ROLLED UP HEMP MASS DESICCATION IN FIELD CONDITIONS BY SOLAR RADIATION

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Abstract. According to the present technology in Latvia hemp is harvested in August. After cutting and some predrying on a field the hemp mass is rolled up, the rolls put in stacks and blown by the atmosphere air using a ventilator. Drying from outside to inside is ineffective. The objective of our research is to intensify and speed up the desiccation process by putting the rolls on special vertical perforated tubes of the desiccation device. The tubes have openings in their walls. The atmosphere air blown by the ventilator goes through the tube openings and makes the hemp mass desiccated from the rolls inside to outside, what is more cost-effective. The perforated desiccation tubes are made with gradual decrease of the opening area from the tube bottom to the top. The work of the device was tested in field conditions by desiccating a hemp roll. For the ventilator operation electricity was produced by a thin film solar energy battery, but hot air to intensify the desiccation process was obtained by the use of the solar air heating collector with a reflector.

Keywords: hemp, desiccation, solar, collector.

Introduction

In Latvia hemp is harvested in August because of the technical needs – while the weather conditions are good enough for its desiccation. The average length of a day is about 15 hours; the total solar radiation is up to 145 $kWh \cdot m^{-2}$ per month, the sun is shining 50 % of a day's length [1] and the average air temperature during a day is around 20 ºC [2].

According to the present technology, after cutting and some drying on the ground up to the humidity of 30-40 %, the hemp mass is rolled up, the rolls put in stacks and blown by the atmosphere air flow created by a ventilator. It leads to ineffective use of energy because drying of the rolls is performed from outside to inside. From the energetic point of view it would be more effective to desiccate the rolls from inside to outside.

In this connection a device is offered, where the hemp rolls are put on a special air distributing desiccation device, having vertical perforated tubes with cones on its top ends and with openings distributed evenly in the walls [3]. The air flow going through the tube openings makes the hemp mass desiccated from the rolls inside, what is more cost-effective [4].

From the experimental investigations [5] it comes clear that such a design of the desiccation tube construction does not ensure equable desiccation of the whole hemp mass simultaneously. The roll mass at the top part is desiccated faster, at the bottom part longer. That extends the desiccation process. It happens due to the fact that the hemp mass in the roll bottom part is more pressed as in its top part.

For this, a desiccation device was designed where the opening area in the desiccation tube walls was gradually decreasing from bottom to top, according to the increase of the roll mass density into the bottom part. Such a construction of the tube compensates the change of the roll mass density; air flow velocity and air pressure in the desiccation tubes, and ensures even roll mass desiccation.

The objective of the research is to make the desiccation process faster by drying all hemp mass in the roll simultaneously, decreasing the desiccation time and the amount of energy consumed.

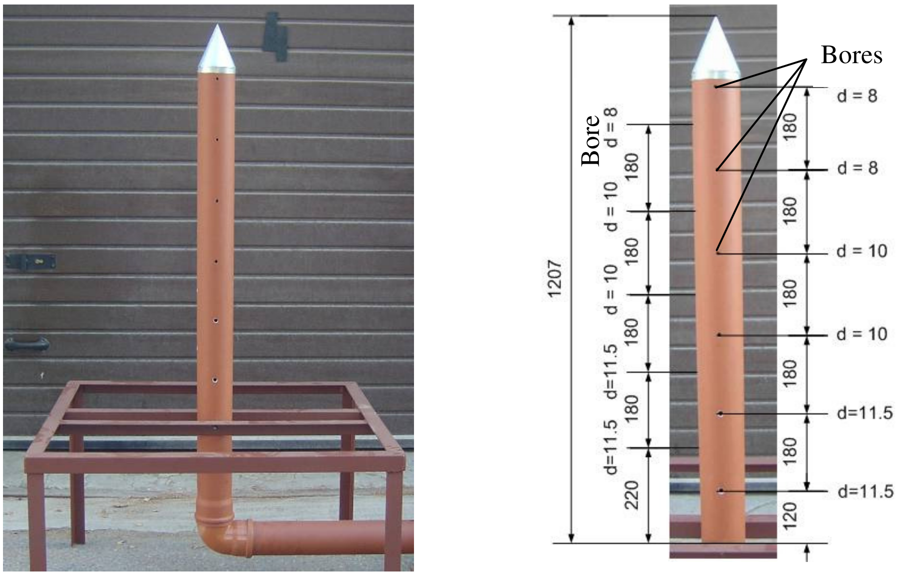
As in field conditions not everywhere the electric grid is available, for air heating and the ventilator operation the electric energy was produced by a thin film solar energy battery (97 W flexible PV module), but hot air was obtained by a solar air heating collector with a reflector.

