FUEL PROPERTIES OF PAULOWNIA BIOMASS

Dinko Vusić[1], Matija Migalić[1], Željko Zečić[1], Marija Trkmić[2], Antonija Bešlić[2], Damir Drvodelić[1]*

[1]Faculty of Forestry, University of Zagreb, Zagreb, Croatia

[2]HEP Proizvodnja d.o.o., Central laboratory for chemical technology, Zagreb

** vusic@sumfak.hr*

Introduction

Future of bioenergy industry strongly depends on the biomass availability. For sustainably managed forests supply is governed by increment/annual cut, but the availability of biomass feedstock for energy is strongly influenced by competition with other sectors (wood industry and pulp and paper industry). One of the promising ways to increase the amount of biomass on the market is establishing dedicated energy plantations of fast growing wood species. Interest in short-rotation bioenergy crops focuses mainly on their ability to produce large amounts of lignocellulosic biomass that can be used as fuel for heat or electricity generation [1]. The high biomass yield potential of *Paulownia* trees reported [2, 3] identify *Paulownia* genus as one of the fastest growing trees in the world with the potential for producing wood for various purposes [4]. The genus *Paulownia* (*Scrophulariaceae*) includes nine species of fast-growing trees that are indigenous to China and East Asia [5]. The species of this genus are suitable to reclaim abandoned farmlands or to restore soils [6], where special emphasis is focused on biomass production [7]. Several recent studies have been focused on its potential for timber production [7], biomass yield [1, 8], its use in agroforestry practices [9], effect of irrigation on the productivity [6], chemical composition of its wood and other raw material properties [10, 1, 11, 8].

The goal of this research is to determine the properties important for biomass to bioenergy conversion (density, moisture content, bark content, ash content, elemental content – CHNS and calorific value) of three Paulownia hybrids (9501, Shang Tong, OXI).

Material and Methods

Samples were taken during the field research conducted in December 2017 to determine the productivity of selected clones on sample plots established in Spring 2015 with plants produced in various ways of vegetative propagation. In total 22 trees were sampled. Sample discs were taken from the root collar upwards every 1.30 m. Moisture content of individual sample disc was determined according to HRN EN ISO 18134-2:2015 [12]. Basic density was calculated as a dry mass to fresh volume ration. Bark was peeled and bark to wood mass ratio was established after drying the samples. Average moisture and bark content per tree was calculated by weighing sample disc values by fresh sample disc mass. Laboratory sample was prepared by comminuting wood and bark samples of the same hybrids to nominal size of 1 mm. Ash content of wood and bark samples was tested according to HRN EN ISO 18122:2015 [13]. Calorimetric method [14] was applied to determine gross calorific value of the samples.

Results were recalculated and expressed as net calorific value based on the ash content, CHN content analysed according to HRN EN ISO 16948:2015 [15] and sulphur content determined according to HRN EN ISO 16994:2016 [16]. Basic density of paulownia samples was compared to values reported [17] for hardwood species, softwood broadleaves and coniferous species. Results of other fuel properties were recalculated as weighed averages based on bark to wood ratio and compared to typical values of short rotation coppice solid biomass fuels reported in HRN EN ISO 17225-1:2014 [18].

Results and discussion

Moisture content in fresh state (just after the felling) amounted to high 62.4±1.7% when compared to our commercial species in winter felling. Berdón Berdón et al. [8] found similar results in the span 62.79 to 64.85% when testing four different clones felled in February. Although is reported that Paulownia timber is easily air-dried [3] future research of natural drying of Paluownia biomass for energy is needed; as experiences with willow wood chips point that high moisture content in wood fuels limits the possibility of long term storage [19] and suggest forced ventilation drying as an option to be considered when a cheap source of waste heat can be found.

Basic density averaged 335±27 kg/m^3; or 60% of the basic density of hardwood species, 75% of the basic density of softwood broadleaves and 85% of the basic density of coniferous species.

Bark to wood ratio ranged from 15.8% to 9.3% strongly following DBH (Diameter at Breast Height) increase (Fig. 1).

