Biomass preparation for conversion humidity and value assessment

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Abstract: Biomass usage for heat and energy purposes is one of the questions which still required more detailed analysis and scientific research. In this research we have focused on an analysis of humidity correlation on biomass preparation to conversion steps and calorific value assessment. The concept of biomass is widely understood, and in this research the chosen research object is agricultural, biomass with a main focus on straw, and additionally for results comparison are analyzed samples, composition are a mixture of straw and hay, with an additional 2% lime additive. For this research analyzed samples and their humidity for production steps is: one chop size reduction (20 mm) straw briquettes, two chops size reduction (30 mm and 10 mm) straw briquettes, pallets composition of 100% straw, 98% straw incl. 2% lime additive, 50% straw and 50% hay, 49% straw and 49% hay incl. 2% lime additive, 100% hay, 98% hay incl. 2% lime additive. Samples of straw and hay mixture, also with a lime additive is choosen because it is discussed widely that not only is it possible to use surplus straw from agricultural biomass as renewable energy and heat source, as a lime additive helps to keep a higher temperature on the combustion process and to generate more energy, but it is not healthy for the plant and not recommended under environmental aspects. The results received will help to estimate and determine the material humidity impact on biomass preparation for conversion steps, following an energy requirement for the production of briquettes and pallets, combustion factor and efficiency. It is defined as material calorific, HHV (higher heating value) and ash content which is one of the main factors and the criteria for fuel valuation will allow to determine tested samples further usage for heat and energy purposes. The research results will help further research tasks on bio energy as an agricultural biomass usage.

Key words: biomass, straw, calorific value, HHV (higher heating value), ash.

Introduction

The increased use of bio-energy is one way to meet the expanding demand for energy which is compatible with the efforts to decrease global warming (Silva & Silva, 2011).

As bio refining conversion technologies become commercial, feedstock availability, supply system logistics, and biomass material attributes are emerging as major barriers to the availability of corn stover for biorefining. The material characteristics of corn stover creates barriers with any supply systems design in terms of equipment capacity/ efficiency, dry matter loss and capital use efficiency (Hess J.R et al., 2009).

Biomass can be converted into energy (heat or electricity) or energy carriers (charcoal, oil or gas) using both thermochemical and biochemical conversion technologies. Combustion is the most developed and most frequently applied process used for solid biomass fuels because of its low costs and high durability. During the combustion process, the biomass first loses its moisture at temperatures of up to 100°C, using heat from other particles that realise their heat value. As the dried particles heat up, volatile gases containing hydrocarbons, CO, CH_4 and other gaseous components are realised. In a combustion process, these gases contribute about 70% of the heating value of the biomass (Gravalos et al., 2010).

The use of biomass feedstock from agricultural sources for the bio energy production might play a key role, since it would allow to pursue the following three objectives: 1) reducing emissions of the greenhouse gases, 2) diversifying energy sources to reduce dependence on oil and gas, 3) indentifying productive alternatives and new sources of income to farmers especially in areas affected by the process of agro-industrial conversion (Librenti et al., 2010).

Biomass moisture significantly influenced comminution energy consumption (Miao Z. et al., 2011).

Compared to the incineration of fossil fuels the overall CO_2 balance is considerably less affected by the usage of biomass. An important property of fuel is its heating value. The so called 'higher heating value' (HHV) is the enthalpy of the complete combustion of a fuel with all carbon converted to CO_2, and all hydrogen converted to H_2O. The higher heating value is given for standard conditions (101 kPa, 25°C) of all the products and includes the condensation enthalpy of water Varmuza et al., 2007).

The ashes are the inorganic material that remains after biomass burning. They contain mainly calcium, magnesium and phosphorus, elements that effect the ash fusion. The ash fusibility is a key parameter for evaluating the biomass performance in plants. (Librenti et al., 2010).

The field of thermo chemistry is one of the foundation stones of a modern energy society. The proximate and ultimate analysis of biomass and coal are necessary for their efficient and clean utilization while the HHV of these materials determine the quantitative energy content of these fuels (Parikh et al., 2005).

Materials and methods

Research was performed at Fachhochschule Stralsund laboratory. For the research two different particle size briquettes were chosen. Examples produced by one chop (20 mm) and two chop (30 mm and 10 mm) fractions together with six examples of pallets which composition is of 100% straw, 100% straw pallets, 98% straw incl. 2% lime additive, 50% straw and 50% hay, 49% straw and 49% hay incl. 2% lime additive, 100% hay, 98% hay incl. 2% lime additive.