During the experimental investigation at different stages of the desiccation the mass of the hemp roll was weighted, the temperature, relative humidity and velocity of the air flow, the amount of electric energy produced and consumed as well as other parameters were measured, registered and analyzed.

Materials and methods

At the desiccation process the air going through the hemp mass serves as a source of heat and the transporter of water vapor. Going through the hemp mass the air becomes saturated with water vapor and cools down, because for water evaporation heat is taken from the air going through the hemp mass. Every gram of water evaporated from 1 m^3 of air decreases its temperature by 2 ºC. The lower the outgoing from the hemp mass air temperature, in comparison with the ingoing air temperature, the more intensive the desiccating process. The intensity of the desiccation process depends on the velocity of the air flow through the desiccation mass, the air relative humidity and its temperature as well as the humidity of the desiccating mass and its biological properties.

For experimental investigation of the desiccation process of herbaceous plants like hemp a specific device consisting of an air flow distribution tube and perforated desiccation tube of diameter 100 mm and the internal cross-section 78.5 cm^2 was made (Fig. 1, a).



a) b)

Fig. 1. **Desiccation device of herbaceous plants rolled up in a roll mass:**
a – design of the device; b – location and diameters of the bores

In the desiccation tube the wall 22 openings were bored in 4 vertical lines with total cross-sectional area 18 cm^2 (Fig. 1, b). The diameter of the bores and the distance among them was chosen according to the changing density of the hemp mass in the roll and the pressure of the air flow in the desiccation tube.

Fig. 2. **Hemp desiccation device with the heated airand solar radiation energy concentrator:** 1 – concentrator; 2 – heater

For air heating a cylindrical two space solar air heater was fabricated (Fig. 2) consisting of two cylinders – outer and inner. The outer cylinder is made of a transparent plastic film, but the inner is made of a metal sheet, painted in black from outside and serving as an absorber of the solar energy going through the outer cylinder. Both ends of the cylinders are closed with metal sheet covers, having openings for air inflow and outflow. For the ventilator operation an electric motor using 12 V of direct current was used. The electric current was obtained using the solar energy battery “97 W flexible PV module”. The rated voltage of the solar battery “97 W flexible PV module” was 14 V. In order not to overload the motor of the ventilator the solar energy battery was connected to the ventilator motor using the voltage stabilizer. The scheme of the connection of the elements for the experimental investigation is presented in Fig.3, where the desiccation tube 3 by means of the air tubes 6 and 8 is connected to the air ventilator 7 and the air heater 10. By an electric cable the ventilator and the electric motor are connected to the electric voltage stabilizer 14 and the solar battery module 13.

The air temperature and humidity of the outside air and air into the desiccation material were measured and registered using two logger HOBO-H08-007-02 modules. One of them 4 was placed into the middle part of the desiccation material (internal sensor) (Fig. 3), where it measured and registered the air temperature and relative humidity inside the roll, but by the outside (external) sensor the inflow and outflow air temperature of the air heater have been measured. In order not to measure and register the air flow velocity in the tubes, the direct current electric motor was used, which was fed by the voltage produced by the solar battery module using the current voltage stabilizer. Using coherence $V = f(U)$, the necessary air flow velocity into the device tubes was provided by adjusting into the voltage stabilizer a corresponding voltage value of the ventilator motor feeding current.

