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OPTIONS OF USE OF WASTE BIOMASS FROM HERBAL PRODUCTION FOR ENERGY PURPOSES

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ABSTRACT

The objective of the research was to determine and compare the value of the heat of combustion of waste biomass in the form of above-ground parts of the selected species of herbs. The research included leaved stalks of milk thistle, non-leaved stalks of thyme and garden sage and inflorescence axes of lavender and fennel. The heat of combustion of waste biomass was determined with the use of a calorimeter according to the applicable standard PN-EN ISO 9831:2005. Based on the obtained results it was stated, inter alia, that, from among the investigated species the lowest average value of the heat of combustion of 13.28 $MJ \cdot kg^{-1}$ was in case of biomass obtained from milk thistle. The heat of combustion of biomass of the remaining species was similar and it was at the average of 20.47 $MJ \cdot kg^{-1}$. Weight of ash after combustion was the highest in case of milk thistle and it was 0.23 g whereas in case of the remaining species it did not exceed 0.03 g.

Introduction and objective of the research

A present increase of interest in natural medicine, healthy food and addition of herbs in food generates an increased demand for herbal raw materials, which may lead to a gradual increment of the cultivation area of this group of plants. In Poland there are many modern specialized farms related to herb cultivation, many of them cultivate some species of herbs on the acreage which is above twenty hectares. Herb plantation covers in Poland the area of over 30 000 hectares. Almost 20 000 farms cultivates herbs (Jambor, 2007). Except for the obtained raw material for a specific purpose, herbal production generates also wastes. They form both at producers during harvesting, drying and initial processing of the harvested crop as well as in plants which deal with processing of herbal raw materials. For example in Herbapol Białystok S.A. plants approximately 30 tonnes of fine waste are produced annually during packing herbs (Obidziński, 2013). One of the alternative ways of managing these waste fractions, which also should be taken into account, is their use for energy purposes through direct combustion. Investigations carried out by Obidziński (2012) and concerning

energy management of waste from a tobacco industry as well as from herbal industry in the form of excessively ground lemon balm herb proved that such material after processing into pellets may be successfully utilized as organic solid fuel. Herbal raw materials shortly after harvesting should be preserved in order to stabilize active bodies which occur therein and to ensure their safe storing without losses (Karwowska and Przybył, 2005). Drying is the most popular manner of preservation. Thermal drying in drying houses is recommended in order to obtain raw material of a proper quality. Nowadays the most popular method of drying herbs and other plant materials on the industrial scale is convective drying (Karwowska and Przybył, 2005) in chamber driers, where solid fuels may be also combusted with a heat source. The use of waste biomass from production and processing of herbal raw materials in such drying houses would allow reduction of costs of such a process.

The objective of the research was to determine and compare the value of the heat of combustion of waste biomass in the form of above-ground parts of the selected species of herbs.

Methodology

Material for the research was collected in 2014 from the plantation of herbs which is located on the area of the Department of Production Engineering and Power Energy of the University of Agriculture in Krakow. Before the value of the heat of combustion was determined, it was combined with the already possessed part of material of the same type, from the previous year. The research covered waste biomass of: milk thistle (*Silybum marianum* (L.) Gaertner), common thyme (*Thymus vulgaris* L.), garden sage (*Salvia officinalis* L.), lavender (*Lavandula angustifolia*) and fennel (*Foeniculumcapilla-ceum* Gilib.).

Thyme and sage sprouts as well as lavender inflorescence were collected in the maturity phase, which is suitable for raw material purposed for essential oil extraction. Milk thistle was harvested in the period of fruit ripening. Leaves (thyme and sage), flowers (lavender) and fruit (milk thistle and fennel) were separated from the material. Thus obtained waste material in the form of leaved stalks of milk thistle, non-leaved stalks of thyme and sage and inflorescence axis of lavender and fennel were initially dried in air to the moisture of 22%. In order to obtain possibly the lowest moisture, material was dried in a laboratory drier in the temperature of 35ºC. During drying moisture was controlled with an oven-dry method. The final water content in the material purposed for research was 4.5%.

