STALK BIOMASS DRYING RATE EVALUATION

Martins Ozollapins, Aivars Kakitis, Imants Nulle
Latvia University of Agriculture
m-ozollapins@inbox.lv, aivars.kakitis@llu.lv, imants.nulle@llu.lv

Abstract. Locally produced bioenergy will boost the national energy security and increase the national energy independency. In order to increase the energy efficiency, improve energy produced quality, and reduce emissions in its thermochemical energy conversion, drying of the biomass to the required moisture content is important in the development of energy productions systems. To avoid overdrying or incomplete drying process characteristics – the drying rates and other parameters, have to be determined. It is known that reed canary grass, reed and hemp are potential energetic crops suitable for fuel production in Latvia. They can be combined with peat to increase fuel durability and density. Drying processes of the above mentioned materials are researched at constant air flow and temperature and at 3 different layer thicknesses. The results are shown in graphs; equations for drying rate calculation are obtained. Comparison of the drying characteristics is demonstrated, to highlight the differences in the drying technology needed for production of fuel with composite structure.

Keywords: drying, stalk biomass, bioenergy, renewables.

Introduction

Energy security and climate change mitigation are core elements in the current European energy policy. The European Union is mandated to meet by 2020 a target of 20 % renewable resources in the energy supply [1]. The demand for biomass for energy in the EU will increase from 5.7 EJ per year in 2012 to 10.0 EJ per year by 2020 [2]. The potential of energetic crops for production of energy in Latvia is approximately 9000 GWh per year [3]. Biomass production with energy aims can generate employment and if intensive agriculture is replaced by less intensively managed energy crops, there are likely to be environmental benefits, such as reduced leaching of fertilizers and use of pesticides [4].

In order to increase the energy efficiency, improve energy produced quality, and reduce emissions in its thermochemical energy conversion, drying of the biomass to the required moisture content is important in the development of energy production systems. Selection of a suitable drying system and drying operation conditions is critical to resolve these issues and to achieve the required final moisture content [5].

Currently, the mayor driving force for innovative drying techniques is the need to produce better quality products at higher throughputs. To meet these requirements, new ideas in dryer design are required. The need to reduce the energy consumption of dryers is revived as a result of the present high rise of the fuel costs [6].

The drying rate is defined as the variation of the moisture content with respect to the time. In the drying process it is necessary to distinguish theoretically three periods [7]:

1. Increase of the temperature of the product to desiccate;
2. Superficial evaporation of the adherent water. The process exists while the process of evaporation takes place up to point of "critical content water";
3. Final phase. The process in this period slows down due to the water absence adherent in the surface.

The target moisture content for production of pellets or briquettes is approximately 10% depending on the materials and technology used [8]. If biomass is used directly for pyrolysis it needs to be dried till less than 2 % of moisture content, if for gasification less than about 10% and direct combustion can handle biomass up to 20 % moisture content [9].

In previous researches it has been investigated that herbaceous biomass as cereal crop straw (mainly wheat straw), common reeds, rape straw and reed canary grass are the most prospective stalk materials for solid biofuel production in Latvia. As heat additive peat can be used, because it improves the density, durability of stalk material briquettes and pellets and avoids corrosion of boilers [10].

Investigation of material drying rates is important for development of the conveyor/belt and other types of dryers where the material is fed in a constant layer or portions.

Materials and methods

To increase the biomass fuel production efficiency the drying rates of common energetic crops and also peat have been investigated. These crops are reeds (*Phragmites australis* L.), reed canary grass (*Phalaris arundinacea* L.) and hemps (*Cannabis sativa* L.). The dimensions of the samples were different due to different cutting technology used (Fig. 1).

