EVALUATION OF STRAW PELLET PRODUCTION PROCESS

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Abstract. Growing attention is paid to usage of renewable energy resources all over the world. This is conditioned by two major reasons. The first - uneven distribution of the fossil fuel resources in the world, therefore economy in most countries is highly dependent on imported energy resources. The second – the global warming phenomenon stipulates reduction of greenhouse gas emissions into the atmosphere and search for alternatives to burning of fossil fuels. Unused straw in technologies of agricultural production, as by-product of grain production, can be utilized successfully as biofuel. The moisture content is the most important indicator of the straw quality. The research has shown that moisture has great influence on the physical properties of straw; when moisture increases, straw becomes more resistant to tearing, breaking and pelleting. This reduces the capacity of the straw preparation and pelleting technological line. Higher energy consumption in the pelleting technological line depends on moisture evaporation from pelleted straw. During processing of wet straw, condensate accumulates on the building constructions of the production department and this complicates the process of pellet production. The task of the research was to determine the influence of the straw moisture content on the energetic efficiency of the pellet production technology.

Key words: straw, moisture, pelleting, energy consumption, calorific value.

Introduction

Renewable energy resources gradually attract more attention in the world. There are two reasons for this. The first – the world's fossil fuel resources are unevenly distributed, and most economies are highly dependent on imports of energy resources. The second - pessimistic forecasts concerning global warming encourage the reduction of greenhouse gas emissions into the atmosphere, by searching for alternatives to fossil fuel combustion. Such alternatives are renewable energy sources, combustion of which reduces dependence on fuel imports. Biofuels are the most commonly used energy sources. Increasing costs of electric energy, thermal energy, gas and digging, dependence on foreign natural resources, lack of new jobs and the environmental aspects promote the biomass researches and biomass utilization for energy purposes [1 – 6].

Biofuels are the dominant fuels in some developing countries. Unused agricultural by-products could be successfully utilized in fuel production, by processing raw material into briquettes or pellets. Total energy value of straw that can be utilized as fuel amounts to 870 ktne per year. In conformity with the straw calorific value, 1 t of straw can replace 0.28 t of fuel oil. Supposing that 0.5 million tons of straw are utilized every year, 0.14 million tons of imported fuel could be saved in the country. Biofuel can be in a solid, liquid or gas state. In the first case, minimal mechanical processing as chopping of biomass is sufficient; thermal, chemical, biochemical and microbiological processes can be avoided in this case. It is considered that utilization of biomass for energy purposes does not increase carbon dioxide emissions to the atmosphere, because growing plants remove carbon dioxide from the atmosphere through photosynthesis [1; 2; 6 – 10].

Water content is one of the most important indicators of the straw quality. The optimal moisture content of straw for pellet production should not exceed 14 percent [10]. Moisture content of straw as of raw material depends on the ambient weather conditions during harvesting, handling techniques and on storage conditions. Excess moisture promotes biodegradation of straw, storage losses and results in reduced calorific value of a product. Reduced moisture content in fuel could be achieved by means of timely straw harvesting, proper storage and additional drying [10; 11].

The purpose of the study is to analyse the production processes of straw pellets for energy purposes and to determine the energy balance of the product.

Objectives are to analyse the technological processes of the straw pelleting line, to determine dependency of the pelleting line capacity on the moisture content of raw material and to determine the influence of straw storage conditions on variation of straw moisture content.

Object of the study

The straw pelleting process has been studied during chopping and pelleting with the technological line, produced in Radviliškis Machine factory, ŠSGL – 1 (Fig. 1). [12]:

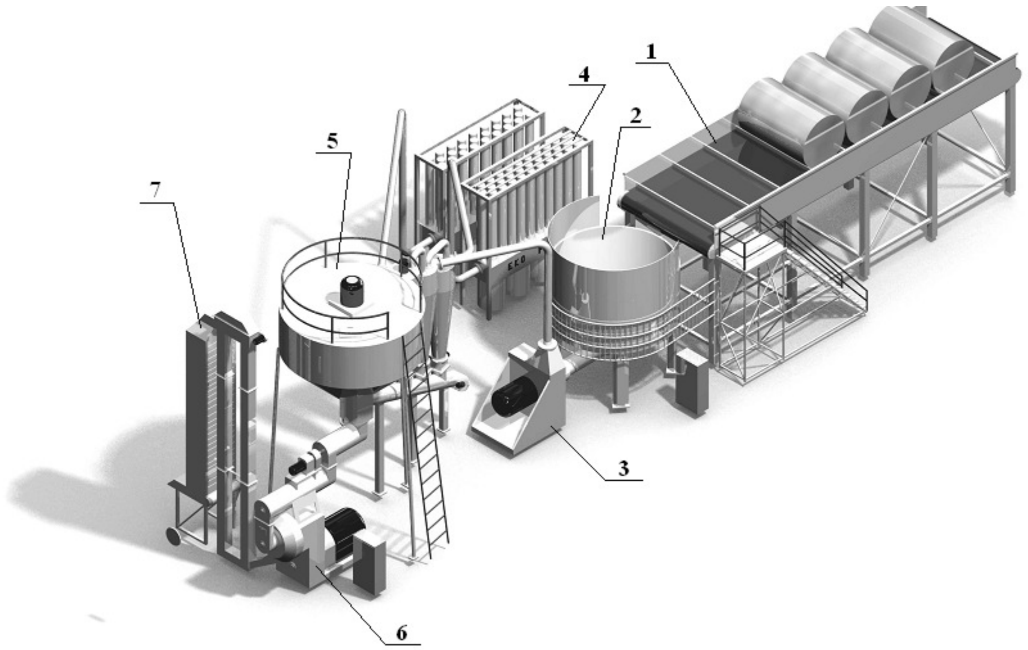

Fig. 1. **Technological line for straw pelleting:** 1 – conveyor, 2 – shredder, 3 – mill, 4 – air cleaning system, 5 – hopper for chopped material, 6 – pelleting press, 7 - cooler

Once they are loaded on a conveyor (1) belt, straw bales are transported into the straw shredder (2) and are shred therein. Then an air flow transfers straw into the mill where it is ground to 2 - 4 mm fraction. Dust is settled in the air filters (4). Straw from a hopper (5) is directed towards the pelleting press (6), and then the pellets are conveyed into a cooler (7). Electric energy consumption was determined according to the readings of the electric energy meter at different levels of raw material moisture content and at different loads of the production line.

Materials and methods

Investigations were carried out in Varėna, Kaunas and Panevėžys regions. Straw moisture content and temperature were recorded before entering the shredder, after shredding, after grinding and after pelleting processes. Calorific capacity was determined as well.

Moisture was determined according to variation of the sample weight; the samples were dried in the oven Memmert 600, at 105 ± 2 ºC up to constant weight. The scales "KERN ABS" with a tolerance of ± 0.02 g were used for weighing of the samples. The research was carried out with at least three repetitions.

Calorific capacity was determined with the calorimeter "IKA Verke C2000". After weighing of a sample with the scales "KERN ABS" (tolerance ±0,02g), it was placed in a burning chamber and burned using technical oxygen. The calorific capacity of a sample was calculated by a microprocessor in the "IKA Verke C2000" device. The tests were carried out in three repetitions.

Temperature of straw raw material was determined with a thermometer "AMM-1", with an accuracy of ± 0.5 ºC. Raw material was placed into an isothermal container and was kept there for 30 seconds.

Results and discussion

It was determined during our studies that the moisture content of raw material affects the output of the production line and increases comparative electric energy consumption.

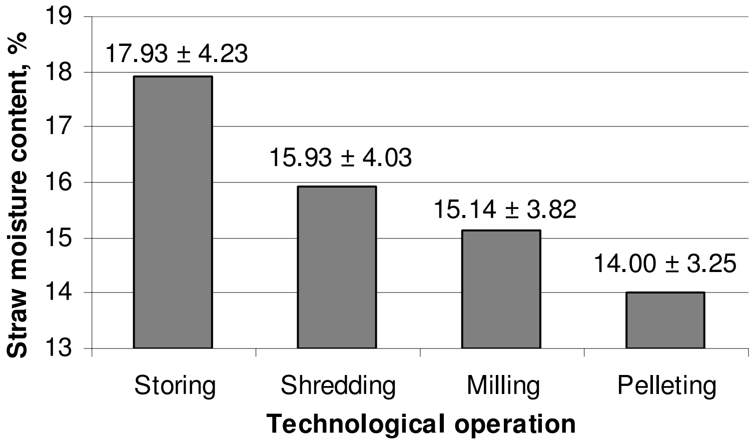

Fig. 2. **Variations of straw moisture content in the technological line**

The processing technique has influence on changes of the straw moisture content. When straw passes all technological operations required before pelleting, it loses 2.79 % of its moisture, whereas during the pelleting process losses of moisture content are approx. 1.2 %. The most of straw moisture (2.0 %) evaporates during the shredding process. Temperature of the processed straw increases in each technological operation. Assuming that the temperature of stored straw is 6.2 ºC, after shredding it goes up to 6.8 ºC, temperature of ground straw is 22.5 ºC and temperature of pellets after cooling is 21.5 ºC. The temperature of the processed straw increases in each technological operation, whereas its moisture content decreases. A significant part of the consumed energy is used for drying of raw material.

