TIMBER WASTE AS A SOURCE OF ENERGY

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Abstract. This paper presents the results of a research on combustion heat and calorific value carried out on pine, oak, ash and walnut sawdust. The research showed the highest calorific value was obtained from pine sawdust (18.1 $MJ \cdot kg^{-1}$) and oak sawdust (17.9 $MJ \cdot kg^{-1}$) while a slightly lower one from walnut (15.9 $MJ \cdot kg^{-1}$) and ash (13.7 $MJ \cdot kg^{-1}$); at the same time, the two latter exhibited a higher degree of moisture (29. 8% and 33.2%, respectively). Lower calorific value of the examined raw materials in comparison with the fossil fuels does not disqualify them as attractive sources of energy to be applied for heating households.

Key words: calorific value, timber waste, biomass.

INTRODUCTION

For thousands of years now timber has been used as the basic fuel in Europe; it dates as far back as the beginnings of the industrial era. Presently, we can observe this energy source experience its renaissance, with an assumption of reasonable exploitation not exceeding the balance level. For heating the so-called fuel wood or brushwood is used, obtained in the process of managing the woodland waste generated as a result of clearing and maintaining the forests. Industrial waste, on the other hand, is generated in processing the wood in the sawmills. Besides, it is also possible to reuse the timber retrieved from pallets, containers, house demolitions, etc. [Wach 2002].

Timber and its derivatives are presently the most important renewable sources of energy in Poland. They are used for heating households, mainly the rural ones. For energy generation purposes only 6 to 8% of the large timber is used and more than 50% of brushwood and other slash obtained in the woods. Timber used for energy purposes is also derived from local tree-covered areas, orchards and parks as a by-product of forest renovation activities, tree clearings, hurricanes, etc. [Pawlak 2004].

How much timber obtained in our woodlands is used for energy purposes? This is one of the so-called dark figures in our forest and energy management. It is obvious that consumption of fuel wood is dependent also on the pace of changes in the small, local power engineering, and a decrease of this consumption depends on modernisation of the local, mainly rural, heating systems. More and more modern heating installations, gas and oil, appear and the so called low-temperature water-heaters are used in which ground timber waste (such as sawdust, tree bark, deadwood, woods maintenance waste material, slash from sawmills and woodworking shops, etc) is burnt or gassed.

Woodlands cover 28.3% of the area of Poland and there are plans to increase this coverage up to 33% by 2025. In 1999 26,018,000 m^3 timber was obtained in which fuel timber was 2,363,000 m^3. General Administration of the State Forests estimates that further 2-2.5 m m^3 of timber waste still remains in the woodlands and is not used due to limited demand. Also in the timber industry there is a lot of unused waste. Official statistics show that the share of timber in generation of the original energy in Poland is about 30 PJ of energy, which is 0.7%, and taking into account non-commercial timber production, this figure would grow to 2%. Thus, the use of this source could be significantly increased [Wach 2002].

Energy-related policy adopted in Poland until 2025 makes the Ministry of Agriculture and Rural Development committed to determine the demand for biomass and estimate the amount of biomass to be obtained from woods, roadside trees, production waste, city waste, etc [Żmuda 2005].

Estimates made by Wach on his own [2002] show that the timber potential in Poland is the following:

- woodland resources 35 PJ,
- other tree-covered areas 15 PJ,
- industrial waste 30 PJ,
- recycling 30 PJ.

It is also possible to obtain some timber material from yearly sanitary clearings and from the renewals of the tree stand in orchards, carried out every few years. The idea to use timber obtained in this way may be considered even more reasonable in the light of close location of such tree-covered areas to agricultural farms and no need for long-distance transportation. According to Maciak and Lipińska [2006] average quantities of timber possible to be obtained from orchards at particular densities of the orchard stands would be the following:

- at density up to 1,200 trees per $\cdot ha^{-1}$ average quantity of timber obtained from stumps is 12.75; from branches 13.04; from clearings 0.83 $m^3 \cdot ha^{-1}$,
- at density from 1,200 to 2,400: average quantity of timber obtained from stumps is 11.98; from branches 6.84; and from clearings 1.71 $m^3 \cdot ha^{-1}$, and
- at density above 2,400 average quantities of timber obtained are: 2.9 from stumps; 2.18 $m^3 \cdot ha^{-1}$ from branches.

Timber obtained from orchards, due to the small sizes of presently cultivated fruit trees, can serve mainly as fuel, whereby the most advantageous and efficient way to use it is burning it in the form of chips. The fact that it is possible to obtain large quantities of this material confirms that this material may constitute significant share in the balance of energy of the rural households. This solution is evidently favourable, both from the economic and ecological perspective.

