INTEGRATED UNIT FOR UTILISATION OF BIOMASS ENERGY ON THE RURAL FARM

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Abstract. Developed integrated unit for environmental heat production from waste biomass including composting heat utilization system combined with two stage incineration system providing temperatures above 850 °C during at least 2 seconds for waste biomass burning. Ashes content in different biomass is investigated to make the decision for biomass usage for composting or for burning. Birch and sallow wood have ash content less than 1%, therefore they are the best materials for starting of furnace. Sallow bark and apices is preferred as compost material due to high content of ashes. Straw is considered as material usable for composting only, due to low ashes melting temperature, that can cause sedimentation on walls of channels, filter and chimney.

Key words: incineration, integrated heating unit, composting heat utilisation, organic fertilizer.

Introduction

Biomass energy usage should substitute fossil energy sources widely to slow down the global heating. In 2003, a study conducted by Jeff Dukes of the University of Utah calculated the total amount of carbon that would be needed to sustain the present (related to 1997) global energy demand. At current levels it would take 22% of all the plant matter that grows on earth throughout the year to meet our current total primary energy requirements per annum (roughly double our current agricultural use) [1]. It is very important to increase the biomass for energy and fertilizers production to substitute the fossil fuels. The European Commission estimates that EU should be able to supply 8% of the region's primary energy needs from biomass by 2010, without unduly affecting agriculture or the environment, largely using waste residues and forest products, as well as energy crops on set aside land with the further target of 20% [4].

Biomass contains less energy per mass unit than fossil fuels. This means that raw biomass typically cannot be cost-effectively shipped more than about 50 miles before it is converted into fuel or energy. It also means that biomass energy systems are likely to be smaller than their fossil fuel counterparts, due to restrictions on biomass quantity in one place. Individual farms will be able to design energy systems that are self-sufficient, perfectly adapted to their own needs and having maximal sustainability in respect to environment [3]. Heat energy production is required for drying of harvest, for heating of houses or greenhouses, etc. Heat energy obtained in burning process of fossil fuels causes greenhouse gases emission and increases the global warming. Renewable biomass burning is considered as the process not increasing the global warming. However, the poisonous gases are produced during burning of biomass also, polluting atmosphere and resulting in lowering of quality of wildlife, including quality of subsistence of human beings. It is very important to provide the burning process at temperature more than 850 °C (or 1100 °C for waste containing chlorides more than 1%) during at least 2 seconds, that is recommended in the EU directive for waste biomass incineration [5]. Such a process can be provided in a 2-stage burner, where the more clean part of biomass is burnt for heating and gasification of rest part the waste biomass, while the appointed temperature and time period (850 °C, 2 seconds) is provided during final burning of gases emitted by gasification. However, burning of biomass even under such advanced conditions contains much of components causing the further pollution of atmosphere. Utilisation of composting heat did not suffer by the features mentioned above and therefore can be considered as the most environmentally acceptable way for production of heat and fertilizer. Composting heat utilisation can be performed using practicable scheme consisting of composting material with heat exchanger and heated panel [2]. Composting heat output slowly changes from minimum up to maximum during first 1-3 days and than slowly decreases at the end of biomass composting cycle. If the biomass is composted in containers, usage of more than one composting container evens the output rate of the composting heat during the utilisation period. As heat energy requirement for agricultural production can change largely in dependence on technological requirements (drying of harvest, heating of greenhouses or other premises, etc.), it is recommended to have the combination of slowly varying composting heat flow with quickly alterable heat flow released in the result of burning the biomass. The aim of the investigation is evaluation and dividing of rural biomass into two basic fractions – first for heat utilisation in the composting process and other for heat utilisation in the burning process. Further aim is dividing the burnable (high heat value, low or moderate ash content, low content of chlorides, high ash melting temperature) biomass in two parts, the first includes most "clean" biomass (low ash content, high heat value, low moisture) for starting of the burning process, preheating of the burner and second the part of biomass is proposed as subject for gasification only.