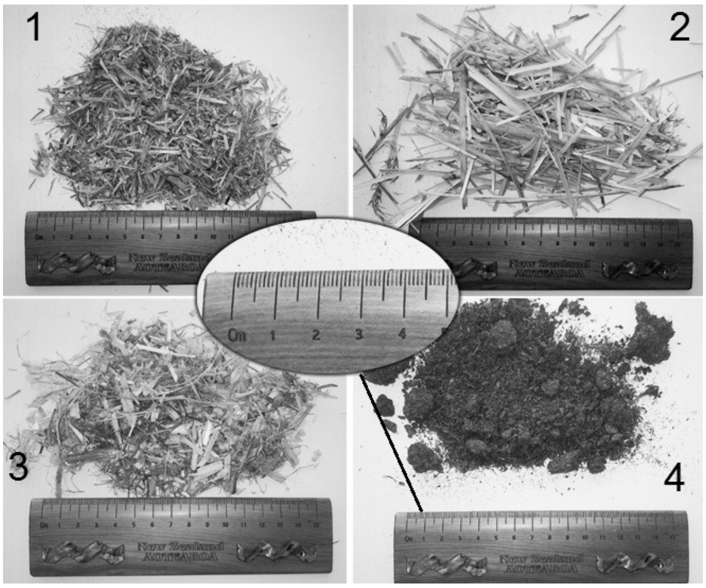

Fig. 1. **Drying material samples:** 1 – reed canary grass; 2 – reeds; 3 – hemps; 4 – peat

Due to small particles of the drying material, air is used as a drying agent to avoid dust explosion that can occur if flue gas is used. The drying rates were investigated in constant flow rate and temperature. For development of the drying equipment the drying material layer thickness can be important to avoid overdrying or incomplete drying. Because of that three layer thicknesses *h* were used – 35 mm, 50 mm and 100 mm of the drying material.

The experimental equipment (Fig. 2) consists of a camera that is made from heat insulating foam plastic. The camera is connected to the ventilator with a heater and positioned on the force sensor for uninterrupted mass measurements in time. Heat loss through the camera walls reaches 65 W. The area of the drying zone is 0.0441 m^2. Productivity of the ventilator q_{air} is 12.7 $m^3 \cdot h^{-1}$, and so the air flow velocity through the drying material reaches 0.08 $m \cdot s^{-1}$.

Drying agent – air temperatures were recorded before – t_1 and after drying – t_3. The temperatures were measured also in the material layer – t_2. Inflowing air temperature t_1 is constant and reaches 67 ± 2 ºC. To avoid fire hazard the material temperature has to be held under control. Humidity of the drying agent is recorded at inflow and outflow of the camera (ω_1; ω_2). The inflow agent humidity is constant and reaches 2.0 ± 0.5 %.

The drying rates are determined as loss of the moisture content in a time period:

$$R = \frac{MC_1 - MC_2}{t_2 - t_1} \tag{1}$$

where R – drying rate, $\% \cdot min^{-1}$;
MC_1 – initial moisture content in period, %;
MC_2 – final moisture content in period, %;
t_1 – start time of drying, min;
t_2 – end time of drying, min.

The moisture content is defined according to equation:

$$MC\%_n = \frac{m_{M\,n}}{m_{T\,n}} = \frac{m_{M\,(n+1)} - m_{T\,n} + m_{T\,(n+1)}}{m_{T\,n}} \tag{2}$$

where $MC_{\% n}$ – moisture content in material, %;
$m_{M n}$ – initial moisture mass in period, g;
$m_{M (n+1)}$ – final moisture mass in period, g;
$m_{T n}$ – initial total material mass in period, g;
$m_{T (n+1)}$ – final total material mass in period, g.

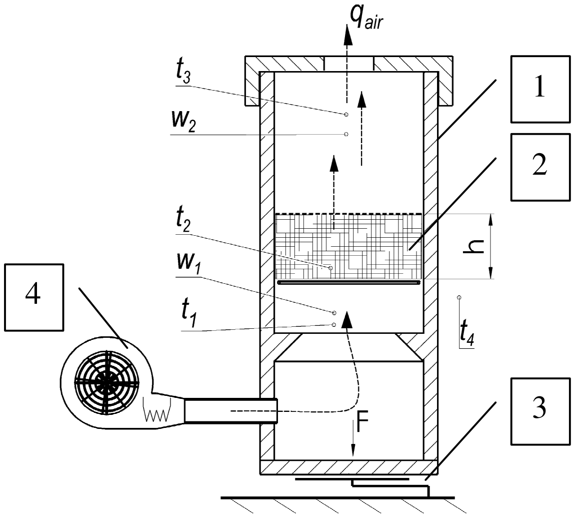

Fig. 2. **Experimental drying equipment:** 1 – drying camera; 2 – drying material; 3 – force sensor; 4 – ventilator with heater

The measurements were recorded with computer program PICO Recorder, afterwards the data were processed in MS Excel and resulting graphs were developed.