Samples for analysis were prepared by cutting the dried material with pruning shears into 102 cm pieces, which were further ground with a laboratory mill. The size of particles of the ground material was 0.7 mm. The heat of combustion was determined in 5 iterations on the calorimeter KL-10 pursuant to the applicable norm: PN-EN ISO 9831:2005. Samples of the material compressed to the form of 1 g pills were combusted in the oxygen under the pressure of 2.8 MPa in the calorimetric bomb immersed in the water jacket and the water temperature increase was measured. The value of the heat of combustion was calculated automatically acc. to the internal application of the device. The remains after combustion of each sample were weighed on the laboratory scale with a precision to 0.001 g and the ash weight was determined.

The obtained results were statistically developed in STATISTICA 10 SOFTWARE in the module *ANOVA*/MANOVA. Homogeneous groups were determined with the use of Duncan

test at the significance level of α=0.05. Regularity of data distribution was checked with Shapiro-Wilk test.

Results and discussion

Energy assessment of waste from herbal production, as any other type of biomass, requires the use of the same principles, which serve for evaluation of traditional solid fuels (Winnicka et al., 2005). Heat of combustion is one of the main physical and chemical parameters of solid fuels. The weight of ash which remained after combustion is, inter alia, one of the most important criteria of assessment (Zawistowski, 2003; Niedziółka and Zuchniarz, 2006). In literature, there is presently no information concerning calorific value of herbal plants biomass. Such data would facilitate making a decision on a possible energy use of post-production wastes from plants belonging to this group. The research showed that the value of the heat of combustion of waste biomass from lavender, common thyme, garden sage, fennel and milk thistle is within 13.28 to 20.66 MJ·kg^{-1} (fig.1).

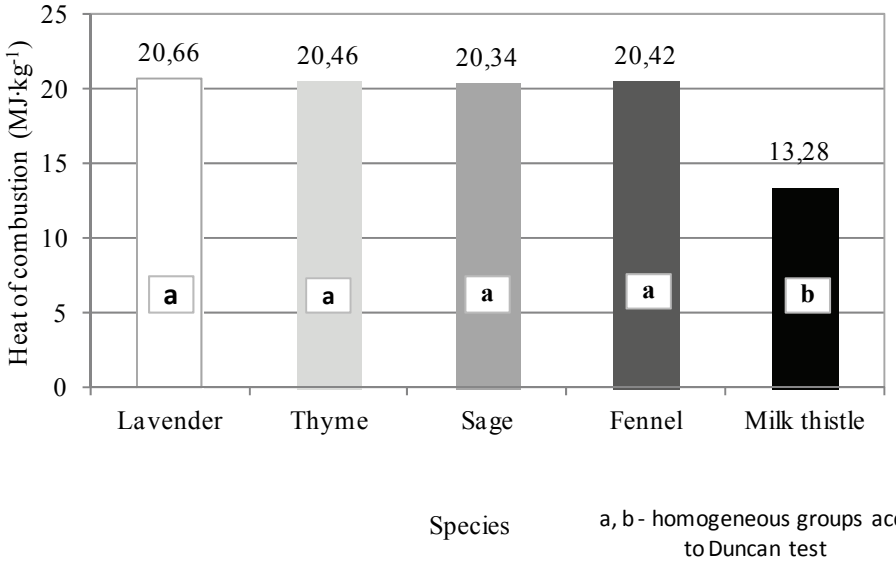

Figure 1. Values of heat of combustion of waste biomass of the investigated herbs species

