DRYING RESEARCH IN PERENNIAL MUGWORT (*ARTEMISIA DUBIA* WALL.)

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Abstract. Lithuania's annual consumption of energy is 201 PJ, of which about 30 % is extracted from biomass. Herbaceous energy crops which are growing in a high biomass yield can be successfully used by biofuel. All herbaceous plants have high humidity which influences the possibilities of the harvest storage. Humidity of *Artemisia dubia* Wall. was 59.15 ± 0.8 % when they were cut in October. A drying research in thick still layer was carried out at the laboratory of biomass treatment, logistics and solid fuel processes in the Aleksandras Stulginskis University. It was found that using ventilation of 11.16 ± 3.9 ºC temperature and 83.9 ± 13.2 % relative humidity of unheated environmental air through a layer of crushed *Artemisia dubia* Wall. while using supplied comparative intensity of ventilation which was changing from 150 to 590 $m^3 \cdot (t \cdot h)^{-1}$, the drying time has decreased from 10.9 to 4.7 days. Biomass has been dried to safe 11.66…13.06 % moisture. During studies an established influence was found at intensity of ventilation for the mass drying process and change of the physical properties of *Artemisia dubia* Wall.

Keywords: biomass, perennial plants, *Artemisia dubia* Wall., drying, active ventilation

Introduction

Expanding industry, increasing energy demands and constantly descending fossil fuel: oil, gas, coal, etc., pushes us to think about alternative energy usage possibilities. The European Union intends to increase this energy 3...3.5 times till 2020, and 3.5...4.5 times till 2030 [1]. Lithuania is committed to increase renewable energy consumption by not less than 23 % of general energy consumption in the country till 2020 [2]. In 2013 Lithuania used 201 PJ of energy, of which about 30 % was extracted from biomass [3].

In the middle climate latitude about 74 % of renewable energy is accumulated in plant biomass. That is why plant biomass is the most important renewable energy source in Lithuania. It takes a huge part in local biomass. Plant biomass resources could be used to supplement energy consumption. The biggest potential of plant biomass fuels (more than 1 mln. tons) are in Vilnius county, smaller (from 700 to 750 thousand tons) – Panevėžys, Šiauliai and Utena, and the smallest (from 300 to 420 thousand tons) – the remaining counties [4].

Herbaceous and coarse-energy plant usage for energetic objective possibilities is explored worldwide. Priority is given to perennial crops, which have significant potential and could grow a high yield every year. It reduces the growing costs of raw materials and has positive impact on net energy balance [5-8]. Depending on the selected technology of cultivation and existing environmental conditions, reed canary grass (*Phalaris arundinacea*) yields vary from 7 to 14 $t \cdot ha^{-1}$ dry weight, namely miscanthus (*Miscantus spp*.) - from 4 to 30 $t \cdot ha^{-1}$ dry weight, common mugwort (*Artemisia vulgaris*) - from 3.1 to 7.3 $t \cdot ha^{-1}$ dry weight [8-11].

Perennial mugwort (*Artemisia*) is a broad genus of plants. It owns more than 500 species [12]. Mostly regarded as weeds these plants have little exploration. There are 11 species [13] of perennial mugwort (*Artemisia*) growing in Lithuania. Mugwort (*Artemisia dubia* Wall.) is also included, which in conditions of Lithuania produces almost 30 $t \cdot ha^{-1}$ of dry weight and it can be used as a raw material for bioenergy production. However, all herbaceous plants have a high humidity. This complicates their storage after harvest. When moist raw material is in storage, the layers create favorable conditions for biochemical and microbiological processes, evolving mold fungi, diminishing the quality of raw materials and increasing their wastage. Thus, the harvested plant biomass should be preserved or its unwanted processes taking place in the layer should be otherwise managed. In many cases, to devote a long-term storage of energy for herbaceous plants humidity should not exceed 20 % [4]. It is difficult for a raw material to be dried to safe moisture content in natural conditions. Final moisture content of raw materials depends on the time of the year, natural environmental conditions and plant characteristics. The plant biomass can be dried to a safe moisture content of 8-15 % when special drying technology is used and the drying process is controlled [14].

The aim of the research is to investigate the mugwort (*Artemisia dubia* Wall.) drying process in a thick still layer.