Materials and methods

Multi-functional unit for heat and fertiliser production system is developed to manage biomass utilisation at agricultural farm in most environmentally acceptable way. Multi-functional unit contains composting chambers 1 as source of composting heat energy, that is supplied to panel 2 and to heat accumulator 3 by heat exchangers 4 and heat carrier contour 5. Heat is utilised from aerobic composting gases outflow also by pipes build in floor panel 2. Composting gases is cleaned in biofilter 6.

The furnaces 7 and 8 are activated in periods with increased heat consumption, in the cold weather or during starting up period of system. More clean biomass, having less ash content, is reserved for burning in primary furnace 7. Waste biomass having increased ash content should be burned and partly gasified in secondary furnace 8. Gases in furnace 8 are mixed with additional fresh air and finally burned under specific conditions in camera 9, where temperature have effect over than 850 °C during at least 2 seconds period for every portion of gas mixture. If the temperature of burning process is lowered below 850 °C in camera, an inflammable mixture is fired in additional burner 10 automatically.

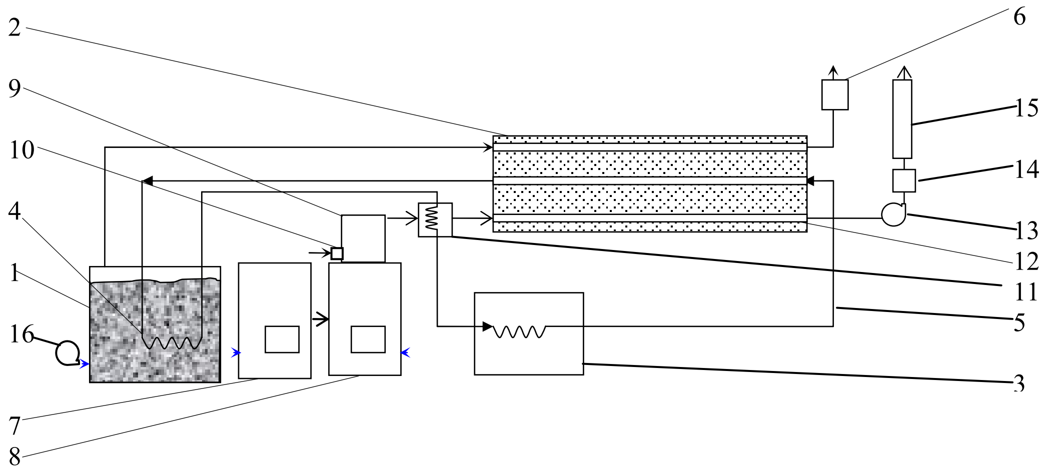

Fig. 1. **Integrated unit for production of heat and fertiliser in rural farm**

Heat from burning process is utilised by heat exchanger 11 and heat carrier contour for heating the panel and/or for accumulating in heat accumulator. Residual heat from fume is utilised in floor panel in vents 12. Fumes are forced by fan 13 through furnaces, panel, fume filter 14 and chimney 15. Floor panel is designed with large thickness providing heat energy accumulation and evening of panel's surface temperature. Overheating of floor panel is restricted by heat carrier contour 2. Heat energy, if stored in heat accumulator, can be utilised also for another purposes (home heating, hot water production, etc.). System is actuating automatically as valves, heat carrier pump (not showed), biomass composting and burning process is regulating by control station in dependence on current parameters. Biomass should to be sorted for composting or for burning in regard on ashes content before its usage in integrated unit for heat and fertiliser production. The different biomass available on a farm (birch, sallow, fallow grass, straw, note paper) was investigated for ash content.

For investigation for ash content biomass samples were dried in exsiccator at temperature 105 °C during 18 hours and burnt in oven at 550 °C. Ash percentage for biomass samples is calculated based on sample mass ratio at 105 °C and 550 °C:

$$Ash\% = \frac{100\, m_{ash}}{m_{dm}}, \tag{1}$$

where *Ash%* – percentage of ashes in biomass sample, %;
m_{ash} – weight of ashes in biomass sample, g;
m_{dm} – weight of dry matter in sample, g.