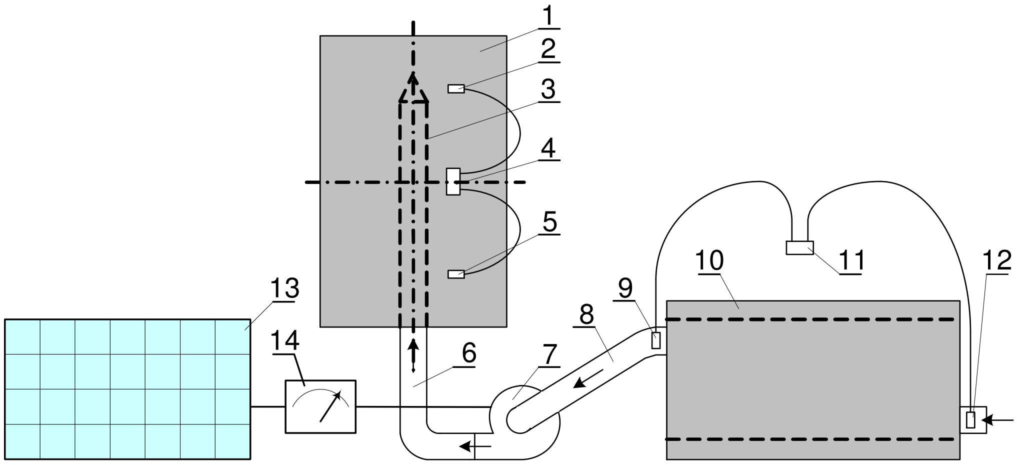


Fig. 3. **Measurement data recording scheme:** 1 – hemp roll; 2 – temperature sensor (T4); 3 – air distribution tube; 4 – data (T1;RH) recorder HOBO-H08-007-02 (Nr.853857); 5 – temperature sensor (T3); 6 – air duct; 7 – ventilator; 8 – air duct; 9 – temperature sensor (T4); 10 – two-chamber cylindrical solar air heater; 11 – data (T1;RH) recorder HOBO-H08-007-02 (Nr.697103); 12 – temperature sensor (T3); 13 – the solar cell module; 14 – voltage regulator-stabilizer

The power of the electric motor for the ventilator drive was used for the air flow creation in the desiccation tubes as well as for compensation the air flow losses in the ventilator, connections and desiccation tubes.

The useful power P of the ventilator drive was calculated as follows [6]:

$$P = \frac{L \cdot p}{1000}, \tag{1}$$

where L – ventilator drive, $m^3 \cdot s^{-1}$;
p – air pressure, Pa.

The full ventilator drive power considering losses to overcome friction into the ventilator body, in bearings and other, was computed by the following formula [6]:

$$P_f = k_r \frac{L \cdot p}{1000 \cdot \eta \cdot \eta_b \cdot \eta_e}, \tag{2}$$

where k_r – coefficient of power reserve;
η – coefficient of hydraulic losses from air flow friction;

η_b – coefficient of power losses in bearings;
η_e – coefficient of power loses in the electric motor.

During the desiccation process the static air flow pressure created by the ventilator is used to overcome the air resistance in the desiccation material as well as to overcome the friction in the air distribution tube. The power losses make around 5 % from the pressure losses in the desiccation material.

The air pressure losses into the desiccation material roll can be stated experimentally using coherence similar to that for the calculation of the pressure decrease in uneven air duct [7]:

$$p = \lambda_r \frac{h \cdot \rho_d \cdot v^2}{2 \cdot d_e}, \tag{3}$$

where λ_r – coefficient of air flow total resistance;
h – thickness of desiccation material, m;
ρ – density of desiccation material, kg·m^{-2};
v – velocity of air flow through desiccation material, m·s^{-1};
d_e – equivalent of air flow duct diameter, m.

Results and discussion

Before starting the desiccation process, the velocity of the air flow through all the desiccation tube openings was measured (Table 1) using an electric air flow velocity measuring device (Testo 425). During the measurements the electric motor of the ventilator was fed by direct electric current produced by the solar battery "97 W flexible PV module" with voltage 14 V, which was adjusted and delivered to the motor using the voltage stabilizer.

In the same way to one of the bottom air flow openings the coherence between the air flow velocity and feeding voltage of the electric motor was determined.

For the experimental investigation on the desiccation device stand (or framework) a sheet of veneer / plywood was put and covered with a plastic film. Then on the desiccation tube a hemp roll with diameter 60 cm and height 1.3 m was put (Fig.3). Dried up on the field a hemp roll before starting the desiccation process was weighed on a balance with accuracy ±5 g and the mass was 26.32 kg.

