Short Communication:

Fuel Properties of Some Native Tree Species for Biomass Energy in Thailand

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ABSTRACT

Thailand is a tropical country and rich in plant species diversity. At present, most of the forest plantations in Thailand are established using exotic species. Many native species are expected to have potential as biomass energy but information on wood yield, coppicing ability and fuel properties is lacking. This study determined some fuel properties of seven native species (*Albizia lebbeck*, *Albizia procera*, *Broussonrtia papyrifera*, *Cassia siamea*, *Combretum quadrangulare*, *Melia azedarach* and *Trema orientalis*). All species were analyzed for wood density, higher heating value (HHV), and components of the proximate and ultimate analysis. Results showed highly significant differences ($P < 0.001$) in all but one trait ($P < 0.05$ for hydrogen content) among the species. The HHV was in the range 4,285–4,653 kcal/kg (17.9–19.5 MJ/kg) which was comparable to some commonly used bioenergy species such as Eucalyptus and Leucacena. Three species (*T. orientalis*, *M. azedarach* and *B. papyrifera*) had high HHV, high volatile matter and low ash content, suggesting their suitability for biomass energy. The results indicated the potential of native plant species in Thailand for use as bioenergy.

Keywords: Native species, fuel properties, biomass energy

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INTRODUCTION

In order to strengthen Thailand's long-term energy security and global economic competitiveness, the country has committed to develop its alternative energy capabilities. This policy emerged at the national level as the Alternative Energy and Development Plan (AEDP) with a 10–year initiative (2012–2021) to better diversify and build a more sustainable energy sector. With this plan, Thailand has set the target of increasing alternative energy consumption from 9,025 kilotons of oil equivalent (kote) in 2014 to 24,638 ktoe in 2021 (AEDP, 2015). Energy sourced from biomass is one of the main players in the AEDP initiative to ramp up renewable energy production. The end goal of the AEDP is to achieve 25% reliance on total national energy generation from alternative or renewable sources by the year 2021 and to set the country's socioeconomic development on a path towards a low–carbon usage base, away from fossil fuels.

Thailand is a tropical country and rich in native plant species diversity. According to Flora of Thailand and research from Forest Herbarium, Department of Forestry, there are more than 10,000 native species of 1,763 genera in 245 families in Thailand (RECOFTC, 1993). However, less than 100 species are used for plantation establishment and ornamental planting. The majority of the species are not used in agriculture, forestry or other industries and therefore information about their potential uses is scarce. Fast–growing tree forest plantation is a potential source of bio–energy. At present, most of the forest plantations in Thailand are established using exotic species such as *Eucalyptus* sp., *Acacia* sp. and *Leucaena* sp. Some of the exotic species, especially *Eucalyptus* sp. still face resistance from people because of environmental concerns. Many native species are expected to have potential as biomass energy but information on wood yield, coppicing ability and fuel properties is lacking.

In this study, fuel properties of selected native species were determined with a view to develop plantations for bio–energy production and to increase the choice of species for plantation development.

MATERIALS AND METHODS

Wood samples were collected from seven native species in Thailand known to have good adaptability over a range of soil and climate conditions. These were Cassod tree (*Cassia siamea*), White Siris (*Albizia procera*), Siris tree (*Albizia lebbeck*), Charcoal tree (*Trema orientalis*), Bead tree (*Melia azedarach*), Paper mulberry (*Broussonetia papyrifera*) and Sakae Naa (*Combretum quadrangulare*). The sampled trees were located in the central region of Thailand and had a diameter at breast height of 7–10 cm, select 3 trees for cut and mixed. The wood samples of each species were divided into two parts for physical and chemical property tests. The samples of block size 16 cm^3 (25 mm x 25 mm x 25 mm) were used for density test, while those ground to fine particles smaller than 1 mm were used for chemical property test.