Some samples of fallow grass or straw were fired on the tray to imitate burning of field residues in fallow land or in stubbly field. For this purpose samples were dried at 105 °C (for dry matter investigation), than moistened anew up to initial moisture help by water vapour condensation into the sample material. Samples were stored afterwards in a closed package for 6 hours to even the moisture distribution within sample. After samples were fired on tray using open flame and then residual ashes and not burnt particles were investigated for mass losses at temperatures gradually from 300 °C up to 950 °C. Samples of whole sallow were cut in pieces each in length of 0.5 m, then debarked and weighted for wood to bark mass ratio investigation.

Results and discussion

Samples of wood biomass were investigated to evaluate the ash content in dependence on varying diameter of birch branches and sallow bushes (Figure 2, 3).

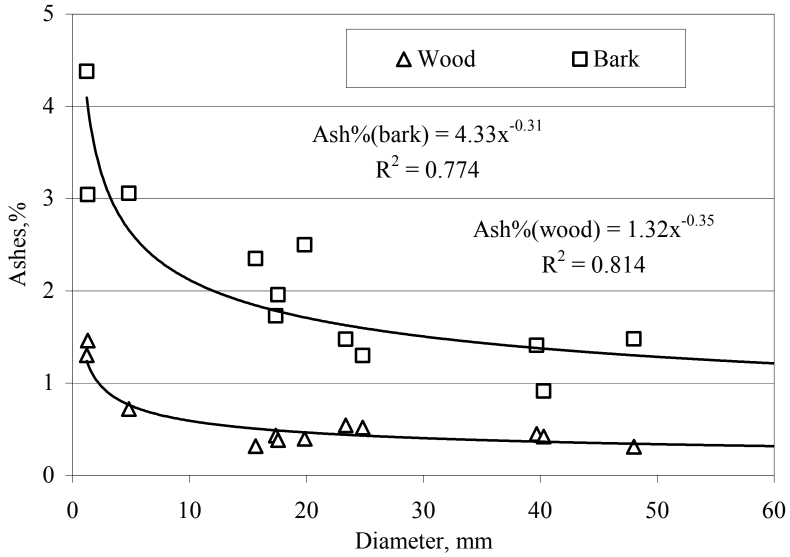

Fig. 2. **Ash content in wood and bark in dependence on birch diameter**

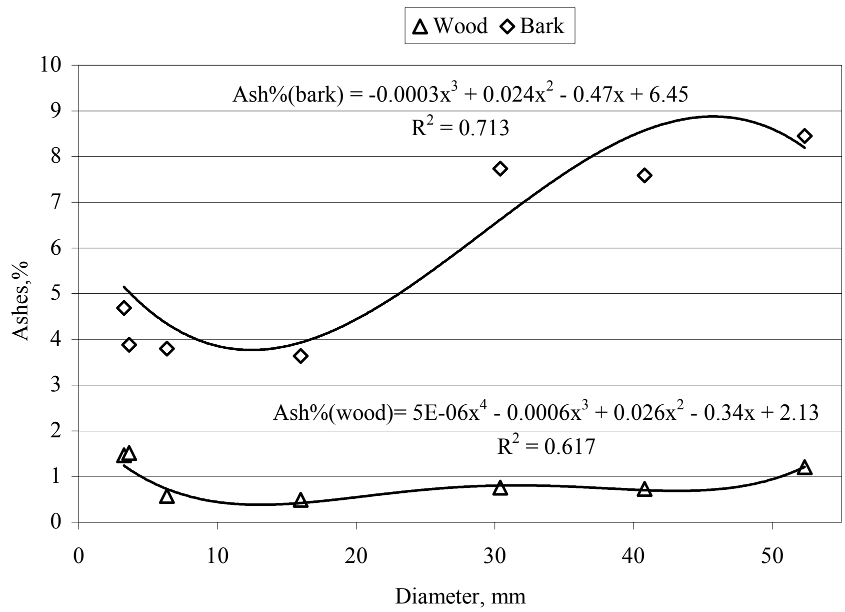

Fig. 3. **Ash content in wood and bark in dependence on diameter of the sallow**

It is important feature, that content of ashes increases for smaller branches of birch. The different values of ashes content is obtained for sallow, where ashes content in bark increased both for smaller branches as well as for pieces with diameter more than 20 mm (Fig. 3).