Table 1

Velocity of the air outflow through the desiccation tube openings at the ventilator electric motor feeding voltage 14 V

To opening rows from bottom to top	Air flow velocity, m·s^{-1}					
Front view	14.4	14.5	14.5	14.7	14.8	14.5
Left side view	14.5	14.5	14.2	14.3	14.0	-
Rear side view	14.1	14.0	14.0	14.2	14.3	14.0
Right side view	14.5	14.7	14.5	14.3	14.0	-

In the first stage of the experiment the air heater without the solar energy concentrator was used, but in the second stage the energy concentrator has been used (Fig. 4).

Favorable weather conditions for desiccation set in on September 14, 2014 and the sky without clouds remained till September 20. The hemp roll was desiccated for 4 days. During the first 2 days (September 4 and 15) the air heater was working without the solar energy concentrator, but the second two days (September 16 and 17) the air heater with solar energy concentrator was used (Fig. 5). In the afternoon on September 17, the hemp roll was taken away from the desiccation tube and weighed. The weight was 19.53 kg. During 4 days 6.79 kg (25.8 %) water has been desiccated. During the desiccation time the electric motor of the ventilator was operating with the voltage 14 V ensured by the voltage stabilizer, when the voltage produced by the solar battery was higher than 16 V. In order to produce voltage higher than 16 V it was necessary for the solar battery to track the sun.

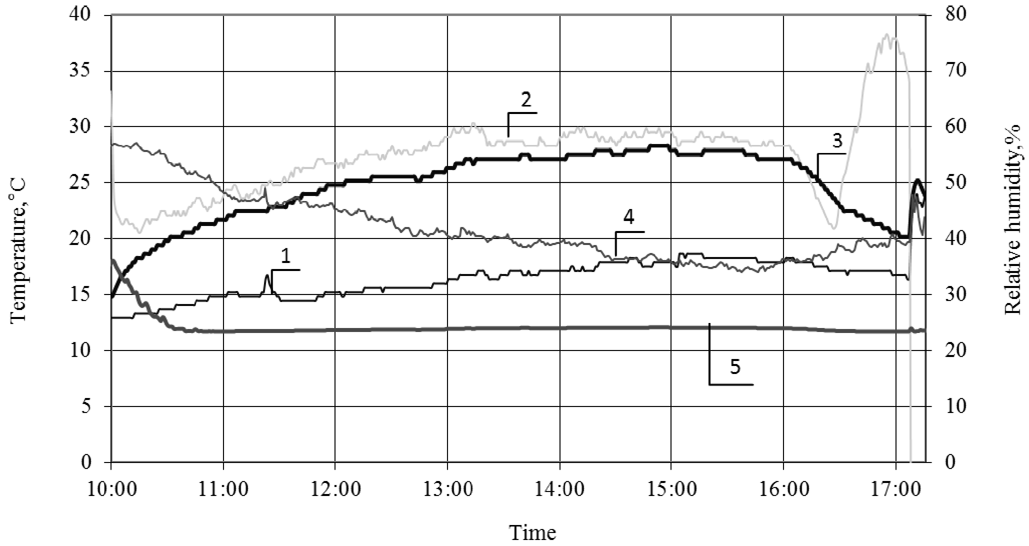


Fig. 4. **Hemp desiccation parameter characteristic graph using the heated air without the solar radiation energy concentrator:** 1 – ambient air temperature; 2 – ambient air relative humidity; 3 – outflow air temperature; 4– temperature inside the hemp roll; 5 – relative humidity inside the hemp roll

Using the data from Table 1 the total air flow through the air desiccation tube at the feeding voltage of the electric motor 14 V has been computed. It was stated that the average air flow velocity through the desiccation tube openings was $v = 14.34\ \mathrm{m \cdot s^{-1}} = 5.16 \cdot 10^4\ \mathrm{m \cdot h^{-1}}$ and the intensity of the outgoing air flow was 93 $\mathrm{m^3 \cdot h^{-1}}$.

