INFLUENCE OF HARVEST TIME OF *ARTEMISIA DUBIA* WALL. PROPERTIES

Zivile Cerniauskiene[1], Algirdas Raila[1], Egidijus Zvicevicius[1], Zydre Kadziuliene[2], Vita Tilvikiene[2]
[1]Aleksandras Stulginskis University, Lithuania;
[2]Lithuanian Research Center for Agriculture and Forestry
zivile.cerniauskiene@asu.lt

Abstract. In the world, scientists are constantly looking for alternative crops, which would be suitable for energy. Their harvesting period choice is an important task in order +to reduce the production of biofuels-storage costs. This choice has influence on the properties of plants, technology of production-preparation and storage, also natural conditions. Lithuania is in the temperate zone, which is characterized by changeable weather. Often prevailing precipitation determines the harvesting possibilities of herbaceous energy crops, their biometric, mechanical and thermal properties. The dry biomass yield of *Artemisia dubia* Wall. has influence on: the growing years, fertilization, soil quality and other conditions. The study had shown 22.0 to 27.6 $t \cdot ha^{-1}$ DM yield potential of *Artemisia dubia* Wall. in Lithuania on *Endocalcari-Endohypogleyic Cambisol (CMg-n-w).* Morphological part (stems and leaves) quantities of the total mass dependence on the harvesting time of *Artemisia dubia* Wall. were fixed. The lowest stems (73.73 ± 2.66 %) and the largest leaves (26.27 ± 2.66 %) mass percentages share were found of raw materials, when they were harvested in October. When harvested in the spring, *Artemisia dubia* Wall. stem weight had increased, and the leaves of the mass fraction of the raw material decreased by 20.65 percentage points. Material moisture variation depending on the harvesting time was found. From October to March, the raw material moisture content decreased from 59.15 ± 0.8 % to 10.98 ± 0.60 %. This directly affected the biological activity and storage capabilities of the raw material without additional energy input. In early spring, removing *Artemisia* without further preparation, it can be successfully used for thermal conversion.

Keywords: energy crops, *Artemisia dubia* Wall., harvest, humidity, biological activity.

Introduction

Lithuania as well as many European Union countries are not rich in fossil fuel: natural gas, oil or coal resources and therefore actively interested in potential of alternative energy resources[1; 2]. In the middle climate latitude about 74 % of renewable energy is accumulated in plant biomass. The significant part of it consists of woody energy crops – wood and forest felling waste. This is a traditional biofuel. The EU forests cover 161 million hectares (that is 4 % of the world's forest area). They cover 38 % of the EU area [3], but their distribution is uneven. The 1st country under forest coverage in the EU is Finland (72 %), 2nd place – Slovenia (60 %), 3rd – Sweden (58 %). The Baltic states are also rich in forests: Estonia's forest coverage reaches 61 %, Latvia's – 44 %, Lithuania's – 33.2 %. Currently, in Lithuania 7 million m^3 of wood per year are felled [4; 5]. It is all kinds of cuttings. Moreover, the wood as the raw material is important for other branches of economy and more complex conversion technologies than burning extraction heat and electricity.

Agriculture is abundant in secondary products: straw, cleaning waste of grain crops, which can be used to produce energy. The elemental composition of dry weight of straw is slightly different from wood, but it is characterized by a lower calorific value, lower melting temperature (ash deformation begins at 735-840 ºC) and a higher ash content (from 4.5 to 6.5 %) [6]. However, the resulting total amount of straw we cannot use for energy purposes. Also, straw is used as feed or litter for animals, as raw material for art, as mulch – in gardening, as a fertilizer – in crop production and construction material. Therefore, it is very important to have many non–food crops that could be appropriate and effective sources of renewable energy [7]. Lately, much attention is paid to herbaceous energy crops, which are able to accumulate high yields of dry matter. For example, switchgrass (*Panicum virgatum* L.) yield varies from 5 to 23 $t \cdot ha^{-1}$ DM, raygras (*Lolium* ssp.) from 9 to 12 $t \cdot ha^{-1}$ DM, reed canary grass *(Phalaris arundinacea)* from 7 to 14 $t \cdot ha^{-1}$ DM, cocksfoot grass (*Dactylis glomerata* L.) from 8 to 10 $t \cdot ha^{-1}$ DM, namely, miscanthus*(Miscantus spp.)* from 4 to 30 $t \cdot ha^{-1}$ DM, common mugwort *(Artemisia vulgaris)* from 3.1 to 7.3 $t \cdot ha^{-1}$ DM. [8-13]. The plants with high potential of yield and large quantities of lignin and cellulose are attractive for production of biomass. Moreover, these plants can be grown in unused land areas, which in Lithuania are about 20 %.