For density test, the samples were conditioned at 105 ± 2°C and 65 ± 5% relative humidity unless constant mass was obtained. The blocks were measured for volume in dry condition using the mercury displacement method (Chauhan and Walker, 2011). These blocks were then oven dried at 105 ± 2°C until they achieved constant mass. Basic density (B_D) was determined using equation $B_D = W_{OD}/ V_g$, where W_{OD} is the oven–dry biomass and V_g is the green volume of biomass.

For other property test, the wood samples were ground to pass through a 0.25 mm sieve. Moisture content was determined by drying the samples at 105 ± 2°C until they reached a constant weight (ISO 18134: 2015). The samples were then burnt at 900 ± 10°C with inert condition for 7 min (ISO 18123: 2015) to determine volatile matter content. Ash content was determined after burning in a muffle furnace at 550 ± 10°C to constant weight (ISO 18122: 2015) using an automated proximate analyzer (LECO TGA–701). Fixed carbon content was estimated by subtracting the sum of moisture content, volatile content and ash content from 100%.

Higher heating value (HHV) was determined in accordance with the ISO 18125: 2017 standard. The samples were combusted in the IKA C 5000 automated adiabatic calorimeter, which was calibrated with a benzoic acid standard (heat of combustion 6,315 kcal/kg). The ground sample (approximately 0.5 g) was compacted into a tablet and burnt in an oxygen bomb calorimeter to determine the calorific value. The elemental parameters (carbon, hydrogen, nitrogen and sulfur) were determined using an automated CHN analyzer (LECO– CHN–628). Na and K elements were determined in accordance with the ISO 16967: 2015 standard. The samples were digested at resistance heating 220°C, digestion with HNO3 (65%), HF (40%), H3BO3 (4%), according to ISO 16967: 2015, and detected with flame atomic absorption spectrometry (FAAS). In order to minimize experimental and instrumental errors, experiments were repeated three times (i.e. they were treated as three replicates) and mean values were calculated.

Analysis of variance was performed using GenStat v18 (VPN International, Hemel Hemstead, UK). Least significant difference (LSD) ($P < 0.05$) was used to compare the differences among pairs of means.

RESULTS AND DISCUSSION

Basic wood density of the seven native species varied from 0.29 g/cm^3 to 0.78 g/cm^3 with an overall mean of 0.53 g/cm^3 (Table 1). The highest density was recorded for *C. quadrangulare* and the lowest density was recorded for *T. orientalis*. The physical structure cell wall and lumen (Prabir, 2010) affect the density. In general, biomass having higher density is preferred as fuel due to its high energy content per unit volume (Kumar and Chandrashekar, 2014). However, other fuel property characteristics should also be taken into account.

Proximate analysis of volatile matter, fixed carbon and ash content varied greatly among species (Table 1). *T. orientalis* had the highest volatile matter (81.75% as dry) and lowest in ash content (0.79% as dry) but moderate amount of fixed carbon (17.46%). *B. papyrifera* and *A. lebbeck* had high volatile matter (81.37 and 81.49%) and low ash content (1.72 and 1.6%), but both had the lowest fixed carbon (16.9%). In the case of *M. azedarach*, this species had the highest fixed carbon (18.27%), was relatively low ash content (1.85%) and its volatile matter (79.88%) was not statistically different from that of *T. orientalis*. *C. quadrangulare* which recorded the highest wood density had the highest ash content of 6.47% and lowest volatile matter of 75.5%. Volatile matter and fixed carbon content have a positive effect on burning properties. Volatile is a combustible composition of biomass, and the biomass with high volatile can easily be combustible and subsequently complete oxidation (Demibas, 2002). In contrast, ash content of bio–fuel should be as low as possible in wood. High ash will have a negative impact on the combustion process (HytÖnen and Nurmi, 2014). Low ash content in biomass will also benefit the end users in terms of energy content and time for emptying ash (Uemura *et al*., 2010).

