Drying of Biomass in an Infrared Tunnel with Conveyor Belt

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Abstract: *The article addresses the drying of cellulosic vegetable waste from fruit growing, and viticulture in an infrared tunnel dryer with conveyor belt. Data are presented regarding the average mass resulting from cutting, energy efficiency, calculation of drying speed and drying rate. Also, are presented some of the results of the dryer test according to the test methodology.*

Keywords: *Dryers, infrared, biomass, wood moisture*

1. Introduction

At present, in order to reduce pollution and increase the quality of combustion or to use biomass in processing processes (briquettes, pellets), biomass drying is practiced. Plant biomass, used as a raw material, is hygroscopic material, so it has the ability to exchange moisture with the atmosphere, and as a result has the property to change its calorific value, durability, stability during transportation and storage.
The most representative categories of combustible wood materials are: firewood, tree bark, branches from forest exploitation, chopped branches from the maintenance of tree orchards, vine ropes, sawdust, wood chips, small pieces of timber and other residues from wood processing.
Cellulosic vegetable waste from fruit and viticulture can be a source of biomass, the dryer and greenhouse are direct users of thermal and electrical energy, and ash can be used as an important component of mineral fertilizers used on farms. As an example, the wood biomass obtained from the annual cuttings from orchards and dried up to 20% represents an average mass of 1,500 kg / ha from which a gas energy of 4.5 MWht can be obtained with which it can be dried, with a yield 35% drying, about 8,500 kg of apples. Another example: from one hectare of vineyard on which 4000-5000 logs are in production, 0.65 kg of ropes are obtained at the annual cuttings from each log, so at least 3000 kg / ha of ropes cut with a relative humidity of about 40%. By natural drying or in dryers the cut ropes reach 20% humidity and a mass of very good quality cellulosic fuel of about 2200 kg / ha is reached. From this fuel by gasification can produce a quantity of 4800 m^3 of gas with which can produce a thermal energy of 6.60 MWht. In our country, for wood waste from cutting down trees in orchards, logging, sawmills, etc., it can be estimated that the price of fuel that is introduced into gas is on average 10 € / t, a similar value for other areas in Europe for which similar case studies have been performed. The result is a price for primary energy of maximum 0.6 € / GJ. Dryers are high heat consumers, which leads to high production costs for their products. Reducing thermal energy costs leads to lower overhead costs and increased competitiveness of dehydrated products. The use of locally available biomass can ensure a significant reduction in production costs and an increase in energy independence [1].
One ton of dry biomass has an energy potential of 15.530 GJ / t.bm or 4.3 MWhth. From the published data, for Europe, results an average cost of gathering, chopping and transport for a ton of cuts of about 40 € / t. Taking into account the costs for drying and a profit of 20%, it results that a ton of biomass usable for the production of thermal energy can be sold for about 80 € / t. The specific price for the primary energy of biomass is in the case studied of 5.2 € / GJ or 18.6 € / MWhth, values much lower than those for diesel of 33.22 € / GJ or for LPG of 21.52 € / GJ [2]. The researchers showed that for the artificial drying of biomass from 35% to 15%, 70% of the energy consumed is used for processing, while for the actual pelletizing of pellets - only 7%. Regarding the

moisture of biomass for pelletizing, Li, Yadong and Liu, Henry [3], stated that it should be between 6-12%, and Obernberger, I. and Thek, G [4] recommend values of 8-12%. It should be noted that the moisture content of the biomass at harvest can far exceed the required level. Humidity after maintenance cuttings in orchards or vines is up to 50%. For economic reasons, the reduction of the high humidity of the harvested biomass is recommended to be achieved in natural conditions, using solar energy or atmospheric air [5].

2. Biomass drying

Drying is the operation by which water from solid materials (in our case biomass) is removed with the help of air which has the role of bringing the heat necessary to vaporize moisture and to evacuate the resulting water vapor. The speed of the drying process is defined by the amount of moisture removed from the surface unit of the material to be dried in the unit of time. The factors that influence the drying in the case of biomass are:

• Quantity (flow);
• Shape: powder, granules, sheets, etc.;
• Humidity and the form in which it is found;
• Thermal and oxygen (air) sensitivity;
• Bulk density.

Wood moisture (U) is related to dry mass. This value describes the relationship between the mass of water included, compared to the dry mass. Moisture can therefore be transformed into water content, respectively can be calculated from it. In conclusion, wood moisture can be described as a relationship between water and dry biomass. Wood moisture is a common notion in wood management. Instead, in the practice of wood energy use is calculated only with the water content.

$$M = \frac{G_u - G_0}{G_u} \cdot 100, (\%) \quad (1)$$

$$U = \frac{G_u - G_o}{G_u} \cdot 100, (\%) \quad (2)$$

Where:
• M - Water content;
• U - Wood moisture;
• G_u- Fresh weight;
• G_o - Dry weight.