The statistical analysis proved no significant differences in the values of heat of combustion of sage, thyme, lavender and fennel biomass. On account of this property, these species are within one homogeneous group with an average value of the heat of combustion of 20.47 MJ·kg^{-1} (fig.1). It is higher than the one provided in literature; values of this parameter for biomass of majority of plants, which according to the Resolution of the Minister of Agriculture and Rural Development as of 14th March 2008 on energy plants yield in 2008 are included into the group of representatives. They include inter alia: perennial

shrubby plants: shrubby willow, multiflora rosa, perennial plants: virginia mallow, topinambour, perennial grasses: giant miscanthus, spertina pectinata and in case of trees - poplar and black locust. The heat of combustion of willow wood according to various authors is within 18.3 – 18.9 MJ·kg^{-1} d.m. (Szyszlak-Bargłowicz et al., 2012; Fijałkowska et al., 2014), while for multiflora rosa it is 17.7 MJ·kg^{-1} d.m. (Kieć et al., 2011). In case of biomass from virginia mallow, miscanthus and topinambour it is respectively 18.3, 17.8 and 16.1 MJ·kg^{-1} (Szyszlak-Bargłowicz et al., 2012; Komorowicz et al., 2009). The heat of combustion of biomass from spertina pectinata in a dry state is within 18.4 – 19.0 MJ kg^{-1} depending on the year of cultivation (Kowalczyk-Juśko, 2013). In the group of tree plants, only bark of black locust has a similar value of the heat of combustion as the biomass from the investigated herb species, because it is at the average at the level of 20.5 MJ·kg^{-1}. The heat of combustion of black locust wood assumes even lower value which is at the average of 18.5 MJ·kg^{-1} (Kraszkiewicz, 2008), so it is even slightly lower than the provided value of this parameter for poplar wood and which is approximately 19.3 MJ kg^{-1} (Sannigrahi et al., 2010; Benetka et al., 2002; Luo and Polle., 2009). The heat of combustion of biomass from sage, thyme, lavender and fennel reaches also a higher value than in case of grain straw whose excess is often used in the power energy. The heat of combustion value determined by Świętochowski et al., (2011) for wheat straw, triticale and barley straw in a dry state was at the average of 18.3 MJ·kg^{-1}.

Milk thistle was outstanding in the investigated herb species. It was qualified according to the applied statistical analysis to the separate homogeneous group. The heat of combustion for its biomass was 13.28 MJ·kg^{-1} and was by 35% lower than the one determined for the remaining investigated plants (fig. 1). A relatively low value of the heat of combustion of biomass from milk thistle causes its poorer utility as a solid fuel; however, such manner of managing post-production waste of this plant should also be considered. A considerable national area of cultivation of this species in comparison to other herbs, which is 1500 ha (Seidler-Łożykowska, 2009), and a high crop of dry waste mass in the form of leaved stalks which is 32.6 dt·ha^{-1} (Andrzejewska and Skinder, 2007), which cannot be used otherwise except for a possible grinding after harvesting and mixing with soil speaks in its favour.

Plant raw materials, which may be a potential heating biomass source are highly varied, thus knowledge on them is essential. The yield and energy value are not the only significant parameters, but also the content of ash, which remains as waste from combustion of each solid fuel. Ash may be treated as ballast, which negatively influences the energy value of fuel and the course of combustion itself raising the same energy production costs. Along with the increase of the ash content, the amount of emitted ash also raises. However, some amount of ash in fuel is desired since in case of a grate furnace it protects the grate against excessive heating (Kubica, 2013). The research carried out by Mółka and Łapczyńska-Kordon (2011) proves that the ash level in biomass is lower than in case of the majority of coal. According to Wilk (2006), the ash content in wood biomass is within 0.3-7.4% and in grain straw 4.3-10.4%. Niedziółka and Zuchniarz (2006) in their paper which dealt with energy analysis of the selected types of plant biomass, state that as a result of combustion of clear biomass, the amount of ash is within 0.5 to 12.5%, whereas Wisz and Matwiejew (2005) provide that the typical ash content in biomass is within 0.5 to 5.5%. The ash weight after combustion of waste biomass from sage, thyme, lavender and fennel did not show any significant variability. Thus these species on account of this parameter were in the same homogeneous group. Average ash weight for these species was 0.026g (fig.2) which is

2.6% of the weight of the combusted sample, and it was within the range indicated by the above-mentioned authors.