Materials and methods

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

At first, appreciated biometric indicators of mugwort are estimated. Heights and diameters of the thinnest and thickest stem were measured using the meter and electric caliper "STAINLESS HARDENED". Also the weight basis of stems and leaves was established. After that, mugwort of the raw materials were chopped to 23.2 ± 2.89 mm length of fraction with a cutting machine "ALKO Silent Power 4000" and prepared for drying research. From the prepared raw materials of mugwort a mound layer was formed with an average height of 94.8 ± 0.44 cm. The raw material was dried with unheated ambient air with temperature of 11.16 ± 3.9 ºC and relative humidity of 83.9 ± 13.2 %. The used comparative intensity for ventilation was from 150 to 590 $m^3 \cdot (t \cdot h)^{-1}$. The drying process was analyzed in a special test stand (Fig. 1), which consists of four 0.18 m diameter and 1.15 m high ventilated containers, a fan, a chamber of constant static pressure and hatches for control of air flow.

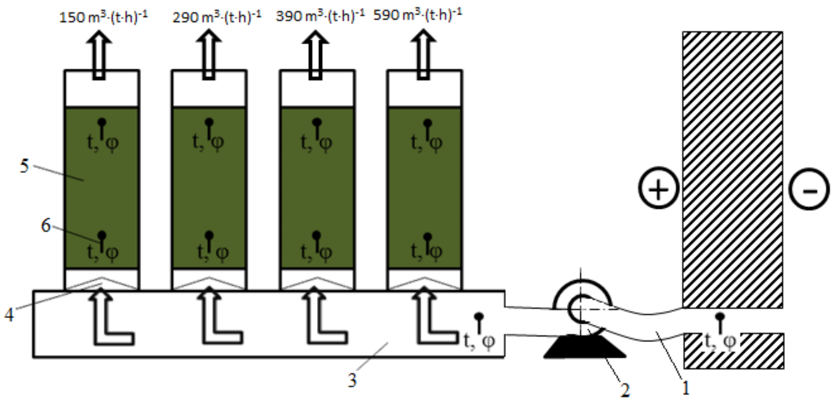

Fig. 1. **Basic scheme of a test bench for material drying in a still thick layer:** 1 – the duct of air supply; 2 – a fan; 3 – a chamber of constant static pressure; 4 – hatches; 5 – ventilated containers; filled with raw material; 6 – air temperature and relative humidity sensors

Chopped *A. dubia* formed four 96.2 ± 0.29 cm, 94.9 ± 0.45 cm, 94.9 ± 0.23 cm, 93.0 ± 0.8 cm layers of raw material in the drying containers. They were forced to ventilate with the air blown from the bottom in different air flows. For parameters of the drying conditions and the drying process to be recorded, temperature and relative humidity were measured in the air intake, in the chamber of constant static pressure and in four ventilated containers, i.e. bottom of the container (from 0.24 to 0.25 m above the bottom of the raw material layer) and top (from 0.47 to 0.48 m from the top of the raw material layer). The measurement results were recorded with the data logging device "Almemo 3290".

Also measured during the research:

- Moisture content of the raw material was determined at the beginning and at the end of the drying process by drying specially prepared samples till the constant weight in a drying cabinet "Memmert UPF 700" at temperature of 105 ± 2 ºC.
- The drying containers were weighed 2-4 times a day using the scales "KERN KVB – TM". Weight changes of the *A. dubia* raw materials were monitored during the drying process and the average moisture content was calculated:

$$w_i^{\tau} = \frac{m_i^{\tau} - m_{s.m.}}{m_i^{\tau}} \cdot 100, \quad (1)$$

where w_i^{τ} – average moisture content of dried raw materials in a container during the drying time, %;
m_i^{τ} – weight of dried raw materials in a container during the drying time, g; $m_{s.m.}$ – dry content of dried raw material, g.

- Intensity of ventilation was controlled and velocity of the air flow through the raw material was measured with the thermo-anemometer "OMEGAFLO HH - 615 M". According to these indications selected intensity of ventilation was maintained:

$$V = 3.6 \cdot 10^6 \cdot \frac{A \cdot v}{m_i}, \quad (2)$$

where A – comparative intensity of ventilation, $m^3 \cdot (t \cdot h)^{-1}$;
v – air filtration rate through drying raw material, $m \cdot s^{-1}$;
S – cross-sectional area of the drying container, m^2;
m_i – weight of loaded raw materials loaded in the container, kg.