It is important to know the plants and to study their properties to promote wider use of herbaceous energy crops for energy purposes[7]. Having the great potential and mugwort (*Artemisia dubia* Wall.)

is considered, which in Lithuania is little explored [14; 15] and still does not have a specific destination. It can be used as a raw material to grow a high potential of yield (22.0-27.6 t·ha^{-1} DM) [14; 15], generate energy during the thermochemical conversion. As well as other herbaceous energy crops, harvest of biomass of mugwort must be removed annually. So, a very important task is to choose an optimal biomass harvesting time and technology. The timing depends on the ambient weather conditions, which affect the moisture content of biomass. The moisture content of biomass of *Artemisia dubia* Wall. at harvest time can reach to 60 % [14; 15]. This complicates the biomass retention and subsequent use for energy purposes without further preparation and energy costs.

Materials and methods

Environmental natural conditions were assessed by analyzing the data of hydro-meteorological stations of the Lithuanian Hydrometeorological Service under the Ministry ofEnvironment. They were analyzed in perennial air temperature and humidity, compared with former environmental conditions in the experimental research period (from April, 2014 to March, 2015) and their influence on the moisture content of removable stems and leaves of mugwort (*Artemisia dubia* Wall.).

Mugwort (*Artemisia dubia* Wall.) is grown at the Lithuanian Research Center for Agriculture and Forestry. Investigations in biomass properties were carried out at the Laboratory of biomass treatment, logistics and solid fuel processes, at the Institute of Energy and Biotechnology Engineering, at the Aleksandras Stulginskis University using above-ground part of *Artemisia dubia* in the second year of its growth.

The assessment ofbiometric indicators was carried out at different harvest periods, i.e. on the 2ndof October, 2014, 2ndof December, 2014 and 19thof March, 2015. The samples of the plants were selected randomly for further research in testing fields and sorted to leaves and stems, then they were brought to the laboratory. Each plant (separately leaves and stems) was weighed by the scales “SCALTEC SPO 51”. Additionally, the length and diameters of the stem over the entire height of the plant each 20 cm were measured. After all measurements, the moisture content of raw material was determined by drying specially prepared samples till the constant weight in a drying cabinet “Memmert UPF 700” at temperature of 105 ± 2 ºC.

Knowing the plant mass of the stems and leaves, also the percentage of the total plant mass of stems and leaves weight ratio was evaluated. All results obtained during the research were analysed using *MS Office Excel* software.

In order to determine the biological activity – amount of carbon dioxide (CO_2) which was released during breathing and heat flow, the above–ground part of the raw materials of *Artemisia* was chopped, then placed in desiccators and weighed. The desiccators were closed tightly and put in a climatic chamber “FEUTRON KPK 600”. There to prepare with biomass (56.93 ± 2.05 % to 20.70 ± 0.42 % humidity) the desiccators were stored at different temperatures, i.e. at 3 ± 0.32 ºC, 10 ± 0.57 ºC, 15 ± 0.51 ºC, 25 ± 2.69 ºC environment. The concentration of carbon dioxide was measured with the gas analyzer “Kane Auto 4-2” inside the desiccators every 2-3 hours. Then the comparative amount of carbon dioxide was calculated:

$$m_1^* = \frac{m_{CO_2}}{m_2^* \cdot t}, \tag{1}$$

where m_1^* – comparative amount of CO_2, which was released during breathing, mg·(kg·h)$^{-1}$;
m_{CO_2} – mass of CO_2, which was received, mg;
m_2^* – mass of raw materials, which was embedded in the desiccators, kg;
t – duration of the experiment, h.

The heat flow was received during breathing calculated according to the nutrient decomposition reaction:

$$q_k = m_1^* \cdot 0.00298, \tag{2}$$

where q_k – heat flow, W·(kg·h)$^{-1}$.

Results and discussion

Lithuania is in the temperate zone, characterized by changeable weather. Frequent precipitation, changes in temperature have influence on the energy crop harvesting time and the technical possibilities to cut harvest. Hydro-meteorological data of the harvesting period (from October, 2014 to March, 2015) of mugwort are presented in Fig. 1.