The final moisture content was determined by using the oven drying method described in the standard LVS EN 15414-3.

Results and discussion

In Fig. 3 the drying rates depending on the moisture content for different materials are demonstrated. The layer thickness is 50 mm. Reed canary grass has the highest rates with the initial drying rate 4.62 $\%\cdot min^{-1}$. Peat shows the lowest drying rates and the highest initial drying rate reaches 0.71 $\%\cdot min^{-1}$. The rates for hemp and reeds are approximately on the same level, accordingly 1.63 and 1.41 $\%\cdot min^{-1}$ at the beginning of drying. The character of the rates is to decrease with loss of moisture and the dependence is slightly exponential.

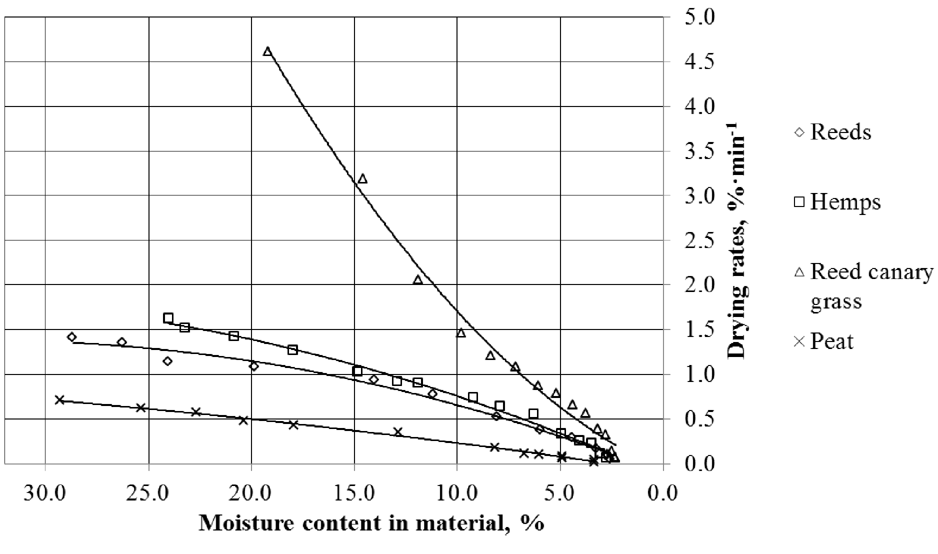

Fig. 3. **Drying rates at layer thickness 50 mm depending on moisture content**

Approximate drying rates for the investigated materials at 50mm layer thickness can be obtained from equations:

- $R_{50mm\text{ - reed canary grass}} = 0.0074MC^2 + 0.1038MC - 0.0719$, $R^2 = 0.991$;
- $R_{50mm\text{ - reeds}} = -0.0006MC^2 + 0.0652MC - 0.0473$, $R^2 = 0.9929$;
- $R_{50mm\text{ - hemps}} = -0.0014MC^2 + 0.0905MC - 0.1126$, $R^2 = 0.9872$;
- $R_{50mm\text{ - peat}} = -0.0002MC^2 + 0.0339MC - 0.0852$, $R^2 = 0.9939$.