Samples humidity and its correlation was determinated on different material preparation to conversion phases. Tested examples succession are:

- samples preparation to conversion stages (briquettes): material from bale, material after one chop size reduction, material after two chop size reduction, final product- straw briquettes;
- samples preparation to conversion stages (pellets): material from bale, material after crusher, material before press, final product- pellets.

All samples taken for research were hermetically closed to keep the present humidity and to avoid any parameters changes. Humidity was determinated in the laboratory, examples were dryed in the oven (WS 51) at a constant 100°C temperature, and additional measurements were taken in periods after 3 h plus 1 h. Samples taken from the oven were held for 1 h in a dish to equalize temperature and to absorb the remaining humidity. To receive objective results and accuracy it each material sample was measured three times.

Samples calorimetre value were determined with IKA Calorimeter C 4000 adiabatic, which follows DIN 51900, ASTM 240 D, ISO 1928 standards. Samples material has been milled with el. mill Fritsch (max power 1800 W), used sieve with holes 0.5 mm in diameter, received milled material in 0.25–0.5 mm particles fraction.

Further steps were to measure quartz crucible first empty and then with samples in 0.1 g accuracy, 0.7 g of each test samples have been measured. The inhibit wire and the tied up cotton thread has been fastened. Bomb was filled in with 5–10 ml distilated water. Prepared subtance were put inside of the bomb, and bomb cover has been bolted. Bomb was filled with 30 bar oxygen. Installed bomb was added into IKA Calorimeter C 4000 adiabatic. Determinated begining (t_E) and end (t_A) temperature. After the process in calorimeter was over, bomb was taken out, cover is opened, inside of bomb liquid was filled 0.1% Phenolphtalin was used to indentify the acidity and titration to know 0.1 N NaOH-solution amount in ml. This parameter is used to calculate heat amount by measuring acid processing.

Fig. 1. Calorimeter bomb.

Fig. 2. IKA Calorimeter C 4000 adiabatic.

According to the received results it was calculated HHV (higher heating value), which assumes that all of the water in a combustion process is in a liquid state after a combustion process. In accordance with DIN 51900 by the term „heat value" only lower heat value is understood, while a higher heating value is called calorific value, which is calculated by formula (1):

$$H_{o,f} = \frac{C \cdot \Delta t - Q_F}{m_{P,f}} \quad (1)$$

C – Thermal capacity of calorimeter system, koeficientas 8410.31, J K^{-1}

Δt – difference of the temperature, K;

Q_F – sum of amount of heat, J;

$m_{p,f}$ – mass (of moist sample), g; (DIN 51900T1); (DIN 51900T2); (DIN 51900T3); (Warn J. R. W & Peters A.P.H, 1996).

Results and discussion

The humidity variation of material in preparation to conversion steps was determined starting from material in bale till the endproduct – briquettes and pellets. To testing briqutte's production phases and preparation to conversion steps, material was taken from bale, after one chop size reduction, after two chop size reduction, and final product- straw briquettes.

The regression equation and correlation coefficient of humidity in production steps of straw briquette samples of one chop fraction (20 mm) and two chop fractions (30 mm and 10 mm) are represented in (Fig. 1) and (Fig. 2). Results show that one chop fraction briquette humidity and its production strongly depend on the humidity of start up material, correlation coeficient R^2 = 0.6904. But in the case of two chop fraction briquette, results showed that humidity starting from primary material in the bale and on the other stages do not have influence on final product product, correlation coefficient R^2 = 0.1241.

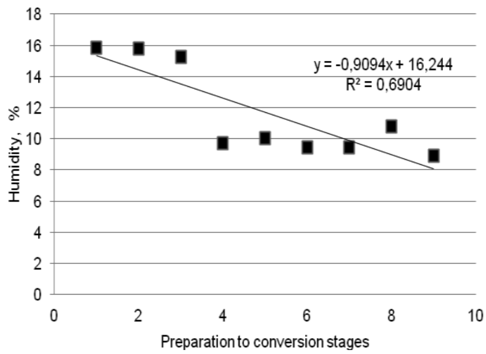

Fig. 1. The influence of humidity on preparation steps to conversion (100% straw briquette, one chop).