Results and discussions

A. dubia were grown in an Endocalcari-Endohypogleyic Cambisol (CMg-n-w). The dry matter yield in the first growing year *A. dubia* was average 6 times less than in the second growing year, i.e. increased from 4.6 to 27.6 $t \cdot ha^{-1}$ dry weight. Stems take the largest above-ground part of the total weight of *A. dubia*. Their weight was 2.98 ± 0.94 times greater than leaves. The stems grew up to 2.41 ± 0.36 m height and the diameter ranged from 9.09 ± 1.31 mm at the thickest part of a stem to 1.38 ± 8 mm at the thinnest part of a stem.

Moisture content of *A. dubia* was 59.15 ± 0.8 % for mixture, 63.53 ± 3.18 % for stems, 56.86 ± 2.84 % for leaves when they were cut in October. The drying researches were carried out with active ventilation in a thick still layer with different 150 ± 7.5, 290 ± 14.5, 390 ± 19.5 and 590 ± 29.5 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilation. Most intense humidity decrease occurred, when it was ventilated with 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilation (Fig. 2). When chopped mugwort was ventilated with 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity, it dried up to 11.66 ± 0.23 % within 4.7 days (113 hrs.), ventilated with 390 $m^3 \cdot (t \cdot h)^{-1}$ intensity – to 10.6 ± 0.14 % within 5.0 days (120 hrs.), ventilated with 290 $m^3 \cdot (t \cdot h)^{-1}$ intensity – to 10.6 ± 0.14 % within 5.0 days (120 hrs.). The longest raw material has dried when it was ventilated with 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity. Its moisture content decreased to 27.11 % within 5.0 days. Safe moisture content (13.06 ± 0.5 %) was reached just through 10.7 days (262 hrs.).

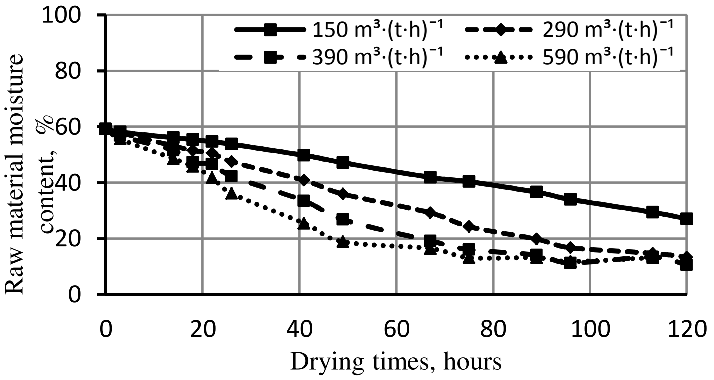

Fig. 2. **Dynamics of mugwort (*Artemisia dubia* Wall.) drying in a thick still layer**

The speed of the raw material drying process can be increased when higher comparative intensity of ventilation through the raw material layer is supplied (Fig. 3). Drying time is inversely proportional to comparative intensity of ventilation. Safe 8-15 % moisture content when ventilated with 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity is reached 2.3 times later than ventilated with 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity, 2.2 times later – ventilated with 390 $m^3 \cdot (t \cdot h)^{-1}$ and 290 $m^3 \cdot (t \cdot h)^{-1}$ intensity.

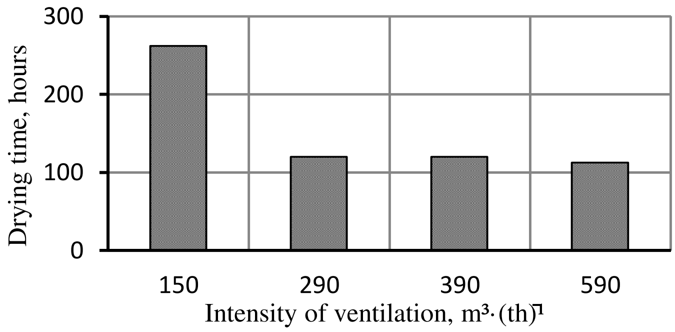

Fig. 3. **Intensity of ventilation influence to drying time**

The temperature and relative humidity sensors which were positioned in different layers of the drying raw material, observed changes of the drying agent temperature and relative humidity of the layer at the bottom and the top. Using unheated 11.16 ± 3.9 ºC temperature and 83.9 ± 13.2 % relative humidity ambient air, 16.51 ± 2.63 ºC temperature and 63.5 ± 16.01 % relative humidity air was blown through a layer of *A. dubia* raw materials. The air warmed on average 3.87 ± 0.19 ºC, and the humidity decreased 2.93 ± 0.14 % in the fan and in the drying agent supply system. The drying process had a significant impact from environmental conditions: precipitation, temperature variations and changes of relative humidity, because non-conditioned ambient air was used. The change of the drying agent temperature was not smooth (Fig.4). Obviously five periods are observed, which are directly correlated with the intensity of ventilation and the actual moisture of raw materials. It was found that if more intense flow was supplied and higher actual moisture content of raw materials, the drying agent and drying process react to the changes of conditions more intensively.