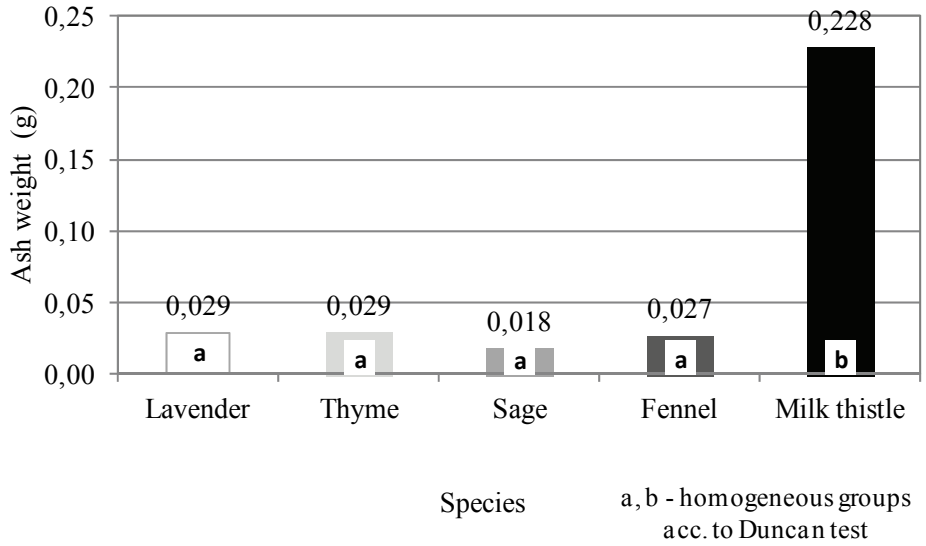

Figure 2. The weight of ash remaining after combustion of waste biomass from the investigated herb plants species

In case of milk thistle, the weight of ash after combustion was almost nine times higher in comparison to the investigated species and it was 0.23gwhich corresponds to 23% of the weight of the combusted wood sample (fig.2).

From the group of the investigated herb plants only biomass of milk thistle on account of values of parameters determined therefor, has a lower energy utility due to its direct combustion.

Conclusions

1. Waste biomass of lavender, thyme, sage and fennel has a similar value of the heat of combustion which is at the average of 20.47 $MJ \cdot kg^{-1}$. For leaved stalks of milk thistle, this value is the lowest and is 13.28 $MJ \cdot kg^{-1}$.
2. The weight of ash after the lavender, thyme, sage and fennel waste biomass combustion is similar and is 0.026 g from 1 g of a sample. The highest weight of ash was reported in case of milk thistle and it is 0.23 g.

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MOŻLIWOŚCI WYKORZYSTANIA BIOMASY ODPADOWEJ Z PRODUKCJI ZIELARSKIEJ NA CELE ENERGETYCZNE

Streszczenie. Celem podjętych badań było określenie i porównanie wartości ciepła spalania biomasy odpadowej, w postaci części nadziemnych, wybranych gatunków roślin zielarskich. Badaniami objęto ulistnione łodygi ostropestu plamistego, bezlistne łodygi tymianku i szałwii lekarskiej oraz osie kwiatostanowe lawendy i kopru włoskiego. Ciepło spalania biomasy odpadowej oznaczono za pomocą kalorymetru, zgodnie z obowiązującą normą PN-EN ISO 9831:2005. Na podstawie otrzymanych wyników stwierdzono m.in., że z pośród badanych gatunków najmniejszą średnią wartością ciepła spalania, wynoszącą 13,28 $MJ \cdot kg^{-1}$ charakteryzowała się biomasa ostropestu plamistego. Ciepło spalania biomasy pozostałych gatunków było zbliżone i wynosiło średnio 20,47 $MJ \cdot kg^{-1}$. Masa pozostałego po spaleniu popiołu była największa w przypadku ostropestu plamistego i wynosiła 0,23 g, natomiast u pozostałych gatunków nie przekraczała 0,03 g.

Słowa kluczowe: roślina zielarska, biomasa odpadowa, ciepło spalania