The ultimate analysis is very important in order to determine the theoretical air–fuel ratio in thermo–conversion processes and also to gain knowledge of the pollution potential. This study showed that carbon (C), hydrogen (H), nitrogen (N), sulfur (S) and chloride (Cl) differed significantly among the species. *T. orientalis* had the highest C (45.59% as dry) but lowest N (0.083% as dry) and S (0.005% as dry). *C. quadrangulare* had the highest Cl (0.2035 as dry) but lowest C (42.707% as dry) and H (5.877% as dry). The main element for heat source was carbon and hydrogen while nitrogen, sulfur, and chloride had a negative effect on the calorific value. In general, low carbon and hydrogen content reflexes weak fuel properties of the biomass (Kumar *et al*., 2010), Furthermore, sulfur and nitrogen compounds are transformed into acidifying substances. When these substances reach the ground, they cause acidification of the soil and water, resulting in acid soil (Sardans *et al*., 2015). This phenomenon is an important cause of damage to the aquatic environment and may severely impair the life of plant and animal species.

Heating value is one of the most important fuel properties which explains the higher energy content and determines the efficiency of biomass fuels. Higher Heating Value (HHV) of the native species in this study varied from 4,285 kcal/kg to 4,653 kcal/kg (17.9–19.5 MJ/kg). The highest HHV was obtained for *T. orientalis* and the lowest for *C. quadrangulare*. These HHV values are comparable to that shown by other tree species commonly planted for production of biomass energy, such as eucalypts 17.6–19.6 MJ/kg, casuarinas 19.1–19.3 MJ/kg and acacias 19.2–19.8 MJ/kg (Telmo *et al*., 2010; Ritesh *et al*., 2011). Carbon and volatile content have a positive effect on the HHV property, the higher the carbon and volatile content the higher the HHV. The volatile is a liquid phase in wood (not including water).

In this study, it was found that species with low wood density such as *T. orientalis* and *M. azedarach* had the highest HHV among all the species tested. A plausible explanation is that if the density is high the wood will have low porous and less empty space for volatile matter. On the contrary low density wood is more porous with more space for volatile to trap the heat.

Table 1 Solid fuel characteristics of seven native tree species in Thailand (Samples consisted of wood with bark)

Species	Density (g/cm^3)	HHV (cal/g)	Proximate analysis (% as dry)			Element analysis (% as dry)					
			Volatile	Ash	Fix C	C	H	N	S	Cl
A. *lebbeck*	0.76	4,488	81.49	1.60	16.90	45.02	6.17	0.09	0.012	0.022
A. *procera*	0.39	4,496	79.76	2.78	17.36	43.82	6.17	0.37	0.018	0.120
B. *papyrifera*	0.32	4,585	81.37	1.72	16.91	45.25	6.11	0.11	0.008	0.052
C. *siamea*	0.68	4,566	79.23	3.51	17.26	43.35	6.28	0.27	0.012	0.130
C. *quadrangulare*	0.78	4,285	75.50	6.47	18.04	42.71	5.87	0.30	0.017	0.203
M. *azedarach*	0.48	4,650	79.88	1.85	18.27	44.44	6.09	0.12	0.017	0.051
T. *orientalis*	0.29	4,653	81.75	0.79	17.46	45.59	6.22	0.08	0.005	0.032
Overall mean	0.53	4,532	79.85	2.67	17.46	44.31	6.13	0.19	0.013	0.087
F probability	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001
LSD (P < 0.05)	0.25	34.00	0.55	0.17	0.53	0.83	0.19	0.06	0.004	0.021

CONCLUSION

This study was the first to investigate the fuel properties of native plant species of Thailand. Results showed the potential of several species that can be developed for bio-energy production. Three species i.e. *T. orientalis*, *M. azedarach*and *B. papyrifera* had high HHV, high volatile matter and low ash content, which are important traits of bioenergy species, However, this research was only preliminary. More studies should be conducted with a systematic sampling of materials from a wider range of distribution in Thailand.

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