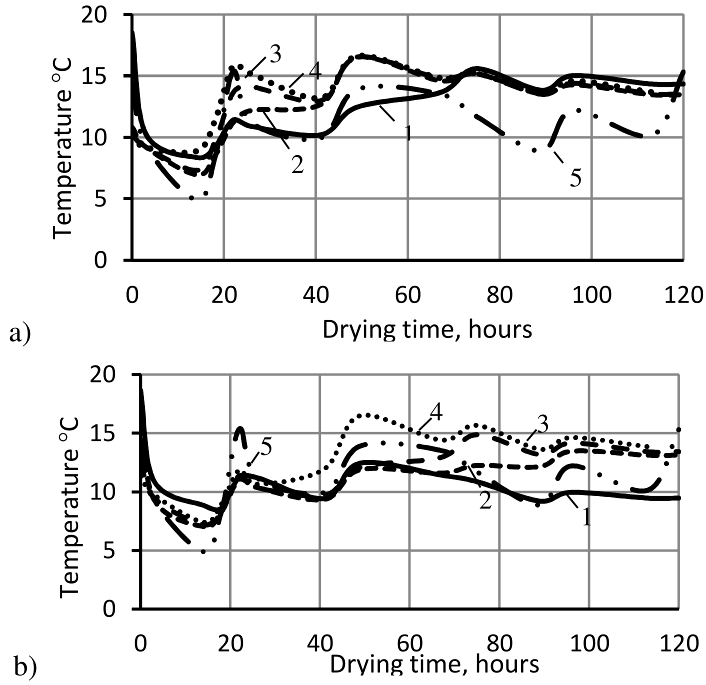

Fig. 4. **Temperature variation of dried raw material in containers at the bottom layer of raw material (a) and at the top layer of raw material (b):** 1 – ventilation with 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity; 2 – ventilation with 290 $m^3 \cdot (t \cdot h)^{-1}$ intensity; 3 – ventilation with 390 $m^3 \cdot (t \cdot h)^{-1}$ intensity; 4 – ventilation with 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity; 5 – ambient air

Also dried produce mound height reduction was followed. The most intensive raw material mound reduction took place in the first 24 hours (Fig. 5). Ventilating with 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity within the first day the mound height was reduced 18.74 ± 0.94 %, ventilating with 390 $m^3 \cdot (t \cdot h)^{-1}$ intensity – 14.82 ± 0.74%, ventilating with 290 $m^3 \cdot (t \cdot h)^{-1}$ intensity – 11.95 ± 0.59 %, ventilating with 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity – 12.27 ± 0.61 %. On later basis the layer stabilized and changed insignificantly, on average 2.38 ± 1.44 % per day. When drying was finished, at 590 $m^3 \cdot (t \cdot h)^{-1}$

intensity of ventilation container the raw material mound height was 25.9 % lower than at the beginning of the drying process (decreased from 92.9 ± 0.14 to 68.9 ± 0.75 cm), at 390 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilation container – 25 % (decreased from 94.5 ± 0.21 to 70.9 ± 0.59 cm), at 290 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilated container – 22.9 % (decreased from 94.9 ± 0.61 to 73.2 ± 0.45 cm) and at 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilated container – 24.3 % (decreased from 96.2 ± 0.14 to 72.8 ± 1.46 cm).