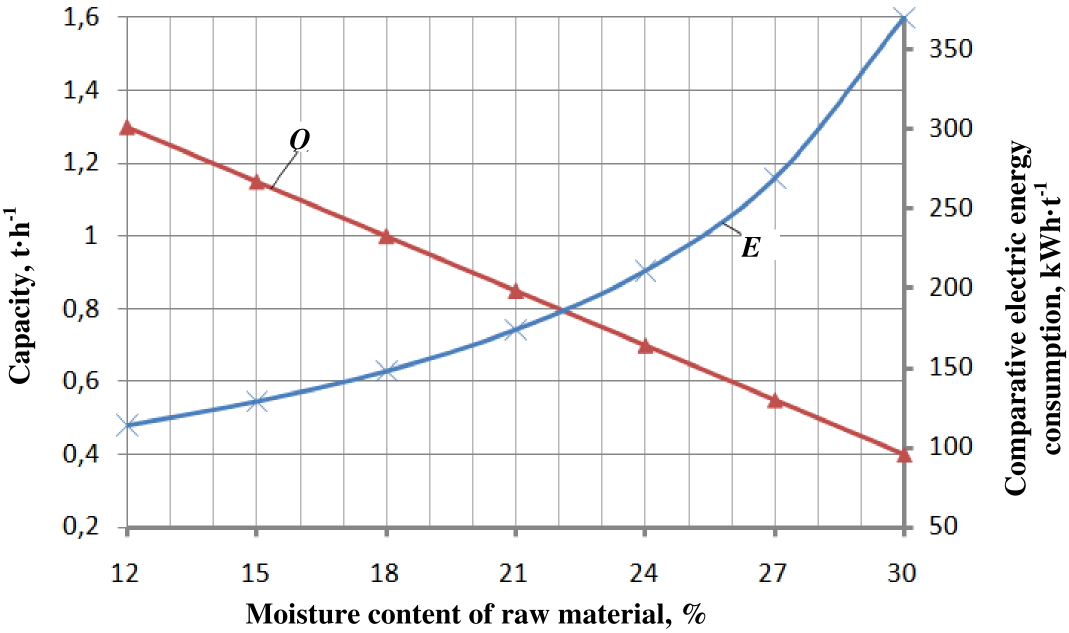

Fig. 3. **Variation of the technological line capacity and energy consumption:** *Q* – capacity of technological line subject to moisture content of raw material, $t \cdot h^{-1}$, *E* – variation of comparative electric energy consumption subject to moisture content of raw material, $kWh \cdot t^{-1}$

Comparative electric energy consumption for pelleting of straw increases proportionally, with increasing the moisture content. This is explained by the fact that the water content in raw material affects the physical properties of the processed straw, therefore, resistance to tearing of wet straw is higher and it has negative effect on output of the straw processing – pelleting equipment. More energy is used to compensate increased resistance in technological equipment and evaporation of excess moisture.