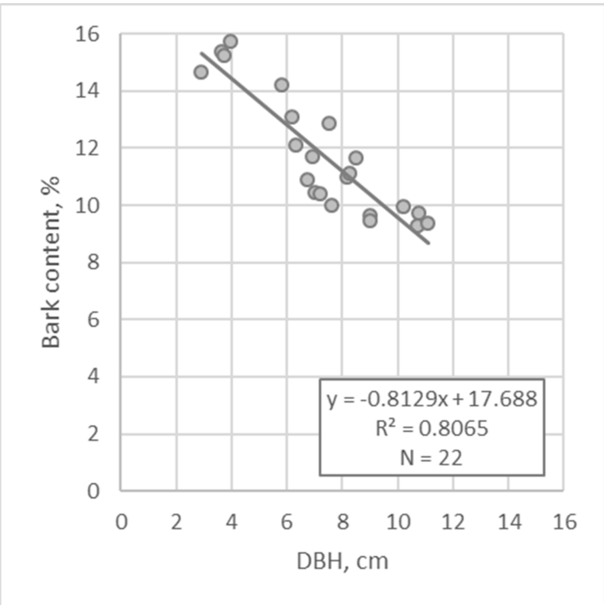

Figure 1. Bark content vs. DBH

Ash content of wood averaged 0.75±0.0.8% and that of bark 4.29±0.92%. When average values of the raw material are compared to values reported for poplar and willow SRC (Table 1) it can be concluded that results place Paulownia biomass at the lower part of ash content variation range reported for poplar and willow SRC (Short Rotation Coppice). Berdón Berdón et al. [8] report higher ash content values for Paulownia biomass, in the range of 1.51. to 1.96%. Ash content is strongly influenced by bark to wood ratio as reported in this and previous research [11] that found 0.23±0.02% ash content in Paulownia stemwood and

2.89±0.13% in bark. Differences in Paulownia ash content compared to poplar and willow SRC can be explained with higher DBH of sample trees, and thus lower bark share (Fig. 1) compared to typically smaller DBH in poplar and willow SRC due to limitations in generally used harvesting technology (modified forage harvester) that can fell and comminute trees up to 6 cm diameter at root collar.
Despite the 5.7 times larger ash content of bark compared to wood, gross calorific value of wood samples (19.32±0.35 MJ/kg) was slightly lower than that of bark samples (19.70±0.26 MJ/kg). Average values on the raw material level (Table 1) are in the range reported for willow and poplar SRC as well as in the range reported in previous Paulownia biomass research [1, 10]. As the calorific value depends on the quantitative conversion of the fuel carbon and hydrogen to water and carbon dioxide it can be stated that calorific value is a function of fuel chemical composition [20]. Therefore, any notable variation in calorific value could indicate differences in the chemical composition of the biomass fuel [1]. Low variability in calorific values between the hybrids tested, results of previous Paulownia biomass research [1, 10] and typical willow and poplar SRC values (Table 1) supports the assumption of elemental content – CHNS similarity that is also confirmed by the results of this research (Table 1).

Table 1. Comparison of short rotation coppice solid biomass fuel parameters

Parameter	Unit	Willow[18]	Poplar[18]	Paulownia		
				9501	Shang Tong	OXI
Ash	w-% d	2.0 (1.1–4.0)	2.0 (1.5–3.4)	1.2	1.1	1.2
Gross calorific value	MJ/kg d	19.9 (19.2–20.4)	19.8 (19.5–20.1)	19.5	19.6	19.2
Net calorific value	MJ/kg d	18.4 (17.7–19.0)	18.4 (18.1–18.8)	18.3	18.3	17.9
Carbon, C	w-% d	48 (46–49)	48 (46–50)	49	49	49
Hydrogen, H	w-% d	6.1 (5.7–6.4)	6.2 (5.7–6.5)	5.8	5.8	5.7
Oxygen, O	w-% d	43 (40–44)	43 (39–45)	44	44	44
Nitrogen, N	w-% d	0.5 (0.2–0.8)	0.4 (0.2–0.6)	0.3	0.2	0.3
Sulphur, S	w-% d	0.05 (0.02–0.10)	0.03 (0.02–0.10)	0.06	0.05	0.05

Conclusions

Results of this research indicate that three Paulownia hybrids tested (9501, Shang Tong, OXI) can achieve favourable values of ash content, elemental content – CHNS and calorific value when compared to results reported for Paulownia biomass in literature and when compared to typical values for willow and poplar SCR biomass.
Other fuel properties determined by this research indicate that comparing biomass yield of Paulownia with other tree species, due to the lower basic density (i.e. quantity of fuel per volume units) demands comparison to be made primarily on (oven-dry) biomass level (t/ha). Stock and increment levels should also be reported on (oven-dry) biomass level (if the feedstock is to be used for energy), especially having in mind that hollow pith of stemwood lowers the »actual« basic density of roundwood for average 5% (in DBH span 3 – 11 cm).
Based on the results of this research it can be concluded that supply chains of Paulownia biomass for energy have to be adopted to deal with the increased values of moisture content

and enable the efficient use of natural or forced ventilation drying. In this respect, future research should be focused on selecting the optimal felling, storage and chipping time. Prospect of natural drying should be explored as some previous research indicate that favourable results could be expected. At this point Paulownia energy wood could be efficiently used in CHP (Combined Heat and Power) plants that operate on the principle of biomass gasification (where a gasifier is coupled to a gas engine to produce electric power and heat). In several CHP gasification plants operating in Croatia poplar wood chips with high initial moisture content are used as a feedstock that has to be pre-dried using the surplus heat. In this respect Paulownia biomass could make an ideal feedstock supplement or even a substitute.

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