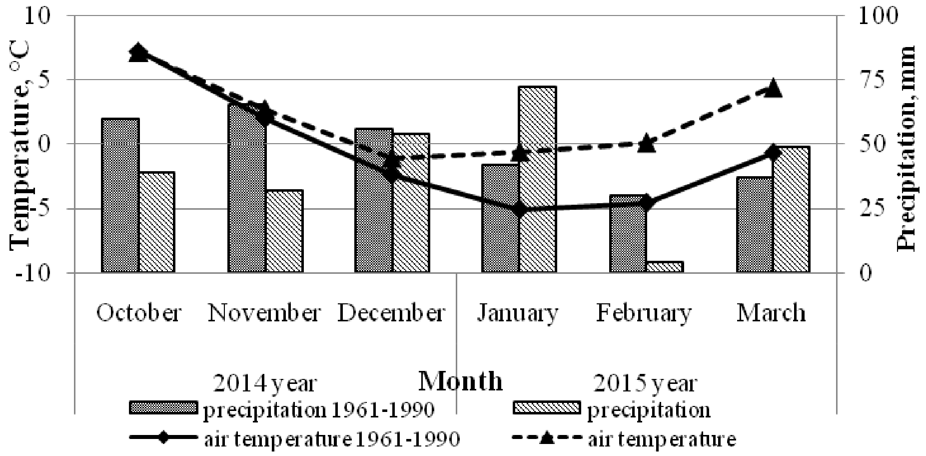

Fig. 1. **Perennial and experimental research period hydro-meteorological data in Lithuania**

From October to February the hydro–meteorological data recorded 0.1 to 7.5 times of the dry period were compared with the perennial data. Particularly striking decrease of precipitation (fell out only 4 mm) was recorded in February. Meanwhile, in January 2015 and March, respectively 1.7 times and 1.3 times more humid period was fixed compared with the perennial meteorological data. Also a warmer period was recorded in the analyzed harvesting period, i.e. from October to March the air temperature has warmed, respectively from 0.1 to 5.1 ºC.

At the beginning of the 3rd decade of November, 2014 there was a 1-5 cm thick snow cover, but at the end of the month and the beginning of December it was less than 1 cm. On 25-28 of December again there was snow and the end of the month the average thickness of it it was 2-7 cm. The snow melted in the 1st days of January, 2015. Again there formed a thick snow cover on the 2nd day of January, but by the mid of the month there was no snow. The snow cover kept for until the end of the month, which formed at the beginning of the 3th decade. The average thickness of the snow cover was 2-7 cm on the 31st of January. A similar thick snow cover is maintained almost the entire 1st decade of February. Later, the snow began to melt rapidly and at the end of the month snow had almost disappeared. In the middle of the 1st decade of March it was snowing and it formed 0.5-3 cm thick snow, which melted after 2-3 days. A thin snow cover was again formed on 22-23 of March.

Frost was recorded in the 1st decade of October. Freezing of the soil was observed in 23-30 days of October, when it strongly began to sour. It lasted for 4-8 days; the depth of frozen ground was 2-6 cm. The frozen ground began to take shape in the soil, when negative air temperature in November had stabilized. The first signs appeared at the end of the 2nd decade, but more seriously frozen ground was fixed in the last five days of November. The depth of the frozen ground was 3-15 cm on the last day of the month. The soil was frozen until 20-32 cm at the end of the 1st decade of December, however, slight (2-3 cm) defrosting was observed. The soils warmed at the end of the 2nd decade and again began on the 26thof December and the thickness was 15-25 cm on the 31thof December. The freezing depth of the soil was 15-26 cm at the end of the 1st decade of January, 2015. More significant defrosting was observed in the middle of the decade. The frozen ground was the deepest in Dotnuva (25 cm) at the end of the 2nddecade. The soil had begun to thaw in the middle of the decade. However, it reformed and reached 9 cm thickness at the end of the decade. The soil was frozen until 17-22 cm in the 1st decade of February. At the beginning of the 2nd decade the depth of freezing followed similarly, but at the end of the decade permafrost thickness increased by 6-10 cm and in the last decade it was 18-32 cm. In some places the upper soil layer was dissolved 3-6 cm. The local frozen soil did not remain at the end of the 3rd decade. The last balances of frozen ground to thaw ended on the 3-6th of March.

The environmental conditions have influence on variation of humidity and other properties in mugwort. The average moisture content of *Artemisia dubia* Wall. was 59.15 ± 0.8 % for the mixture, 63.53 ± 3.18 % for the stems, 56.86 ± 2.84 % for the leaves, when it was cut in October. Variation of the moisture content of raw material in harvesting time is presented in Fig. 2.