Increasing of ashes content for stems of large diameters can be explained with sedimentation of soil particles on the lower part of sallow stem, as the whole stem was cut down for sampling, whereas the sample of birch branch was taken in height around 2 m above the ground level. The distribution of dry matter weight along the whole sallow stem is shown in Fig. 4.

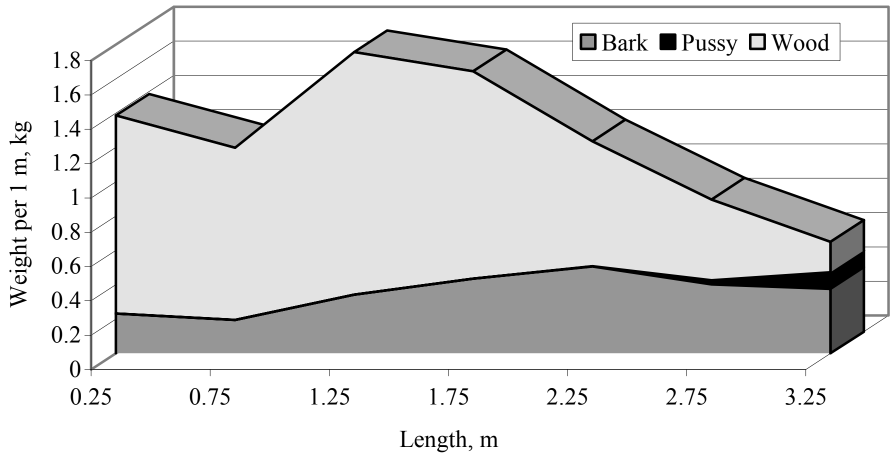

Fig. 4. **Distribution of dry matter of wood, bark and pussy along the sallow stem**

Distribution of dry matter between wood, bark and pussy evidently shows, that wood percentage is decreased below 50% for upper part of sallow stem and therefore the chipped apices can be preferred to use for composting material in integrated unit due to high minerals content in ashes.

Another available biomass that can be used in the multi-functional unit are fallow grass and straw. Investigation of the residual ashes content in fallow grass and straw after firing of samples in conditions similar to burning in stubbly field or fallow are shown in Fig. 5.

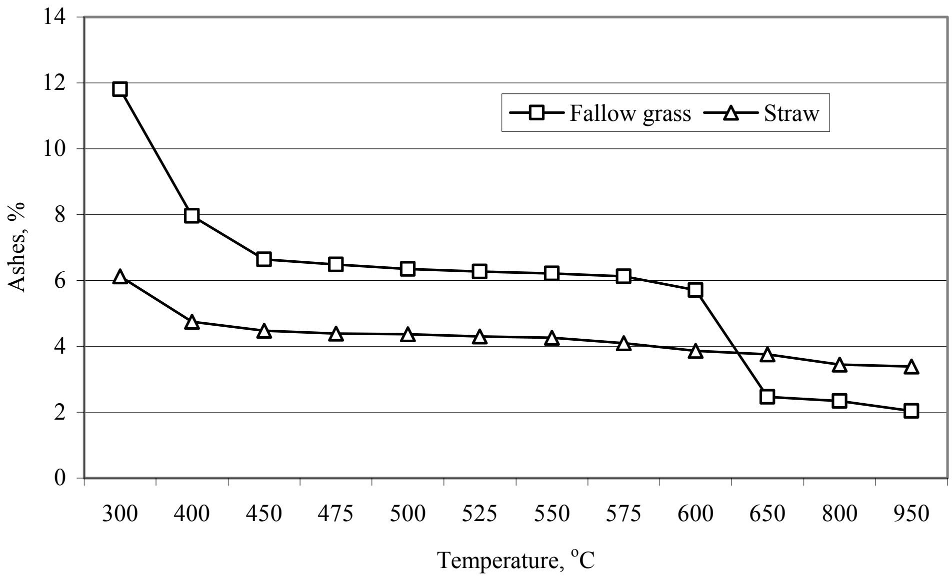

Fig.5. **Ashes content for fallow grass and straw samples after firing in conditions similar to firing in stubbly field or fallow**

Part of biomass, especially in fallow grass, was not burned at all, so it is evident, that a burning in field conditions potentially can cause emission of poisonous gases, e.g., dioxin, etc.