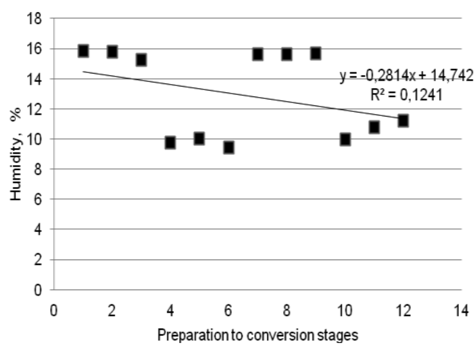

Fig. 2. The influence of humidity on preparation steps to conversion (100% straw briquette, two chop).

In order to test pallets production and preparation to conversion stages, material from bale after crusher, before press, and final product- pallets are taken.

Analysed 100% straw pallets (Fig. 3) and pallets produced on composition 98% straw incl. 2% lime (Fig. 4) and the received results of humidity influence on production steps has showed that there is a strong correlation in both cases.

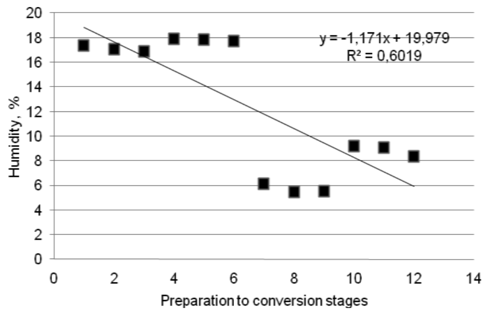

Fig. 3. The influence of humidity on preparation steps to conversion (100% straw pellets).

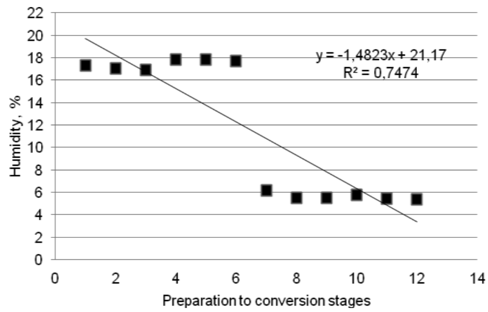

Fig. 4. The influence of humidity on preparation steps to conversion (98% straw pellets incl. 2% lime).

Researched pallets composition of 50% straw and 50% hay (Fig 5) and 50% straw and 50% hay incl. 2% lime (Fig. 6) showed there is a strong humidity correlation coefficient in all preparation steps. Attention should be noted that pallets with a 2% lime additive has a stonger correlation on the humidity impact during production steps.

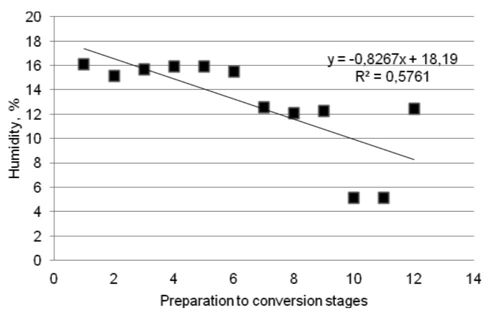

Fig. 5. The influence of humidity on preparation steps to conversion (50% straw and 50% hay pellets).

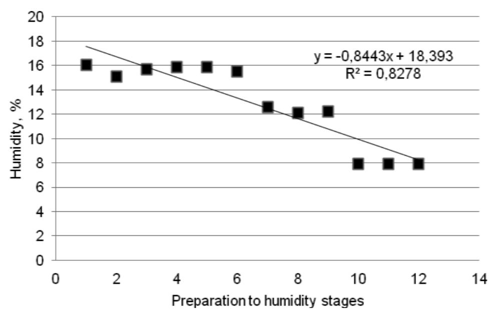

Fig. 6. The influence of humidity on preparation steps to conversion (49% straw and 49% hay pellets incl. 2% lime).

Evaluating pellets composition of 100% hay (Fig. 7) and 98% hay incl. 2% lime additive (Fig. 8) humidity dependence on the earlier mentioned production stages and humidity measuring phases for 100% hay pallets R^2=0.4866, for pallets of 98% hay incl. 2% lime additive, R^2= 0.5566. Lime additive has influenced the pallets production process and humidity factor.