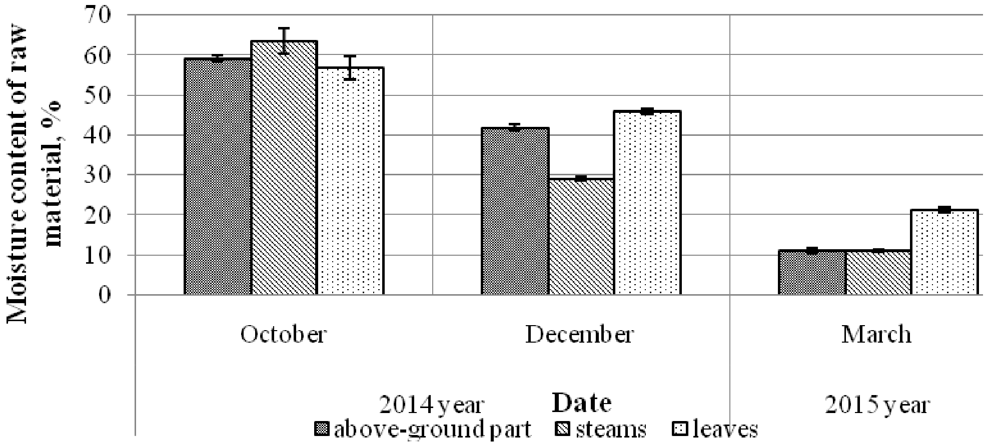

Fig. 2. **Variation of moisture content of raw material in harvesting time**

When biomass harvesting time was postponed to December, then the moisture content of the mixture decreased to 41.95 ± 0.77 %, stems – 29.1 ± 0.57 %, leaves – 46.03 ± 0.61 %. I.e. respectively 1.4, 2.2, and 1.2 times less than compared with the raw material cut in October.Biomass harvesting time postponement from October to March decreased the moisture content of the mixture, stems and leaves, respectively 5.4 (to 10.98 ± 0.60 %), 5.7 (to 11.12 ± 0.26 %) and 2.7 times (to 21.35 ± 0.72 %).

Studies have shown that biomass cutting time also has a significant influence on the raw material quantity of stems and leaves: when the cutting time of raw materials was delayed, the leaves quantity of the total plant mass decreases. The dynamics of mugwort (*Artemisia dubia* Wall.) stems and leaves mass ratio is presented in Tab. 1.

Table 1

The dynamics of mugwort stems and leaves mass ratio

Harvest time	**Stems mass**		**Leaves mass**		**Ratio**
	g	%	g	%	
2014.10.02	68.46 ± 13.39	73.73 ± 2.66	25.47 ± 6.50	26.27 ± 2.66	2.98 ± 0.47
2014.12.02	67.06 ± 23.43	87.61 ± 2.93	9.17 ± 4.01	12.39 ± 2.93	7.88 ± 2.0
2015.03.19	26.71 ± 6.21	94.38 ± 2.44	1.77 ± 1.02	5.62 ± 2.44	27.40 ± 15.17

The lowest stems (73.73 ± 2.66 %) and the largest leaves (26.27 ± 2.66 %) mass percentage share was found of raw materials, when they were harvested in October. When the harvesting time was postponed to December, then the stems mass increased by 13.88 % (to 87.61 ± 2.93 %) and the leaves mass fraction decreased respectively (to 12.39 ± 2.93 %).When harvested in spring, *Artemisia dubia* Wall. stems weight increased (to 94.38 ± 2.44 %) and the leaves of the mass fraction of the raw material decreased by (to 5.62 ± 2.44%) 20.65 percentage points. Also the largest above ground plants parts – stems and leaves mass ratio (27.40 ± 15.17) of the raw material was fixed, when harvested in spring. It is 3.48 times higher than to cut the above-ground biomass of *Artemisia* in Decemberand even 9.19 times higher – than in October.

The biological activity of *Artemisia dubia* Wall. has been assessed by measuring the respiration rate of the chopped above-ground part of the plants mass. The respiration rate has influence on humidity of raw materials and the storage conditions. When the raw materials are cut in October or December, the biological intensity increases exponentially with the increase of the storage temperature (Fig. 3 a and b). Biological activity of the raw material yield has not been fixed in March, 2015. The moisture content of the raw materials was only 10.98 ± 0.60 % and it was too small for microbiological and biochemical processes to develop in the mass of mugwort.