Based on the calculations made by Gradziuk [2004] it is possible to analyse energy equivalents of 1 ton of timber and slash in comparison to the most popular conventional fuels (Tab 1).

Table 1. Energy equivalents of 1 ton of timber and slash compared to the most popular conventional fuels [Gradziuk 2004]

Conventional fuels	Timber		Slash	
	kg	PLN	kg	PLN
Coal	600	228	416	158
Furnace oil	366	586	254	406
LPG	301	722	209	502
Natural gas (m^3)	436	402	302	279

METHODOLOGY OF RESEARCH

The conducted research was aimed at identification of the heat of combustion and calculation of calorific value of the waste material obtained from different kinds of trees. The obtained results showed the possibilities to use that material for burning and producing heat energy. Research material (timber waste) was collected at a few industrial plants. Gathered samples were averaged and their moisture degree was measured by means of the drying and weighing method. The material was diversified in terms of moisture degree due to different storage conditions provided in the plants from which its particular samples came. Ground biomass was dried until stable weight was achieved at the temperature of 105^{o}C. The energy generated in the process of burning oak, pine, ash and walnut sawdust was examined. Heat of combustion and calorific value were established in accordance with the Polish norm of PN-ISO 1928:2002. Measurements were carried out in 3 repetitions for each sample, differences in the obtained calorific values did not exceed the difference between two denotations specified in the procedure at the level of 200 kJ/kg.

According to Rybak [2006] individual kinds of coniferous and deciduous trees do not show important differences in the quantities of particular elements, such as: carbon, oxygen and hydrogen, in the composition of the xylem. We may assume that, on average, dried timber contains 49.5% of carbon, 6.3% of hydrogen, 44.2% of oxygen, 0.04-0.26% of nitrogen and 0.20-2.30% of mineral compounds. The above figure related to the hydrogen content was assumed to be the basis for further calculations carried out on the examined samples.

RESEARCH RESULTS AND THEIR INTERPRETATION

Table 2 presents the results of the research on the heat of combustion and calorific value carried out on the oak, pine, ash and walnut sawdust.

Heat of combustion obtained from burning pine sawdust was 18.4 MJ·kg^{-1}, oak sawdust 18.8 MJ·kg^{-1}, walnut sawdust 16.6 MJ·kg^{-1} and ash sawdust 16.4 MJ·kg^{-1}. Basing upon researches carried out by various authors, Rybak [2006] provided the following combustion heat values: for timber without bark 18.5-20 MJ·kg^{-1}, for bark 18-23 MJ·kg^{-1}, for slash/chips 19.2-19.4 MJ·kg^{-1} and for willow 18.4-19.2 MJ·kg^{-1}.

The conducted research has shown that the highest combustion value was that obtained from pine (18.1 MJ·kg^{-1}) and oak (17.9 MJ·kg^{-1}); slightly lower figures were obtained for walnut (15.9 MJ·kg^{-1}) and ash trees (13.7 MJ·kg^{-1}), for which the moisture parameter was higher at the same time (29.8%; 33.2% respectively).

Tab. 2. Heat of combustion and calorific value of selected kinds of sawdust [the authors' research]

Examined material	Heat of combustion [MJ·kg^{-1}]	Calorific value [MJ·kg^{-1}]	Moisture [%]
Pine sawdust	18.4	18.1	11.8
Oak sawdust	18.0	17.9	7.7
Walnut sawdust	16.6	15.9	2.8
Ash sawdust	14.6	13.7	3.2

While analysing the calorific values of national renewable fuels, Roszkowski [2001] described also timber slashes/chips and forest waste. According to his calculations the calorific value of slashes/chips is 15 $MJ \cdot kg^{-1}$ (2,700 $MJ \cdot m^{-3}$) and of forest waste is 15 $MJ \cdot kg^{-1}$ (1,800 $MJ \cdot m^{-3}$).

To compare, according to Hejft and Obidziński [2006] the calorific value of hard coal (for dried fuel mass) ranges from 27 to 33 $MJ \cdot kg^{-1}$, for brown coal from 25 to 27 $MJ \cdot kg^{-1}$, for furnace oil from 41 to 46 $MJ \cdot kg^{-1}$, and for natural gas from 35 to 49 $MJ \cdot kg^{-1}$.

Lower calorific value of the examined raw materials in comparison to the above- mentioned fossil fuels does not disqualify them as attractive sources of energy to be applied for heating the households. The highest calorific value is obtained for the biomass whose moisture level is 15-20%, which means that it is recommended to dry this biomass in plastic bags under an umbrella roof so that it is not exposed to the weather conditions.