In the energy use of wood, the caloric value of the biomass used in addition to the essence and dimensions of the pieces has an essential importance. Because biomass without water does not exist in nature, larger or smaller amounts of water must evaporate during combustion. The energy (heat) required for this decreases the net energy efficiency.

The influence of water content on the caloric value of the biomass used can be calculated with the following equation:

$$q_{p,net,ar} = q_{p,net,d} \cdot \frac{(100 - M_{ar})}{100} \cdot 0{,}02443 \cdot M_{ar} \quad (3)$$

Where:
• $q_{p,\ net,\ ar}$ - Caloric value of wood at a certain water content [MJ / kg];
• $q_{p,\ net,\ d}$ - Calorific value of dry wood mass in waterless state [MJ / kg];
• M_{ar} - Water content in delivery condition [%];
• 0.02443 - Constant for water vaporization heat at 25 ° C [MJ / kg].

It follows that the caloric value of wood (approx. 18.5 MJ / kg) decreases linearly with increasing water content [6].

Transforming biomass into thermal energy by burning imposes certain moisture values of fuel as follows [6]:
- the maximum humidity of biomass for burning in conventional combustion plants= 25 %;
- the maximum humidity of biomass for burning in specific combustion plants = 60 %;
- optimum humidity of biomass for burning = 7 – 10 %;
- maximum humidity of biomass for gasification = 35 %;
- the maximum humidity of biomass for transformation into pellets or briquettes = 10 %.

Analyzing the data on the humidity values that appear for the use of biomass by combustion, it is necessary to dry it. The high humidity of the biomass at the time of combustion negatively influences the technical condition of the combustion plant [7].

3. Dryers with infrared radiation

Infrared (IR) radiation is electromagnetic radiation whose wavelength is longer than that of visible light (400 - 700 nm), but shorter than that of terahertz radiation (100 µm - 1 mm) and microwaves (~ 30000 µm). Most of the thermal radiation emitted by objects at room temperature is infrared.
Infrared energy is emitted or absorbed by molecules when the rotational-vibrational movements change. Infrared energy excites modes of vibration in a molecule through a dipole change, making it a useful frequency range for studying these energy states for molecules of corresponding symmetry. Infrared spectroscopy examines the absorption and transmission of photons in the infrared energy range.
IR heating power is used in IR infrared dryers. Electromagnetic radiation with a wavelength of 0.76 µm - 1 mm is called infrared. Depending on the wavelength of the radiation, they can be SIR dryers (short IR radiation), MIR dryers (medium radiation) and LIR dryers (long radiation) [4].
The firm S.C. ROLIX IMPEX SERIES has developed, following a subsidiary contract of type D, contract in collaboration with a research organization, INOE 2000, within the contract on structural funds POC, a new solution of infrared dryer.
It is shown in figure 1, and in figure 2 is its practical realization.

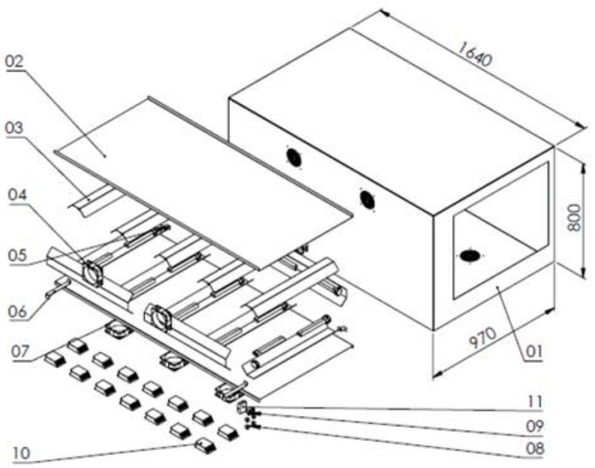

Fig. 1. Infrared biomass dryer

Fig. 2. Physical realization of ME of infrared biomass dryer

The infrared dryer consists of a tunnel housing (1), lamp holder (2), reflector holder (3), IR lamps (4), brackets (5) and (6), fans (7), lamp switches (8), display control module (9), IR lamp holders (10), wireless controller (11).
IR lamps (4) are installed inside the tunnels housing (1) which are mounted on the supports (10). The heat is directed to the chopped biomass fragments by the targeting plate sheets (3).
The drying tunnel enclosure is traversed by the belt-chopped biomass conveyor, driven by its own variable speed electric motor (via frequency converter) and a chain transmission.

The brackets (5, 6) provide the necessary distance between the tunnel housing (1) and the outer jacket of the dryer, for mounting the belt conveyor motor and the 10 fans (7): four on the sides of the outer jacket, two on the lower support plate sheet and four on the top plate sheet.
The operation of the IR lamps is done from the four switches (8), located in the upper part of the front panel of the drying tunnel and the operating of the fans from the control and display module (9), located in the lower part. The fans create inside the dryer the air current for the evacuation of water vapor resulting in the drying process.