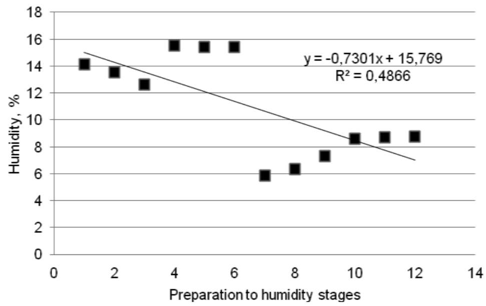

Fig. 7. The influence of humidity on preparation steps to conversion (100% hay pellets).

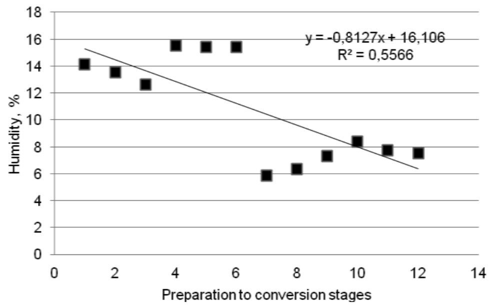

Fig. 8. The influence of humidity on preparation steps to conversion (98% hay pellets incl. 2% lime).

HHV (higher heating value) was calculated under results received on the laboratoty test of calorimetry. Additional criteria for analysis was taken and evaluated for non treatment straw samples from bale. Each test results incl. three repetition is showed (Fig. 9). The lowest HHV value were determined on non treatment straw taken directly from the bale and in pallets which composition is 50% straw and 50% hay samples. Higher figures were achieved in all analysed samples with 2% lime additives. Analyzing seperately 100% straw briquette and 100% straw pallets HHV results, a higher amount was determined on 100% straw briquette samples.

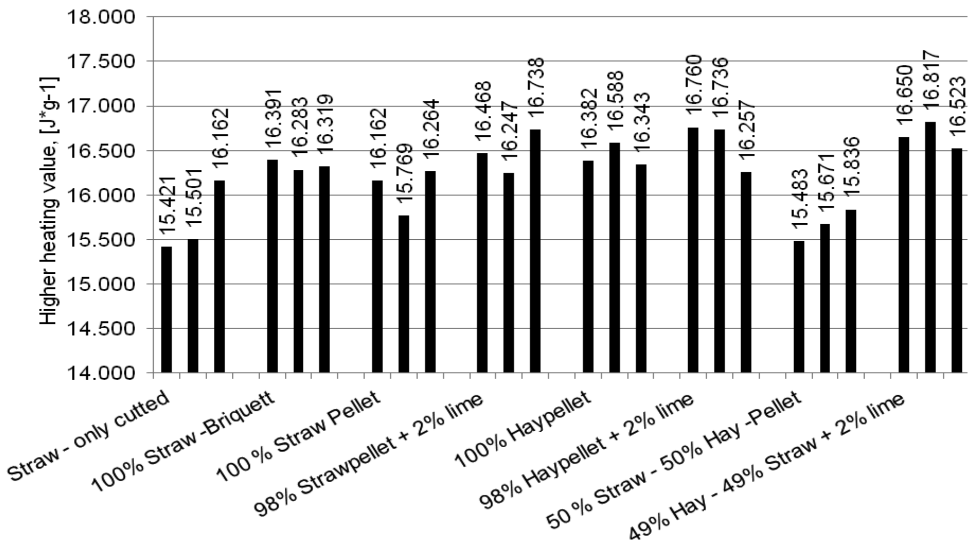

Fig. 9. HHV (higher heating value) of tested material.

Determined ash content % (of solid mass) at tested samples and their values are represented in the diagram (Fig. 10). It is noteworthy that the lowest amount of ash has been defined as the straw briquette sample, the highest amount – at pellets composition of 50% straw and 50% hay. The ash content in non treatment straw from the bale is higher than in 100% straw briquettes samples. Ash quantity at 100% straw pellets is one of the higher values. In the samples which includes a 2% lime additive, the determined ash quantity is lower then at adequate examples.