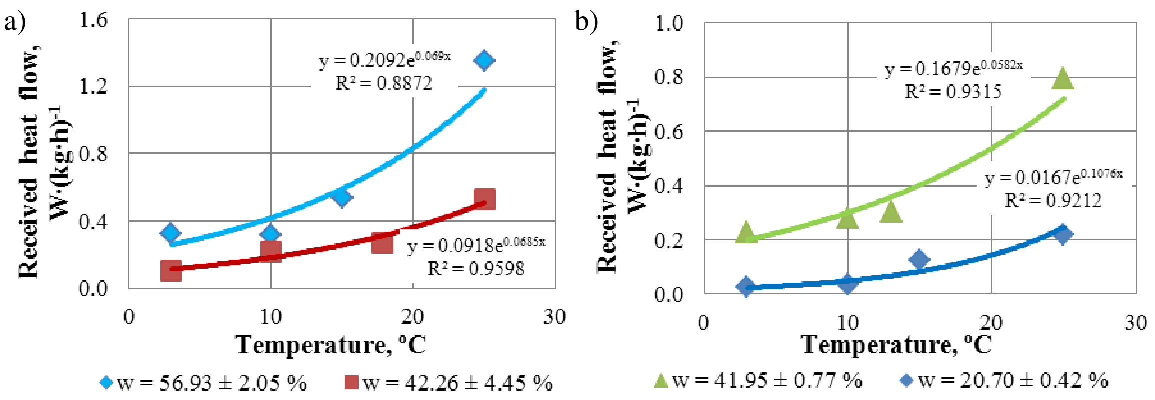

Fig. 3. **Received heat flow in biomass of different moisture content, cutting in October (a) and December (b)**

Intensity of the received heat flow is observed, when the above–ground part of the plant humidity is in average 56.93 ± 2.05 %. When storing 56.93 ± 2.05 % moisture content of the raw material in 3 ºC temperature, the received heat flow (0,324 W·(kg·h)$^{-1}$) approximately 3.1 times higher than 42.26 ± 4.45 % (0.106 W·(kg·h)$^{-1}$) in the raw material. When 42.26 ± 4.45 % moisture content of the raw material was storing in 10 °C temperature the received heat flowwas 0.317 W·(kg·h)$^{-1}$, i.e. 1.5 times more than dry mass (42.26 ± 4.45 %) of raw material (0,214 W·(kg·h)$^{-1}$), when was storing under the same environmental conditions. When the ambient temperature rises to 15 ºC in humid raw material, the received heat flow (0.537 W·(kg·h)$^{-1}$) was approximately 2.1 times greater than 42.26 ± 4.45 % (0.256 W·(kg·h)$^{-1}$). Rising the environmental temperatures to 25 ºC in humid raw material, the received heat flow (1.349 W·(kg·h)$^{-1}$) was approximately 2.5 times greater than 42.26 ± 4.45 % (0.532 W·(kg·h)$^{-1}$).

A similar tendency was observed in raw material when cutting in December. However, comparing a similar moisture content (42.26 ± 4.45 and 41.95 ± 0.77 %) of raw materials, only cut at different times (October and December), we observed that the raw material cut in December emits more heat flow storing in the same environmental conditions. 41.95 ± 0.77 % moisture content of the raw material, when storing in 3, 10, 15 and 25 °C temperature was obtained, respectively, 2.2, 1.3, 1.6 and 1.5 times higher received heat flow than in 42.26 ± 4.45 % raw material.

Conclusions

1. Biomass harvesting time postponement from October to March decreased the moisture content of the mixture, stems and leaves, respectively 5.4 (to 10.98 ± 0.60 %), 5.7 (to 11.12 ± 0.26 %) and 2.7 times (to 21.35 ± 0.72 %).
2. The studies have shown that the biomass cutting time also has a significant influence on the raw material quantity of stems and leaves: the largest above ground plants parts – stems and leaves mass ratio (27.40 ± 15.17) of the raw material was fixed, when harvested in spring.
3. Compared to a similar moisture content (42.26 ± 4.45 and 41.95 ± 0.77 %) of raw materials, only cut at different times (October and December), we observed that the raw material cut in December emits more heat flow, storing in the same environmental conditions.
4. 41.95 ± 0.77 % moisture content of the raw materials, when storing in 3, 10, 15 and 25 ºC temperature was obtained, respectively, 2.2, 1.3, 1.6 and 1.5 times higher received heat flow than in 42.26 ± 4.45 % raw material.
5. The processes, which are in the stored layer of wet products, must be managed. It is possible to make on drying of the raw material to a safe moisture content or constantly checking temperature in layer of the raw material.

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