4. Testing the IR dryer with conveyor belt

4.1 Measurement / recording of the working speed of the conveyor belt (fig.3)

The IR dryer has variable speed on the conveyor belt.
The process speed of the drying process can be determined with the formula:

$$w = \frac{dW}{A \cdot dt} \quad (4)$$

In which:
- w - speed of the drying process;
- dW - the amount of moisture removed;
- A - the unit of surface of the material subjected to drying;
- dt - unit of time.

When the drying speed is known, the drying time is determined by integrating the equation:

$$w = \frac{dW}{A \cdot dt} \Rightarrow \int \frac{dW}{A \cdot w} \quad (5)$$

Knowing the data regarding the drying time, the speed of the conveyor belt can be adjusted in such a way that the material to be dried remains inside the dryer for the calculated duration.
During the test, using the Lutron VT-8204 [8], the rotational speed at the drive shaft of the device in contact with the drive chain of the conveyor belt was measured. The measured rotational speeds (fig. 3) for the preset gears in the control panel were: minimum of 35 rpm and then with the settings in the control panel it was measured: 59.9 rpm, 90.8 rpm, 123.6 rpm, 159.8 rpm, 185.7 rpm, 216.6 rpm, 245.1 rpm and max. 286.3 rpm.

Fig. 3. Measuring the rotational speed of the conveyor belt

After calculating the drying speed, the speed of the conveyor belt is established and adjusted.

4.2 Measurement / recording of vacuum vibration level with Lutron VT-8204 apparatus [8] (fig. 4)

The measured min. value of was 0.130 Hz and max measured value was 0.145 Hz:

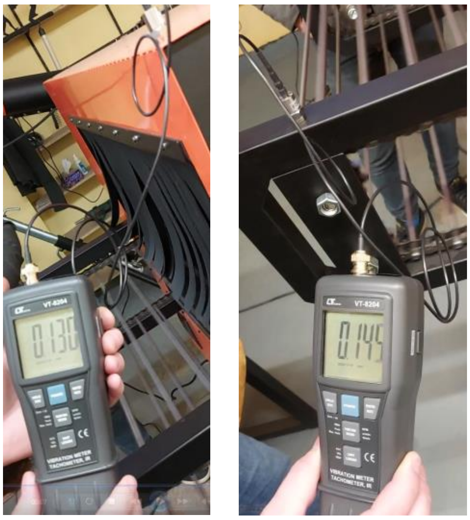

Fig. 4. Measurement / recording of vacuum vibration level with Lutron VT-8204

4.3 Measurement / recording of vacuum vibration level with sound level meter model RS-232:SL-4012 (fig.5)

Using the sound level meter model RS-232: SL-4012 [9], the noise level was measured at a minimum speed of 70 db and that at a maximum speed of 79 db.

Fig. 5. Measurement / recording of vacuum vibration level with sound level meter model RS- 232:SL-4012

4.4 Temperature measurement in the drying tunnel (fig.6)

The measurement was made empty with the Fluke Ti20 Imager [10] which is a last generation thermal imaging unit, pistol type.

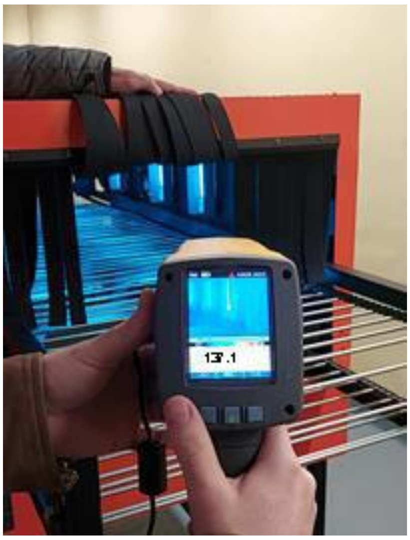

Fig. 6. Temperature measurement in the drying tunnel

The temperature measured in the tunnel, without material, was 137.1 °C.

5. Conclusions

1. The cellulosic vegetable waste from orchards and viticulture can be a source of green energy from biomass.
2. The infrared radiation loses the least energy in contact with air. It does not heat the air but the objects it comes in contact with. Almost all the energy is transmitted to the object we want to dry.
3. The infrared tunnel dryers with conveyor belt are often combined with conventional dryers for efficiency and short drying time.
4. The infrared tunnel dryers with conveyor belt are more economical than conventional ones in terms of energy consumption.
5. The continuous adjustment of the conveyor belt displacement and temperature in the drying tunnel.
6. Drying with infrared lamps and convection fans to make drying more efficient.
7. It saves 30% of electricity compared to similar equipment.

Acknowledgments

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