Approximate drying rates for the investigated materials at 100 mm and 35 mm layer thickness can be obtained from equations:

- $R_{100mm\text{ - reed canary grass}} = 0.0042MC^2 + 0.0361MC + 0.077$, $R^2 = 0.9810$;
- $R_{100mm\text{ - reeds}} = 0.0003MC^2 + 0.0144MC + 0.0977$, $R^2 = 0.9807$;
- $R_{100mm\text{ - hemps}} = 0.0024MC^2 + 0.0319MC + 0.106$, $R^2 = 0.9933$;
- $R_{100mm\text{ - peat}} = 0.0002MC^2 + 0.0025MC + 0.0325$, $R^2 = 0.9863$;
- $R_{35mm\text{ - reed canary grass}} = 0.0394MC^2 - 0.2408MC + 0.6264$, $R^2 = 0.9896$;
- $R_{35mm\text{ - reeds}} = -0.0006MC^2 + 0.0822MC - 0.039$, $R^2 = 0.9914$;
- $R_{35mm\text{ - hemps}} = 0.0042MC^2 + 0.0126MC + 0.3463$, $R^2 = 0.9848$;
- $R_{35mm\text{ - peat}} = 0.0013MC^2 - 0.0123MC + 0.1379$, $R^2 = 0.9827$.

Fig. 4 shows the drying rates of reeds at different layer thicknesses. At 100 mm layer thickness reeds have an initial drying rate 0.86 $\%\cdot min^{-1}$, but at 35 mm its value reaches 1.89 $\%\cdot min^{-1}$. Other drying materials show a similar character.

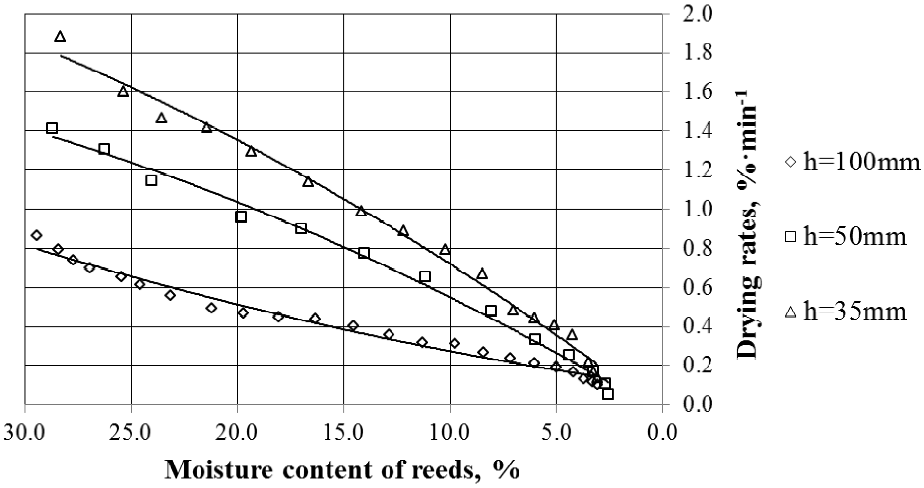

Fig. 4. **Drying rates of reeds at different material layer thicknesses**

The moisture content of the material during drying is shown in Fig. 5. At the beginning of drying moisture evaporates more rapidly and exponentially levels. Initial evaporation occurs on the material surface and with decrease of that slowly inner moisture evaporates.

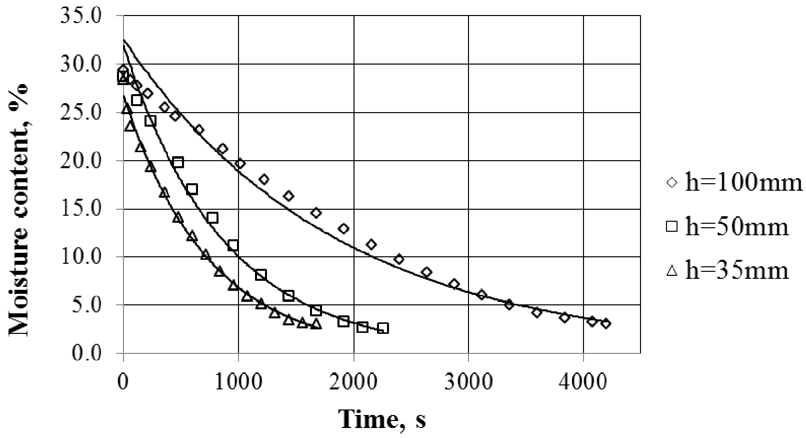

Fig. 5. **Moisture content of reeds during drying process at different layer thicknesses**

