of 4,5 MW, combustion gases filter, regulating system of straw

combustion, its transportation to the broiler and water heating is the subject of patent authorization, so they will not be any further description.

The broiler operation is managed according to operational order, which includes the safety system against fire at the broiler crash and at the attendance as well.

The operation of the broiler started in monitored year and run whole 39 days for 24 hours per day. During that period 12 057,59 t of corn have been dried. None serious disturbances occurred during operation.

Next season we tested the broiler for efficiency, performance, economic efficiency of the operation and air purify.

Energy costs evaluation

From the evidence of utilized kinds of energies for corn drying with the gas and in monitored year with straw, we calculated costs per tone of dried material (table 6). We used current gas prices (0,46 €·m³), electric energy (0,12 €·KWh⁻¹) and straw (36,51 €·t⁻¹).

The financial costs savings represented 5,68 €·t⁻¹. Total cost savings were 68 529 € in monitored year.

The utilization of represented post-harvest line at full projected capacity, the cost savings reach 142 734 €.

Table 6

Energy costs at corn drying with gas and straw

Year		2007	2008
The quantity of humid material [t]		18 145,30	14 111,48
Grain humidity [%]	Before drying	23,05	22,52
	After drying	14	14
The quantity of dried material [t]		15 788,33	12 057,59
Fuel consumption pre season	Gas [m³]	26 8567	–
	Electric energy [kW.h⁻¹]	148 649	212 606
	Straw [t]	–	401,83
Energy costs	Gas [€·t⁻¹]	7,79	–
	Electric energy [€·t⁻¹]	1,16	2,05
	Straw [€·t⁻¹]	–	1,22
Total energy costs		8,95	3,27

Conclusion

The experimental measurements on post-harvest model line confirm the efficiency of embedded investments to the construction of straw combustion broiler for grain drying purposes.

In monitored year, the line worked under the verifying conditions for technical and technological capability.

The total cost savings reach 142 734 € at whole season utilization of dry kiln and broiler for straw combustion, which represented return on investments for 4,2 years at total investments costs of 614 087 €. The experimental measurements were carried out next year.

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