Ashes content is primary factor to be considered to choose right type of utilisation of local biomass in integrated unit. Ashes content for some available biomass is presented in Fig. 6.

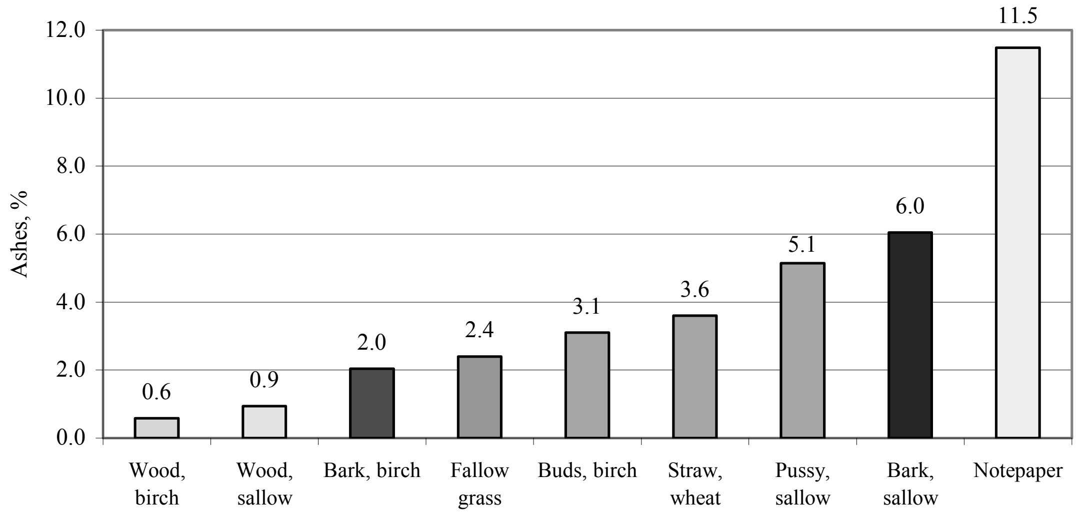

Fig. 6. **Ashes content in different biomass potentially usable for integrated unit for heat and fertiliser production**

The most acceptable biomass for usage in primary burner is birch sallow wood, birch bark and fallow grass. Sallow bark is recommended to use in second burner or for composting. Notepaper composting is preferred due to high ashes content. It is also possible to have presence of chlorides in paper produced in the process using clorides for the raw material bleaching. It is obtained in experiments, that straw has low temperature of ashes melting (850 – 900 °C) and melted ached can cover walls of channels, filter and chimney by layer like enamel, being hardly or impossible to clean off. Therefore it is hardly or impossible to meet EU directive appointing burning temperatures higher than 850 °C for straw biomass. Considering above mentioned and also that straw can contain relatively high content of chlorides (especially, if cereals are fertilised with potassium chloride mineral fertilizer) straw is preferred to use as compost material only. Combinational usage of available biomass residues for heat and fertiliser production can increase farmer's independence minimising need for fuels and fertilisers input.

Conclusions

1. Integrated heat and fertiliser production unit for environmental heat production from waste biomass can be developed by combining of composting heat utilisation and biomass burning in furnaces, if temperature above 850 °C during at least 2 seconds for waste biomass burning is provided.
2. Birch and sallow wood are the best materials for starting of furnaces and/or for operating of first furnace for preheating and gasification of waste.
3. Sallow bark and apices are preferred to utilise in compost due to high ashes content.
4. Wheat straw is recommended to use as compost material only, due to low melting temperature of ashes.

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