The biomass can then be used in special furnaces or central heating boilers meant for burning briquette and granulated timber. The furnaces are used for heating rooms and apartments of relatively low demand for heating energy. Heat exchange mainly occurs through radiation and convection. Obtaining energy in modern combustion devices contributes to stabilisation of the costs of this process. Combustion devices for burning timber, timber waste, slash/chips, sawdust etc., reaching over 90% efficiency, belong to the latest generation of furnaces and boilers, and the microprocessors used to control them enable optimisation of the combustion process and make them user-friendly. They are used for burning materials of up to 45% of moisture [Dobrowolska 2004]. There appear more and more modern heating, gas or oil, installations and more and more low-temperature water boilers in which burned or gassed are various kinds of timber waste materials (sawdust, bark, deadwood, woods maintenance waste material, slash from sawmills and woodworking shops, etc.). The boilers for biomass have large heat exchange surfaces: water walls, water grate, two combustion chambers divided by a water wall; in the second chamber there is a tubular heat exchanger fit for working with combustion gas of low temperature. The flow of the cooling agent (which usually is water) is calculated in a way preventing "boiler whirring" – frequent in other constructions – caused by local water boiling.

Table 3. Content and chemical constitution of ash derived from various kinds of trees [Demirbas 2004, Regland, Aerts, Baker 1991, Sander 1997, Tillman, Harding 2004]

Tree	Content of ash [%]	K_2O [%]	Na_2O [%]	MgO [%]	CaO [%]	P_2O_5 [%]	SO_3 [%]	SiO_2 [%]
Beech	0,55	0,09	0,02	0,06	0,31	0,03	0,01	0,03
Birch	0,26	0,03	0,02	0,02	0,15	0,02	0,01	0,01
Larch	0,27	0,04	0,02	0,07	0,07	0,03	0,01	0,01
Oak	0,51	0,05	0,02	0,02	0,37	0,03	0,01	0,01
Pine	0,26	0,04	0,01	0,03	0,14	0,02	0,01	0,04

While considering usage of timber waste in direct combustion, we have to stress differences in the composition of ashes of various tree kinds in terms of the contents of various oxides. Table 3 presents chemical constitution of ashes obtained from different kinds of tress [Demirbas 2004, Regland, Aerts, Baker 1991, Sander 1997, Tillman, Harding 2004]. Ashes obtained from burning wood always contain quite substantial quantities of silicon dioxide as well as ferric, aluminium, calcium and sodium oxides [Rybak 2006]. Thus, in the light of the above, at the further stage of research on the usage of timber waste as a source of energy, meant for direct combustion, it will be necessary to specify the contents and chemical constitutions of the resulting ashes.

Large content of alkalis, especially potassium K_2O in the ash resulting from biomass is the cause of low temperature of fusibility of the ash. Presence of alkali compounds in the ash leads to agglomeration of sludge in fluidised furnaces and to solid fouling of the boiler's heating surfaces, i.e. slagging, incineration and high temperature corrosion [Rybak 2006]. For energy generation purposes the biomass may be used in the solid, liquid or gaseous form. Solid fuels obtained from biomass are used in the processes of burning, gasification or pyrolysis to produce heat and electric energy.

CONCLUSIONS

1. The highest calorific value was obtained from the sawdust of pine and oak (it was 18.1 $MJ \cdot kg^{-1}$ and 17.9 $MJ \cdot kg^{-1}$ respectively).
2. High calorific value of timber waste makes it a valuable and environment - friendly source of energy.
3. Timber waste of high degree of moisture should be dried before being used in direct combustion.

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ODPADY DRZEWNE SUROWCEM ENERGETYCZNYM

Streszczenie. W pracy przedstawiono wyniki badań ciepła spalania i wartości opałowej przeprowadzone dla trocin dębowych, sosnowych, jesionu i orzecha włoskiego. Przeprowadzone badania wykazują, że najwyższą wartość opałową odnotowano dla trocin sosnowych (18,1 $MJ \cdot kg^{-1}$) i dębowych (17,9 $MJ \cdot kg^{-1}$), a nieco niższą dla trociny z orzecha włoskiego (15,9 $MJ \cdot kg^{-1}$) i jesiona (13,7 $MJ \cdot kg^{-1}$), które jednocześnie charakteryzowały się większą wilgotnością (29, 8% ; 33,2%). Niższa wartość opałowa badanych surowców w odniesieniu do kopalnych nośników energii, nie dyskwalifikuje ich jako atrakcyjnych surowców energetycznych znajdujących zastosowanie w gospodarstwach domowych.

Słowa kluczowe: wartość opałowa, odpady drzewne, biomasa.