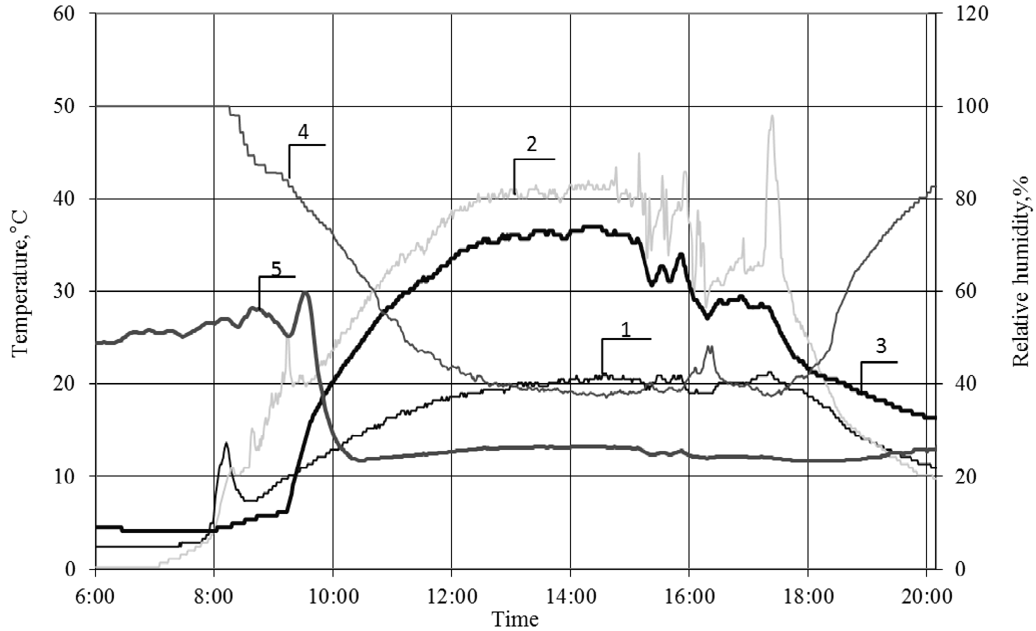


Fig. 5. **Hemp desiccation parameter characteristic graph using the heated air with the solar radiation energy concentrator:** 1 – ambient air temperature; 2 – ambient air relative humidity; 3 – outflow air temperature; 4– temperature inside the hemp roll; 5 – relative humidity inside the hemp roll

As the hemp roll mainly consists of hemp stalks (stems), it is possible to assume that the amount of air delivered from the air heater into the hemp roll was 93 $\mathrm{m \cdot h^{-1}}$.

In Fig. 4 the curves of hemp desiccation characteristic parameters are presented, when the air heater without the solar energy concentrator was used. It follows that at the air flow intensity 93 $\mathrm{m^3 \cdot h^{-1}}$ the air heater without the solar energy concentrator is able to heat the ventilation air by

T_2 = 12.5 ºC above the outside air temperature. As a result the air temperature into the hemp roll (T_3) was higher than the surrounding air temperature by 10 ºC (T_1). More intensive desiccation was taking place in the middle of the day around 13:00 o'clock, when (T_2-T_3) was higher than 2.5 ºC. All the desiccation time the air relative humidity into the hemp roll changed insignificantly and its value was around 24 %.

In Fig.5 the curves of hemp desiccation characteristic parameters are presented, when the air heater with the solar energy concentrator was used. From the air heater outgoing air temperature (T_2) was by 20 ºC higher as the surrounding air temperature (T_1). The air temperature into the hemp roll (T_3) was by 4 ºC lower as from the air heater outgoing air temperature (T_2), what means that the desiccation process was more intensive as in the first case. The relative humidity into the hemp roll (RH_5) during night time increased up to 60 %, but in the morning after starting the desiccation process the relative humidity into the hemp roll decreased to 22 % and with a small fluctuation remained constant till the end of the desiccation process. In the night from September 16 to 17 the hemp roll on a half from top to bottom was covered by a canvas bag that resulted in the decrease of the relative humidity to 23 % and during the day it changed insignificantly.

Conclusions

1. Using the presented experimental facilities and only solar energy during four September days the mass of the hemp roll with diameter 0.6 m and height 1.3 m decreased from 26.32 kg to 19.53 kg or by 25.8 %.
2. Operating the direct current electric motor with voltage 14 V the intensity of the air flow into the desiccation tube and the hemp mass was 93 $m \cdot h^{-1}$.
3. At the air flow intensity 93 m h^{-1} the circular two space solar energy air heater without the solar energy concentrator warmed the inflowing into the desiccation tube air by 12.5 ºC, but with the concentrator by 20 ºC.
4. Using the two space solar energy air heater with the solar energy concentrator, the difference between the inflowing into the hemp roll and outflowing air temperature was about 2 times higher than without the solar energy concentration, it means that using the solar energy concentrator the desiccation process goes faster.

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