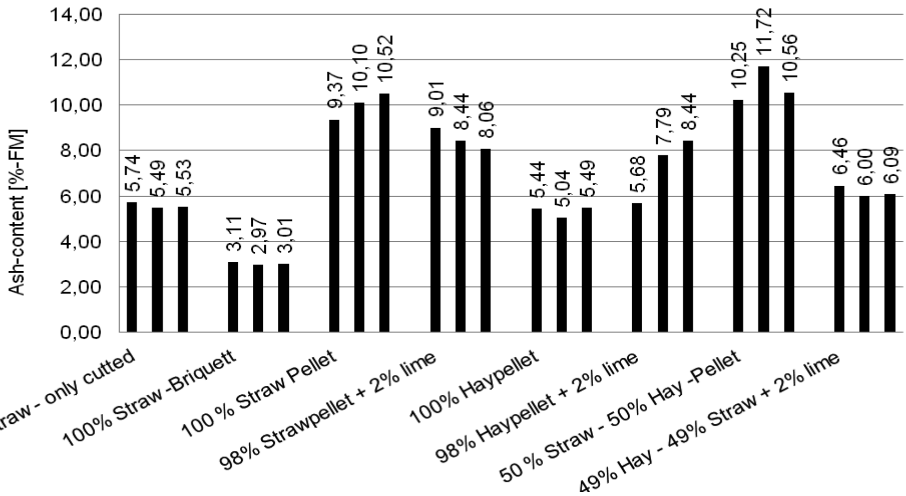

Fig. 10. Ash content, % of tested material.

Conclusions

The represented research is focused on the analysis of humidity correlation through biomass preparation to conversion steps and energy value assessment. Defined material calorific, HHV (higher heating value) and ash content value, which is one of the main factors and criteria for fuel valuation, and it was determined that:

- One chop fraction briquette humidity and its production strongly belong on start up material humidity;
- Material preparation to conversion steps for pellets has a stonger correlation on humidity impact then for briquettes;
- Samples preparation to conversion steps of pellets with 2% lime additive has a stonger correlation on the humidity impact then the remaining tested pallets samples;
- The lowest HHV value were determined on samples which consist of non treatment straw taken directly from the bale and in pellets which composition is 50% straw and 50% hay, accordingly values average 15,695 (J g^{-1}) and 15,663 (J g^{-1}). Higher figures were achieved in all samples with 2% lime additives;
- Higher heating value was determined on 100% straw briquette samples then on 100% straw pellets;
- Lowest amount of ash has been defined as the straw briquette sample, value 3,03%, the highest amount – at pellets which composition is 50% straw and 50% hay, value 8,5%.

References

DIN 51900T1 'Determination of the calorific value with bomb Calometer and computation of the heat value, general Anga ben basic equipments basics procedures' Expenditure August 1997.

DIN 51900T2 'Determination of the calorific value with bomb Calometer and computation of the heat value, procedure also isotherms coat' Expenditure August 1977.

DIN 51900T3 'Determination of the calorific value with bomb Calometer and computation of the heat value, procedure also adiabatic coat' Expenditure August 1977.

Gravalos I., Kateris D., Xyradakis P., Gialamas T., Loutridis S., Augousti A., Georgiades A. & Tsiropoulos Z. 2010. A study on calorific values of biomass residue pallets for heating purpose. FORMEC 2010. Forest Engineering: Meeting the needs of the Society and the Environment July 11–14, 2010. Padova – Italy.

Hess R.J., Kenney K.L., Wright C.T., Perlack R. & Turhollow A. 2009. Corn stover availability for biomass conversion: situation analysis. *Cellulose*. **16**, 599–619.

Librenti L., Ceotto E. & Di Candilo M. 2010. Biomass characteristics and energy contents of dedicated lignocellulosic crops. Third International Symposium of Energy from Biomass and Waste.

Miao Z, Grift T.E, Hansen A.C. & Ting K.C. 2011. Energy requirement for comminution of biomass in relation to paticle physical properties. *Industrial crops and products*. **33**, 504–513.

Parikh J., Chaniwalla S.A. & Ghosal G.K. 2005. A correlation for calculating HHV from proximate of solid fules. *Fuel*, **84**, 487–494.

Silva R.M & Silva A.J. 2011. The potential benefits and risks to the environment in using bio-energy. *Syst Pract Res*, **24**, 545–554.

Varmuza K., Liebmann B. & Friedl A. 2007. Evaluation of the heating value of biomass fuel from elemental composition and infrared data. Chemistry. Scientific papers **35 (5)**, 5–10.

Warn J. R. W & Peters A.P.H, 1996. *Concise Chemical Thermodynamics.* Taylor & Francis e-library, 2005. 204 pp.