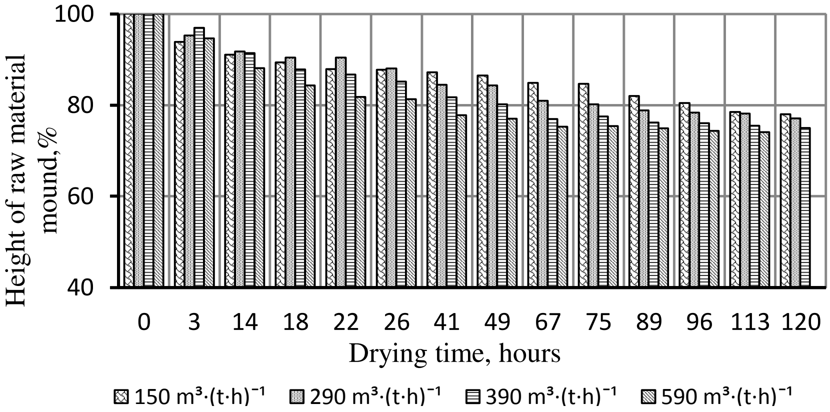

Fig. 5. **Height change of dried raw material mound (*Artemisia dubia* Wall.)**

At the same time the mound density of the dried *A. dubia* raw materials had changed as well. The average density of raw material mounds in the drying containers were 226 ± 6.07 $kg \cdot m^{-3}$, 230, 222, 220 and 232 $kg \cdot m^{-3}$, respectively. On the contrary to the height of the mounds, the most intensive density change in the mounds of dried mugwort took longer – 2-3 days. Ventilating with 390 $m^3 \cdot (t \cdot h)^{-1}$ and 590 $m^3 \cdot (t \cdot h)^{-1}$ intensity (Fig. 6) the most intensive change density of mounds in the first 48 hours: compared with the initial density of dried raw material after 24 hours it was 16.9 % and 21.3 %, respectively, after 48 hours – 30.4 % and 34.6 % less, i.e. 154.7 $kg \cdot m^{-3}$ and 150.4 $kg \cdot m^{-3}$. Relatively stable 143.6 ± 4.15 $kg \cdot m^{-3}$ *A. dubia* density of mounds was reached after 75 hours of drying.

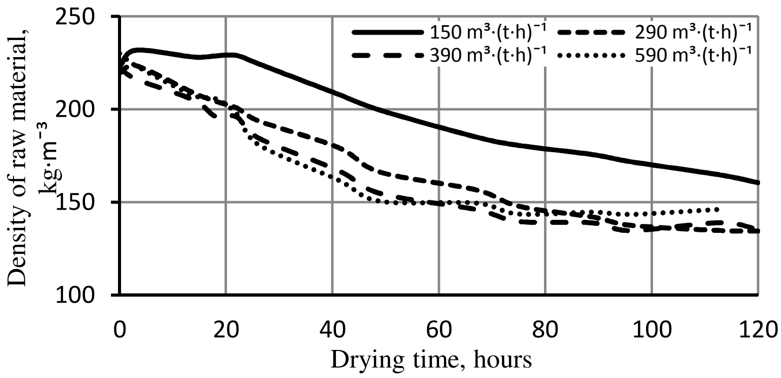

Fig. 6. **Density change in a mound of dried raw materials (*Artemisia dubia* Wall.)**

At the time with 290 $m^3 \cdot (t \cdot h)^{-1}$ the intensity of ventilated raw materials of mounds reached similar density only in the 96th drying hour. During the drying process the density of mound decreased by 38.8 % and was 134.4 $kg \cdot m^{-3}$. The slowest decrease of density of raw materials occurred with 150 $m^3 \cdot (t \cdot h)^{-1}$ intensity of ventilation in the container. After drying (262 hrs.), it decreased to 38.6 % and was 137.1 $kg \cdot m^{-3}$. Irrespective from the selected intensity of ventilation at the end of the drying process chopped *A. dubia* density of mounds was similar, on average 138.2 ± 5.37 $kg \cdot m^{-3}$.

Conclusions

Ventilating with 11.16 ± 3.9 ºC temperature and 83.9 ± 13.2 % relative humidity of unheated ambient air, which has warmed in the air distribution system, was 16.51 ± 2.63 ºC temperature and 63.5 ± 16.01 % relative humidity before getting into the dried layer. Chopped *A. dubia* raw materials were dried to safe 11.66...13.06 % of moisture. Drying duration ventilated with 150 $m^3 \cdot (t \cdot h)^{-1}$ of intensity, the drying time was 10.9 days, when the intensity of ventilation was increasing to

590 $m^3 \cdot (t \cdot h)^{-1}$, the drying time was only 4.7 days, i.e. the drying time decreased by 2.3 times. In Lithuania's conditions during harvest of plant biomass in October, its drying using active ventilation without air preheating does not ensure functioning equivalent flow and smooth drying process. When *A. dubia* was dried, the most intensive reduction in mounds of raw materials occurred during the first 24 hours, while humidity of raw materials was decreasing from 59.2 % to 12.36 %, the height of the layer decreased 22.9...25.9 %, density of mounds – by 1.6 times, i.e. from 220...232 $kg \cdot m^{-3}$ to 134.4...138.0 $kg \cdot m^{-3}$, and it is independent from the intensity of ventilation used in drying.