Fig. 6 demonstrates the moisture content and temperatures of air and the drying material – reeds at 100 mm layer thickness. Material temperature starts to rise significantly at around 15 % of the moisture content and reaches almost the air temperature at 9 % of the moisture content in the material. The outflow air temperature reaches the inflow air temperature when the material is almost fully dried. The final moisture content of current reed drying is 2.1 %. The character of the outflow air moisture content and drop of the moisture content in the material is similarly exponential.

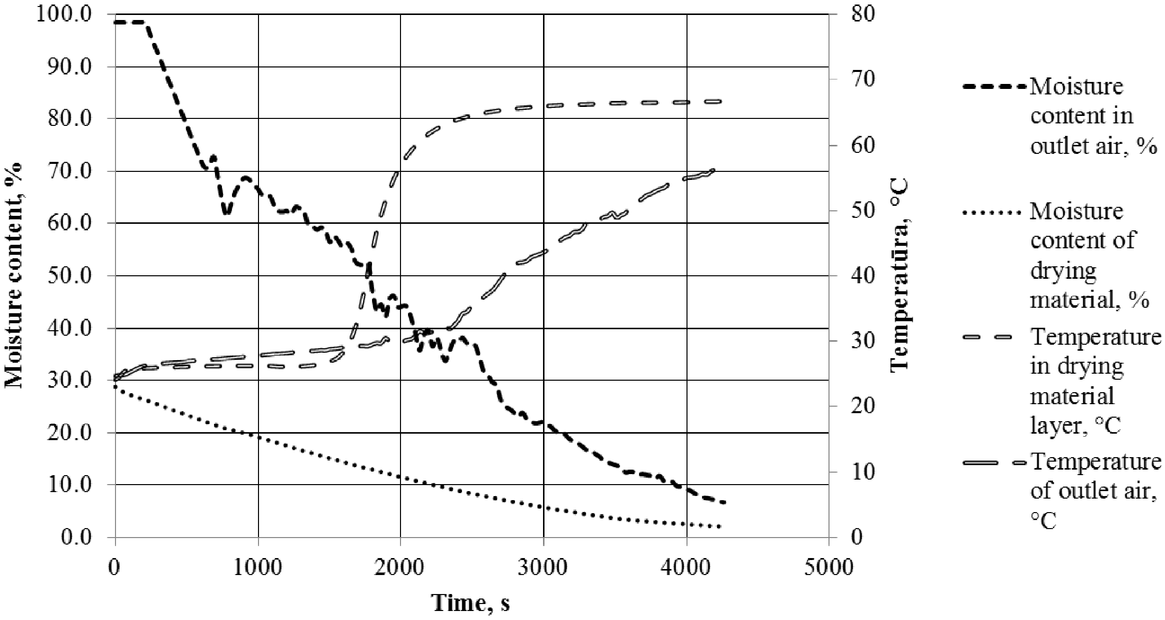

Fig. 6. **Change of temperature and moisture content during drying**

Conclusions

1. Investigation of material drying rates is important for development of the conveyor/belt and other types of dryers.
2. Drying rates can be expressed as loss of the moisture content per time unit and their character is to decrease with loss of moisture and the dependence is slightly exponential.
3. Drying rates were investigated in the constant flow rate and temperature and show significant difference between the drying layer thickness and material being dried.
4. Drying rates of reed at 50mm layer thickness can be obtained by equation $R_{50mm\text{ - }reeds} = -0.0006MC^2 + 0.0652MC - 0.0473$, $R^2 = 0.9929$.
5. Reed canary grass shows the highest value of the initial drying rate at 50mm layer thickness and reaches 4.62 $\%\cdot min^{-1}$.

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