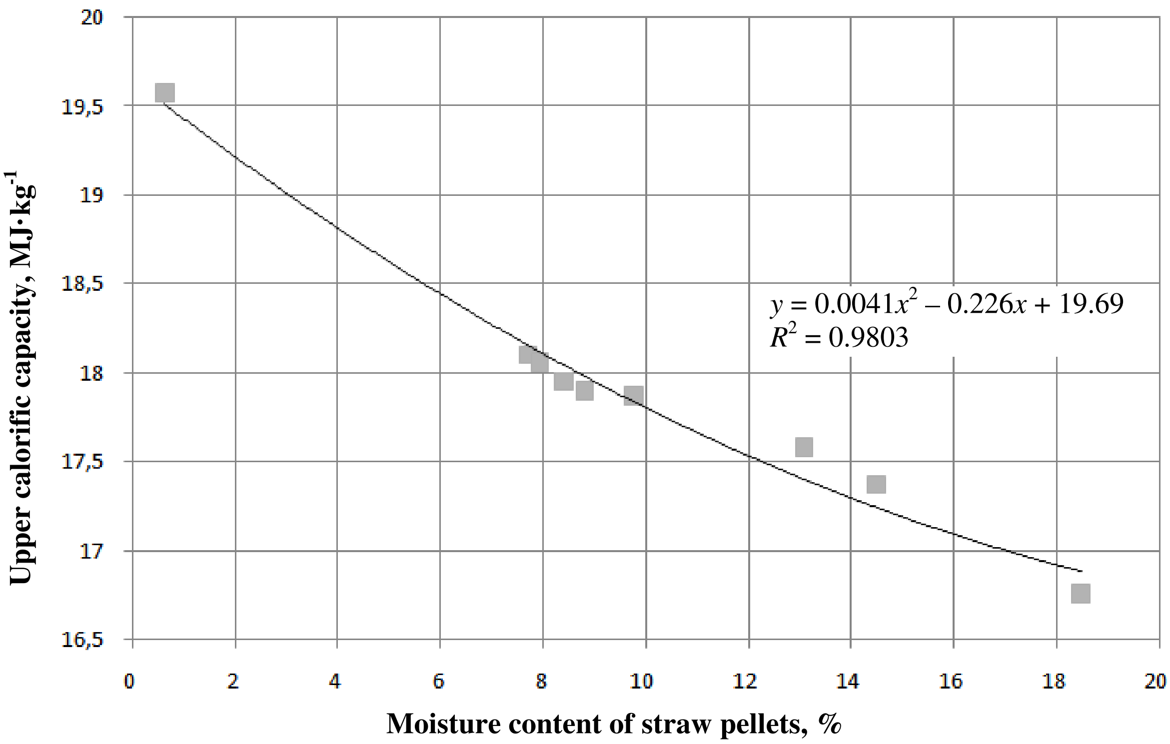

Fig. 4. **Variation of straw pellet calorific capacity**

The resulting mathematical model could be used for calorific value calculations at different initial straw moisture content. The water content of the pellets has influence on the calorific value. When the moisture content of the pellets decreases to 0.63 %, their calorific value is 19.57 MJ·kg^{-1}. When moisture in the pellets increases to 18.48 %, the calorific value decreases to 16.76 MJ·kg^{-1}, therefore, pellets should be dried immediately for longer storage.

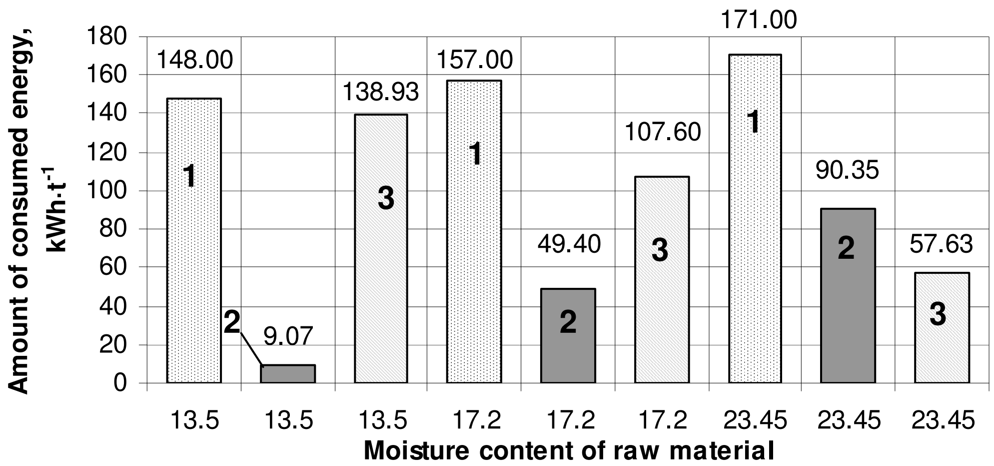

Fig. 5. **Kinetics of energy consumption at changing straw moisture content:** 1 – energy consumed in pellet production; 2 – energy consumed in moisture evaporation; 3 – energy used in mechanical processes of pellet production

When pelleting wheat straw with 17.2 % of moisture, approximately 0,55 t of pellets are produced per 1 hour. This process requires 157 kWh of electric energy (Fig. 5). Where 49.4 kWh of energy is used to compensate resulting higher resistance in technological equipment and moisture removal from straw, and the remaining part – 107.6 kWh is used for straw grinding, milling, and pressing of pellets, aspiration and dust settling. Supposing that straw with 13.15 % moisture content is used for pellet production, 9.07 kWh are needed for moisture evaporation and 138.93 kWh of electric energy is used by the pelleting press; in this case the capacity of the press will increase from 0.55 t to 1.2 t·h^{-1}. In the first case 27.29 % of total useful work in the pelleting line goes to moisture removal from raw material, which is influenced by forces of physical friction. In order to save on electric power, raw material should be stored properly, and the moisture content of straw entering the pelleting line should not exceed 14 – 19 %. At lower level of raw material moisture content, i.e., less than 12 %, the humidifying system should be activated in the pelleting machine OGM – 1.5A (6), because otherwise the pellets will lose stability, crumble after a short time, lots of small fractions will be produced in the pelleting process and during transportation.

Conclusions

1. Water in straw raw material alters the physical properties of the processed straw and has negative effect on the capacity of the straw preparation - pelleting technological line.
2. In the analysed technology, the rated output of the technological line – 1.2 $t \cdot h^{-1}$ is reached, when the moisture content of the processed straw is 14 %; when the moisture content of straw increases to 23.45 %, the output of the pelleting line decreases to 0.75 $t \cdot h^{-1}$.
3. At the moisture content of raw material for pellet production equal to 13.5 %, relative energy consumption was nearly 148 $kWh \cdot t^{-1}$; whilst at a higher level of moisture content – 23.45 %, the energy consumption increased to 171 $kWh \cdot t^{-1}$.

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