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References

1. Communication from the Commission. Biomass action plan. Commission of European Communicaties. Brussels, 7.12.2005 COM (2005) 625 finals, 58 p.
2. Nacionalinė atsinaujinančių energijos išteklių plėtros strategija. (The national strategy for the development of renewable energy resources). (In Lithuanian). [online]. [8.10.2014]. Available at: http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_l?p_id=376097.
3. Nagevičius M. Valstybės veiksmai, reikalingi, siekiant išnaudoti biokuro potencialą energijos gamybai Lietuvoje. Biokuro konferencija, 2014 m.
4. Nagevičius M. Valstybės veiksmai, reikalingi, siekiant išnaudoti biokuro potencialą energijos gamybai Lietuvoje. (The State action is required for order to exploit the potential of biofuels for energy productions in Lithuania.) International Biomass Energy Conference, 2014. (In Lithuanian).
5. Kietoji biomasė. (The Solid Biomass). (In Lithuanian). [online]. [8.10.2014]. Available at: http://www.leka.lt/sites/default/files/dokumentai/kietojim_biomase_lietuvos_energetikos_instituta s.pdf.
6. Heaton E., Voigt T., Long S. A quantitative review comparing the yields of two candidate C_4 perennial biomass crops in relation to nitrogen, temperature and water. Biomass and Bioenergy.2004. Vol. 27(1). pp. 21-30.
7. Kryzeviciene A. Perennial grasses as energy crops in Lithuania // Grassland Science in Europe. – 2005, vol. 10, pp. 178-181
8. Heinsoo K., Hein K., Melts I., Holm B., Ivask M. Reed canary grass yield and fuel quality in Estonian farmers' fields // Biomass and Bioenergy. – 2011, vol. 35, pp. 617-625.
9. Jasinskas A., Zaltauskas A., Kryzeviciene A. The investigation of growing and using of tall perennial grasses as energy crops // Biomass and Bioenergy. – 2008, vol. 32, p. 981-987.
10. Šiaudinis G., Jasinskas A., Šlepetienė A., Karčauskienė D. The evaluation of biomass and energy productivity of common mugwort (*Artemisia vulgaris* L.) and cup plant (*Silphium perfoliatum* L.) in *Albeluvisol.* Žemdirbystė=Agriculture, vol. 99, No. 4 (2012), pp. 357-362.
11. Kryževičienė A., Šarūnaitė L., Stukonis V., Dabkevičius Z., Kadžiulienė Ž. Daugiamečių kiečių (*Artemisia vulgaris* L. ir *Artemisia dubia* Wall.) potencialo biokuro gamybai įvertinimas. (Assessment of perennial mugwort (*Artemisia vulgaris* L. ir *Artemisia dubia* Wall.) potential for biofuel production). Agricultural Sciences. 2010. T. 17. No. 1-2. pp. 32-40. (In Lithuanian).
12. Slepetys J., Kadziuliene Z., Sarunaite L., Tilvikiene V., Kryzeviciene A. Biomass potential of plants grown for bioenergy production. Renewable Energy and Energy Efficiency, 2012.
13. Valles J., Garnatje T. *Artemisia* and its allies: genome organization and evolution and their biosystametic, taxonomical and phylogenetic implications in Artemisiinae and related subtribes (Asteraceae, Anthemideae). pp. 255-285 in Plant Genome: Biodiversity and Evolution. Volume 1B, Phanerogams. Edited by A. Sharma. Science Publishers, Enfield, New Hampshire. 2005.
14. Judžentienė A., Buzelytė J. Šiaurės Lietuvoje augančio paprastojo kiečio (*Artemisia vulgaris* L.) eterinių aliejų cheminė sudėtis. Chemija.2006. T. 17(1). pp. 12-15.
15. Ciganas N., Raila A. Influence of ambient air on the drying process of the stored wood chips. Agricultural engineering. Research papers, 2010, vol 42, no 4, pp. 71-85.